EUROPEAN HEAT PUMP SUMMIT

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SYMPOSIUM + EXPO
NUREMBERG, 20–21.10.2015

Industrial | Commercial | Residential
Heating & Cooling | Components & Equipment

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NÜRNBERG MESSE

Experience with the Operation of a CO_2 driven 400 m Geothermal Thermosyphon

Dipl.-Ing. Johann-Christoph Ebeling

Project: Near-surface and medium-deep CO_2 geothermal pipes of higher thermal power

Partners:

FKW HANNOVER
Forschungszentrum für Kältetechnik und Wärmepumpen GmbH
(Prof. Dr.-Ing. H. Kruse)

Leibniz Universität Hannover

STIEBEL ELTRON

U+B Wöltjen GmbH
Umwelttechnik & Brunnenbau

TUHH
Technische Universität Hamburg-Harburg

VIESSMANN

GeoDienste GmbH
Geologie - Hydrogeologie - Geothermie

Institute for Thermodynamics
at the Leibniz University of Hannover

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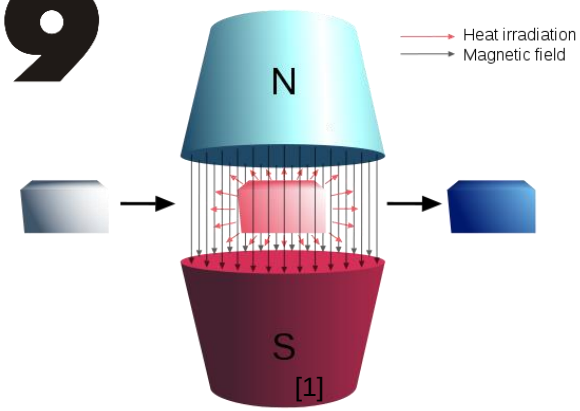
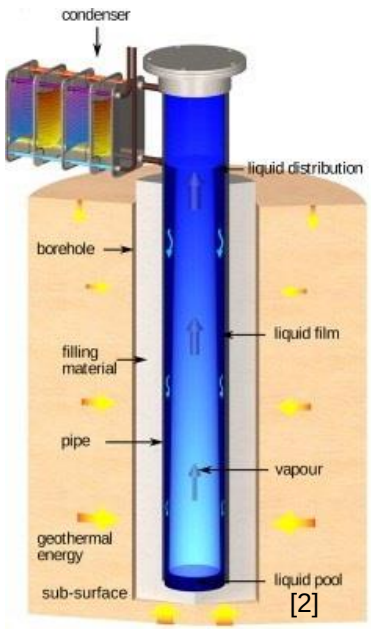
Leibniz Universität Hannover

TU9

Research

- Substance Data
- Energy Converters
  - **Magnetocaloric**
- Heat and Mass Transfer
  - **Geothermal Thermosyphons**
- Thermodynamics of Complex Systems





Teaching

Winter semester
- Thermodynamics I for Mechanical Engineering
- Thermodynamics of Mixtures
- Refrigeration and Air Conditioning Technology
- Numerical Heat Transfer
- Practice of Energy and Process Engineering
- Cryogenic and Bio-Refrigeration (IMP)

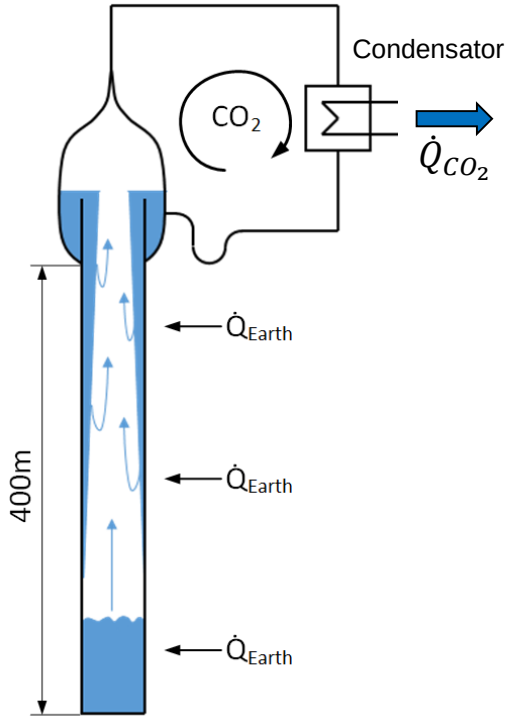
Summer semester
- Thermodynamics II for Mechanical Engineering
- Heat Transfer II (Boiling and Condensation)
- Fuel Cells and Fuel Cell Systems
- Thermal Separation Technology
- Thermodynamics of Chemical Processes

[1] Wikipedia
[2] HARTMANN, Frank ; BEHREND, Ralph ; HANTSCH, Andreas ; GRAB, Thomas ; GROSS, Ulrich: *Numerical investigation of the performance of a partially wetted geothermal thermosyphon at various power demand schemes*. In: *Geothermics* 55 (2015), S. 99–107

CO_2 driven Geothermal Thermosyphon (400m)

What?

- Probe as one closed pipe
- Saturated working fluid (CO_2)
- Heat transfer through phase change



Why?

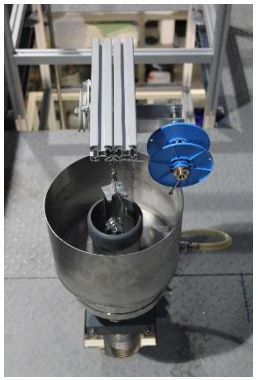
- Intense heat transfer due to phase change
- No pumps due to natural circulation
- Possible within water protection areas
- High extraction rate for urban application

Research topics

- Maximal heat flow
- Optimal filling rate
- Validation data for Simulation
- Plain pipe or helically corrugated pipe

Preliminary Investigations

Test rig:
for a helically corrugated DN 80 pipe



Study of:

- Different Applicators for the CO_2 Flow
- Flow patterns within the probe by using an endoscopic camera and denta floss

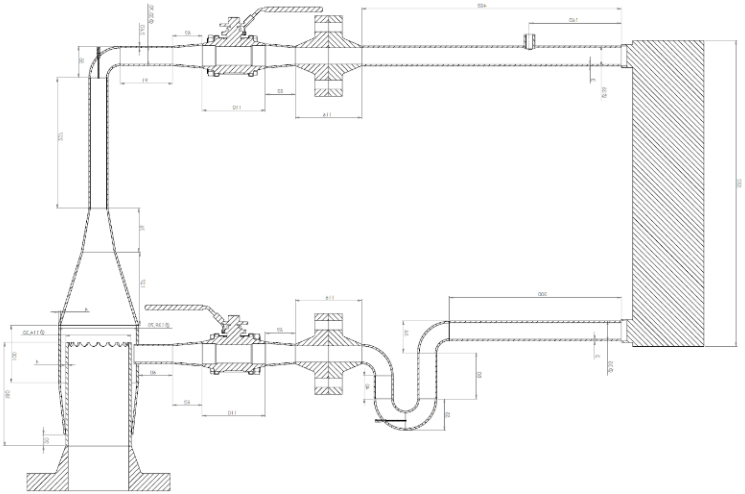
Calculations:
for a helically corrugated DN 80 pipe

Flooding limit by IMURA for a CO_2 temperature of 0°C

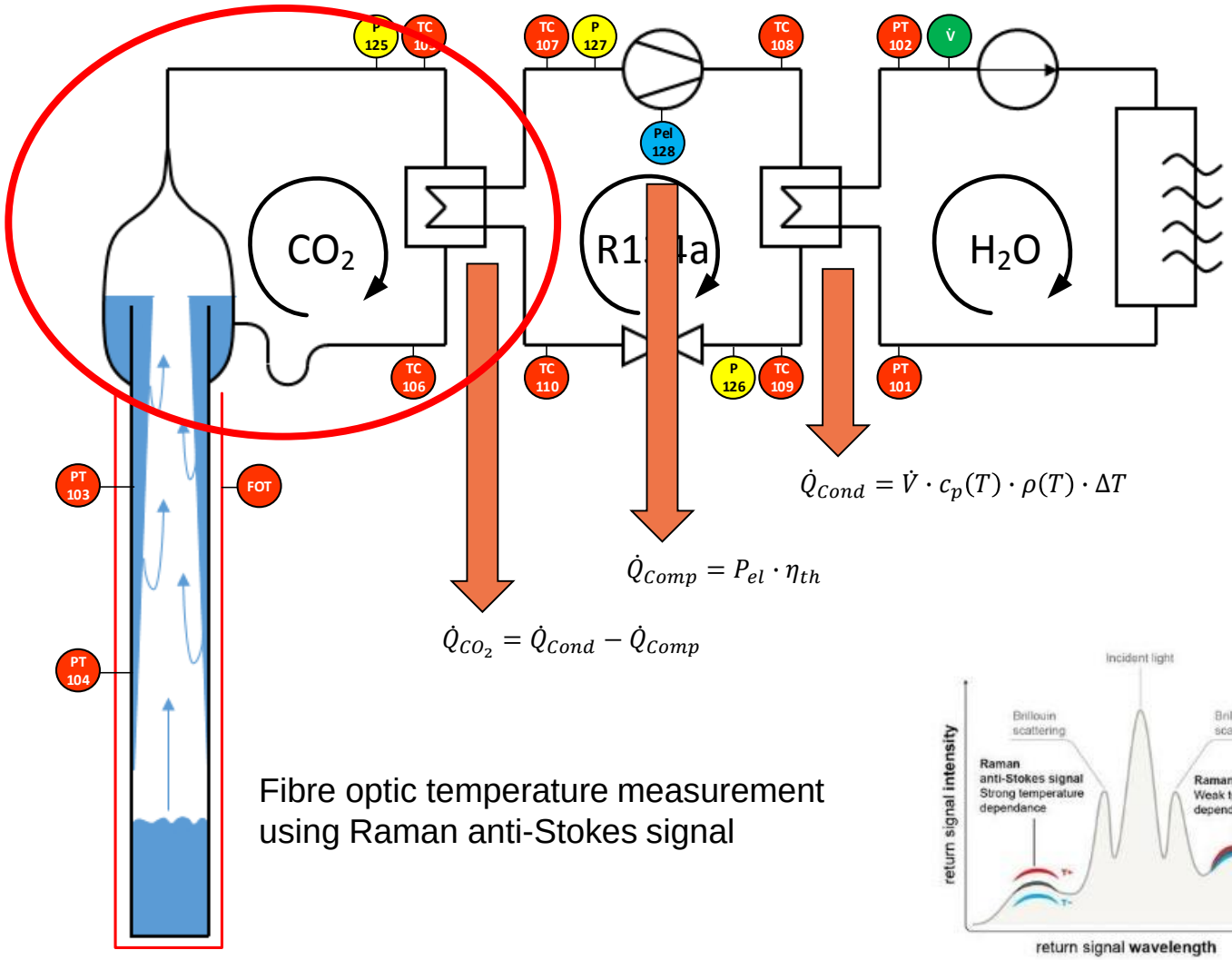
$$\dot{Q}_{max,(0°C)} = 24\ [kW]$$

$$L_{min,(0°C)} = \frac{\dot{Q}_{max}}{\dot{q}_{Earth}} = 400\ [m]$$

Head construction:



Setup - theoretical

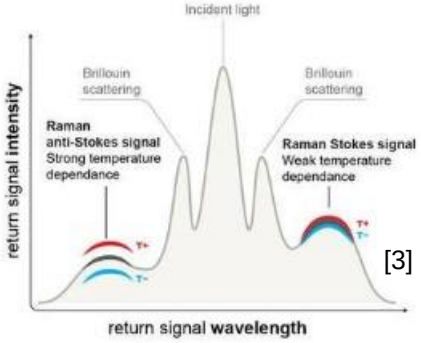


$$\dot{Q}_{Cond} = \dot{V} \cdot c_p(T) \cdot \rho(T) \cdot \Delta T$$

$$\dot{Q}_{Comp} = P_{el} \cdot \eta_{th}$$

$$\dot{Q}_{CO_2} = \dot{Q}_{Cond} - \dot{Q}_{Comp}$$

Fibre optic temperature measurement using Raman anti-Stokes signal



[3]

[3] Graph by AP Sensing

Setup - practical

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Installation of the:
Helically corrugated DN 80 pipe

Continuous installation in one piece

Probe dimensions:

L_{plain}: 368 m
$L_{corr.}$: 384 m
V_{plain}: 3,77 m³
$V_{corr.}$: 3,32 m³

Filling:

$m_{CO2,\ plain}$: 642 kg
$m_{CO2,\ corr.}$: 921 kg
$h_{Pool,\ plain}$: 9 m
$h_{Pool,\ corr.}$: 79 m

Location:
Nienburg (Weser)
Lower Saxony

Installation of the:
Plain pipe DN 100

Installation in pieces per 10m
Screwing together and welding necessary

Results

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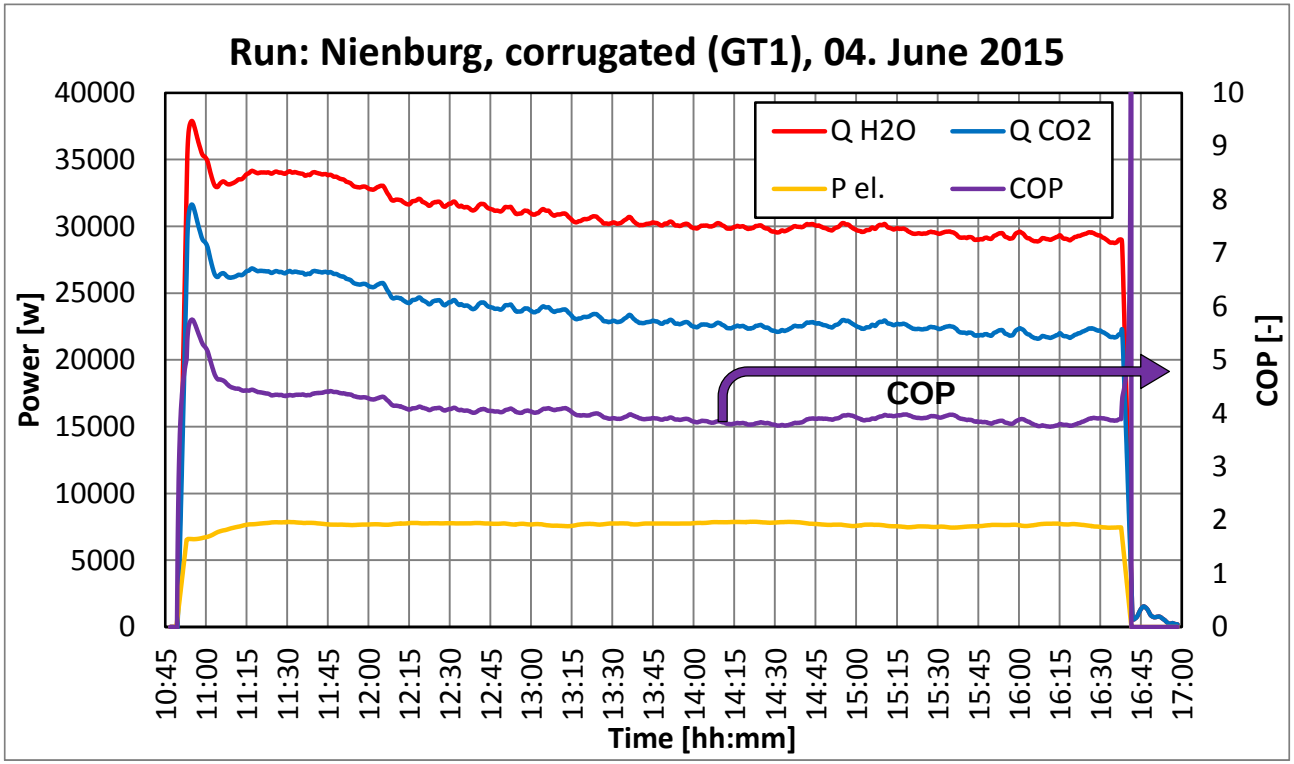
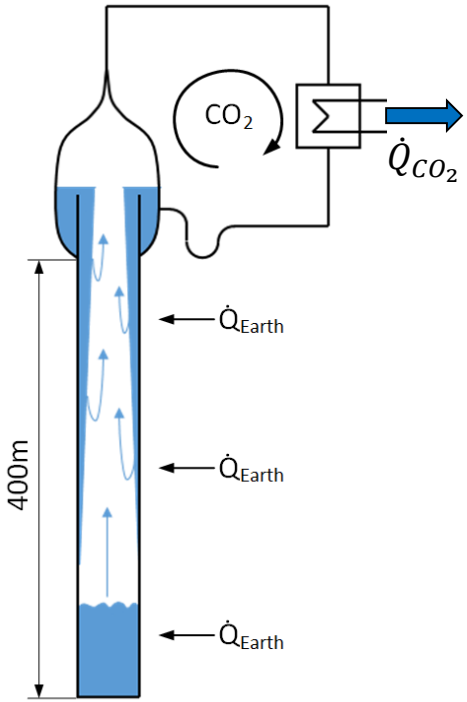
Performance data of the Heat Pump (helically corrugated pipe)





$CO_{2,in}$ = 12,5°C – 3,5°C
H_2O_{out} = 50°C

To improve the CO_2 thermosyphon as a heat source for heat pumps a fundamental understanding of the heat and mass transfer in the probe is necessary!

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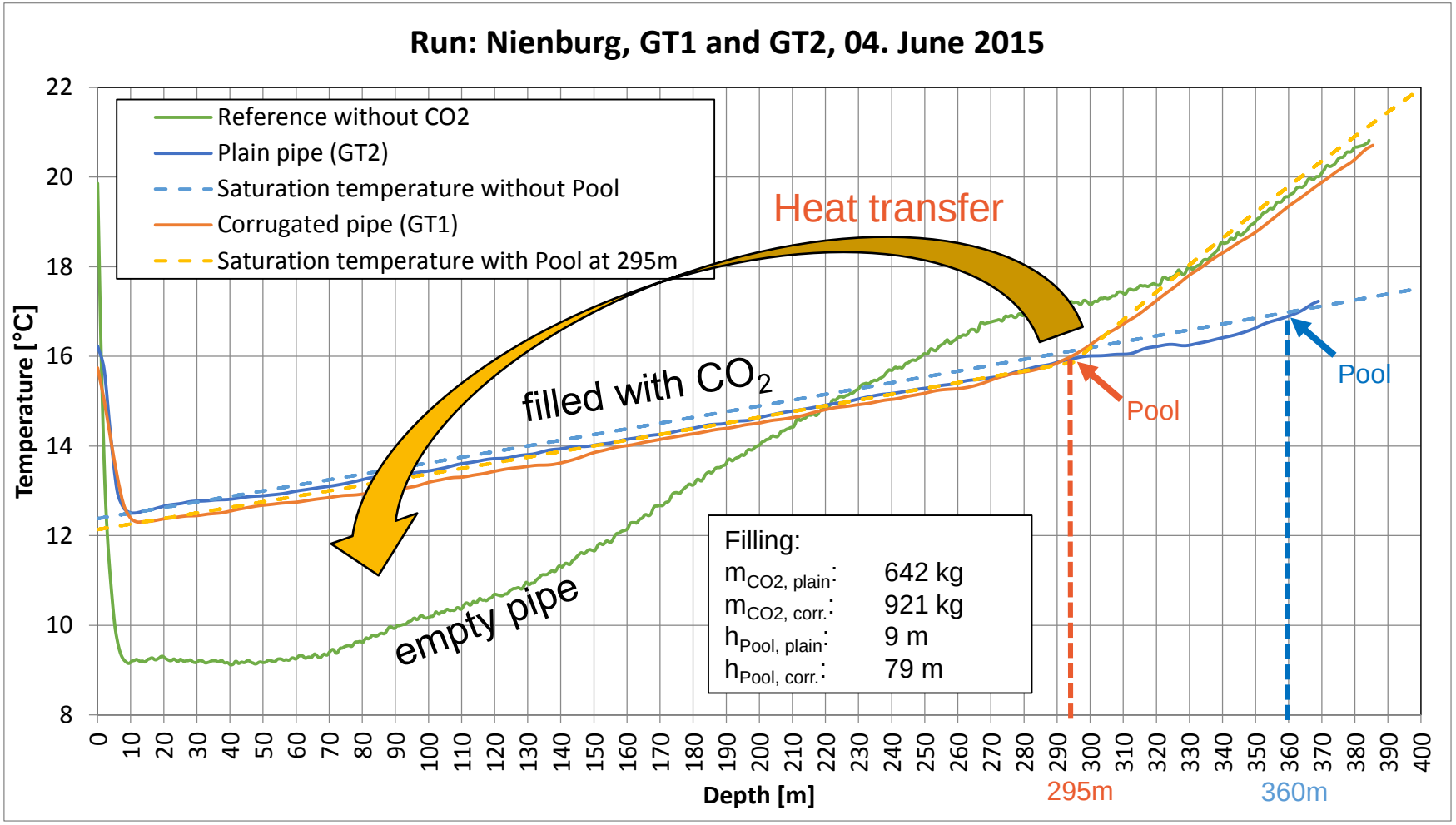
Temperature profile with and without CO_2



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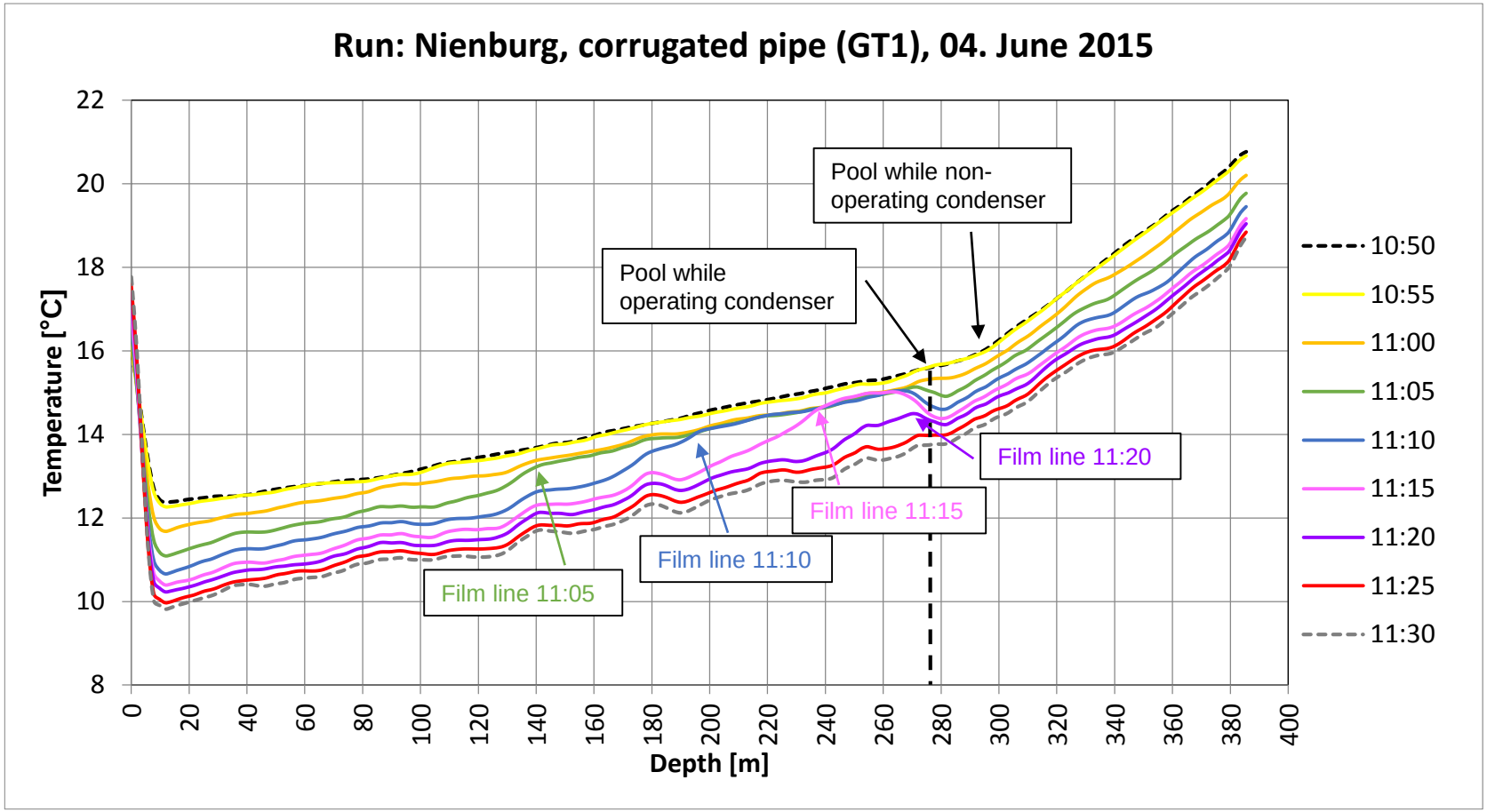
Starting process



$\dot{Q}_{CO2}$ ~ 27 kW

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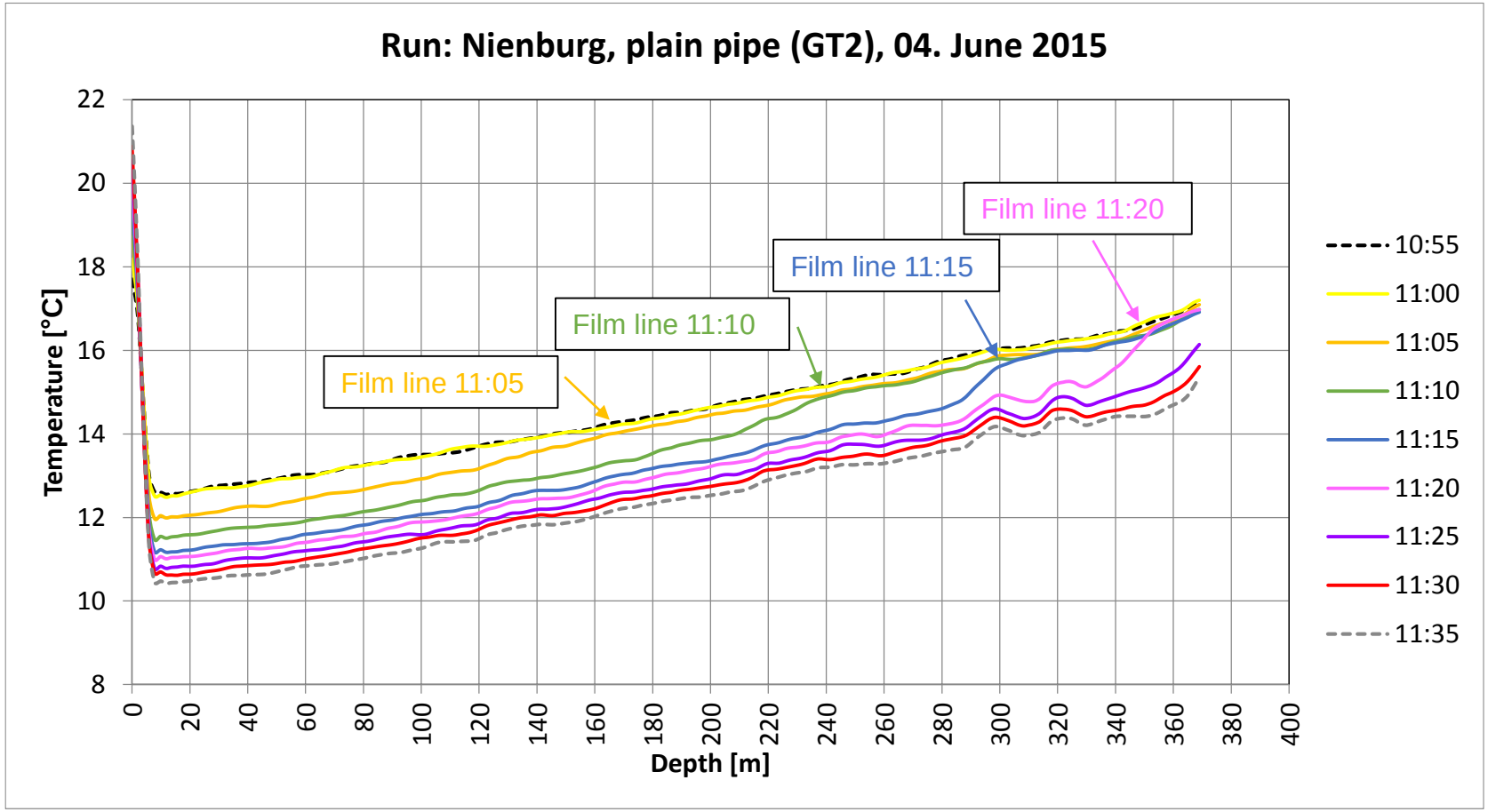
Starting process



$\dot{Q}_{CO2}$ ~ 25 kW

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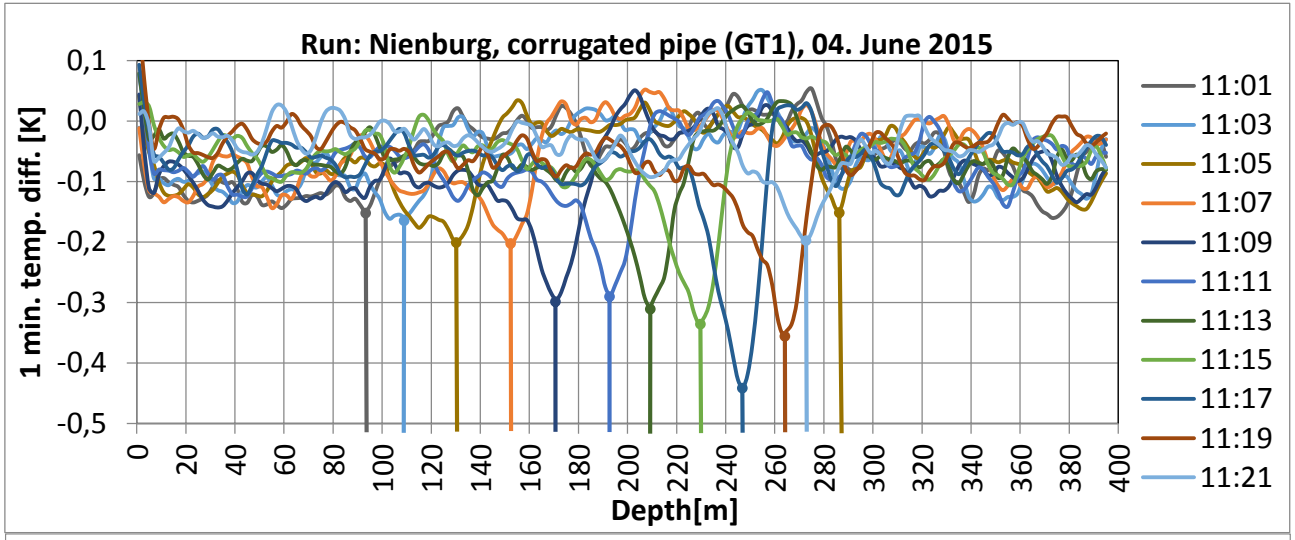
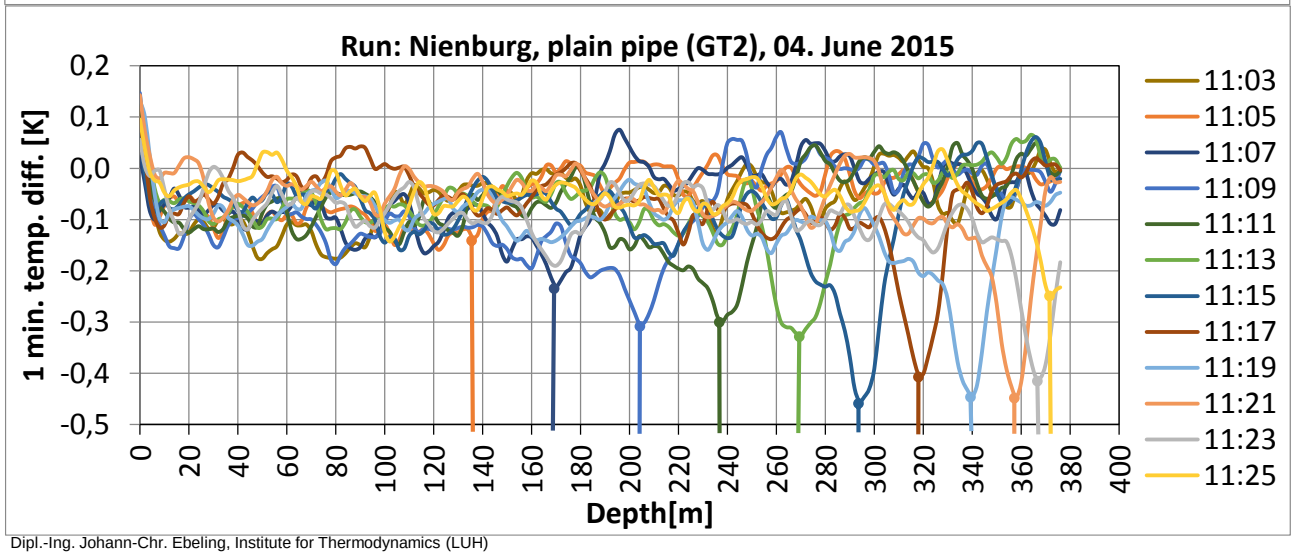
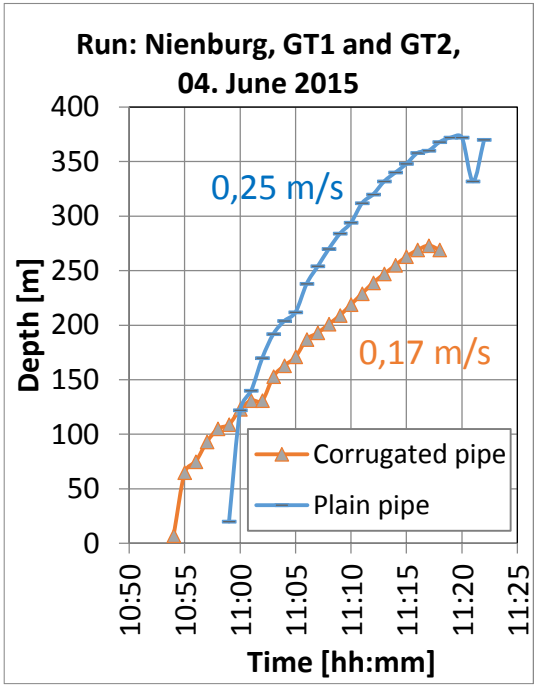
Starting process





Speed of film line



- The film line in the plain pipe moves faster than in the corrugated pipe

Conclusion and lookout

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- There is a natural circulation while non-operating HP
- The temperature profile in the probe depends on the pressure in the probe
- The pool surface is detectable
- The pool surface is moving while the starting process
- The speed of the film line is detectable
- The film line is moving faster in the plain pipe

Further investigation of the pool surface behavior

Effect of the filling level

Simulation of the starting process (unsteady)

Vielen Dank
für Ihre Aufmerksamkeit.

Thank you
for your attention.