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COIL WOUND HEAT EXCHANGERS FOR LNG - INVESTIGATION OF TRANSPORT PHENOMENA WITHIN THE BUNDLE

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THE LINDE GROUP

Linde

Introduction
Background

- Coil wound heat exchangers (CWHEs) in LNG industry as
  ⇨ Precoolers / Liquefiers / Subcoolers
- Dimensions up to
  ⇨ 10,000 tubes
  ⇨ 30,000 m² heating surface area
  ⇨ 20 m in height
  ⇨ 5 m in diameter
- Natural Gas is on tube side
- Refrigerant streams are on tube side and shell side
- Refrigerant is flashed over Joule-Thomson valve and flows downwards on shell side, evaporating as falling film

→ Shell side mal-distribution will lead to radial temperature differences resulting in a reduced performance of the CWHE

→ Liquid mal-distribution can be triggered by uneven distribution from liquid distributor or by liquid migration effects within bundle

Introduction
Aim

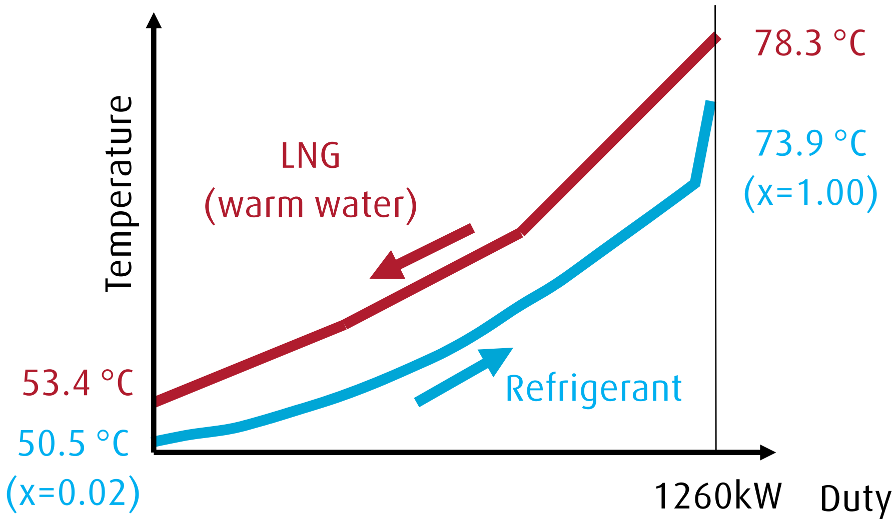
- Improve understanding of physics within bundle
  ⇨ Optimize CWHE's with respect to size and performance
- Investigate influence of transport phenomena on shell side distribution and heat exchanger performance at various conditions with regard to:
  - vapour fraction
  - heat input
  - liquid distribution
  - gas and liquid load
- By use of
  - adjustable liquid distribution system
  - liquid collecting system
  - glass fibre full 3D-temperature measurements

Pilot plant

Overview

Refrigerant:
- 80% n-Pentane, 20% Iso-Octane
- up to 14,000 kg/h
- 1.3 bar(a)

LNG (warm water)
- Up to 80,000 kg/h



Pilot plant
CWHE

Pilot plant CWHE:

— Bundle height of 2 m, 9 layers

— 171 tubes, 2200 m length

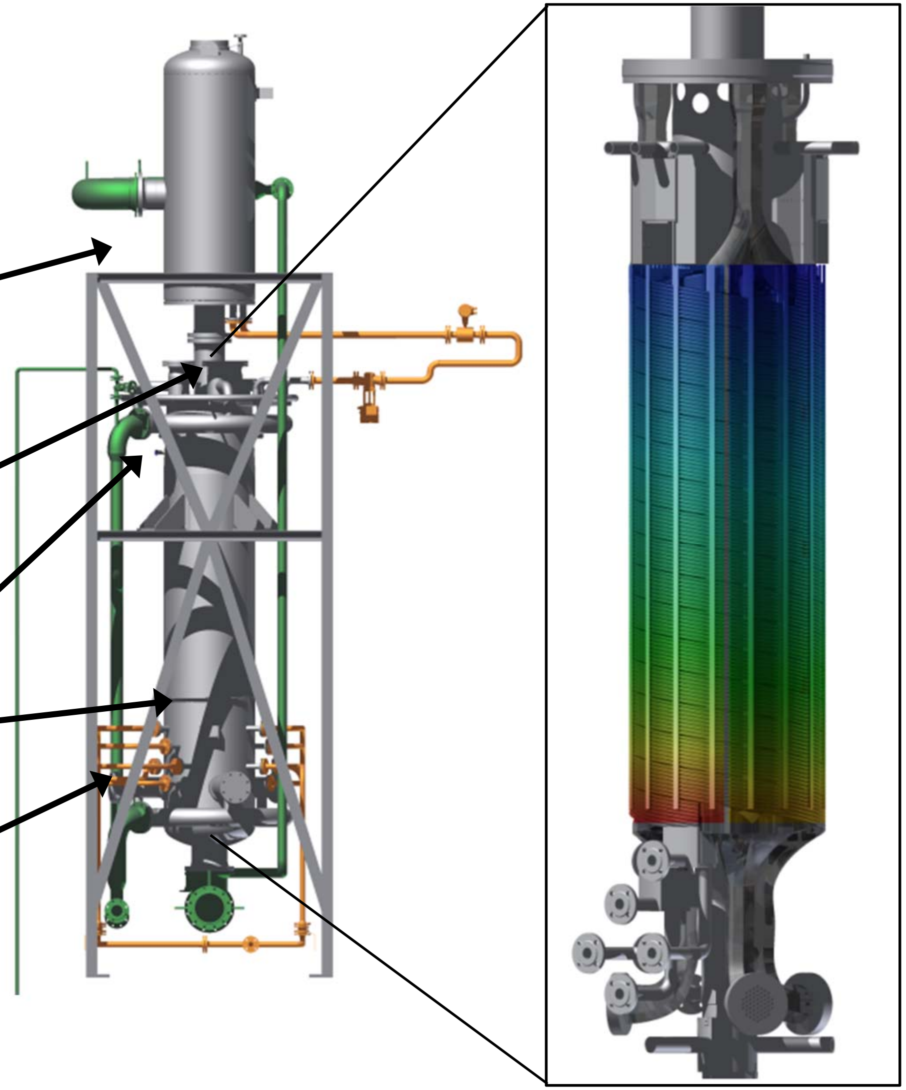
→ Total heat exchanger area of 84 m²

Pre-distributor

Adjustable liquid distributors, control valves and flow indicators

Approx. 150 m fiber optic, 24 temperature and nine pressure sensors within bundle

Liquid collection and flow metering

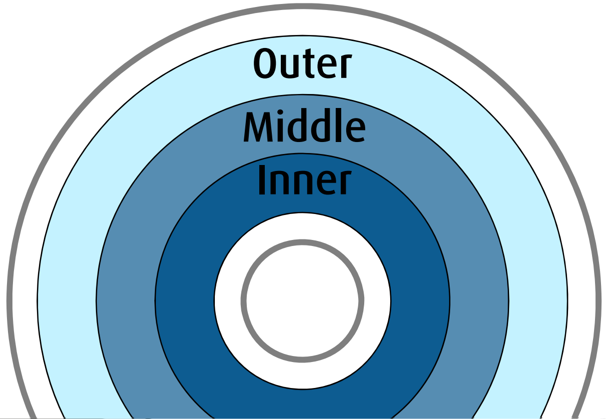


Pilot plant
Video CWHE

Exemplary results
Description

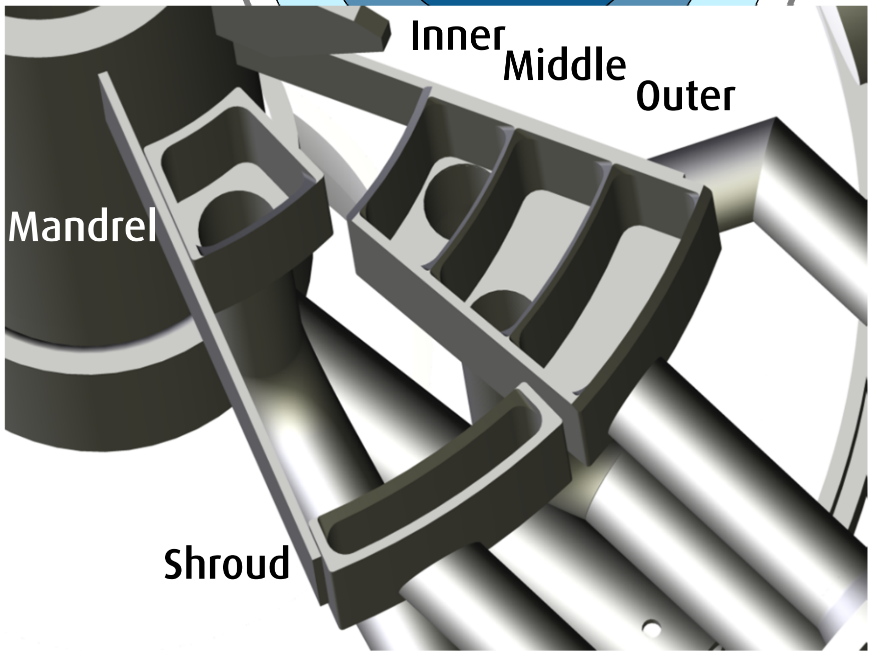
Adjustable liquid distribution above bundle at three sections:

- Inner (layer 1-3, 27 % of total area)
- Middle (layer 4-6, 33 % of total area)
- Outer (layer 7-9, 40 % of total area)



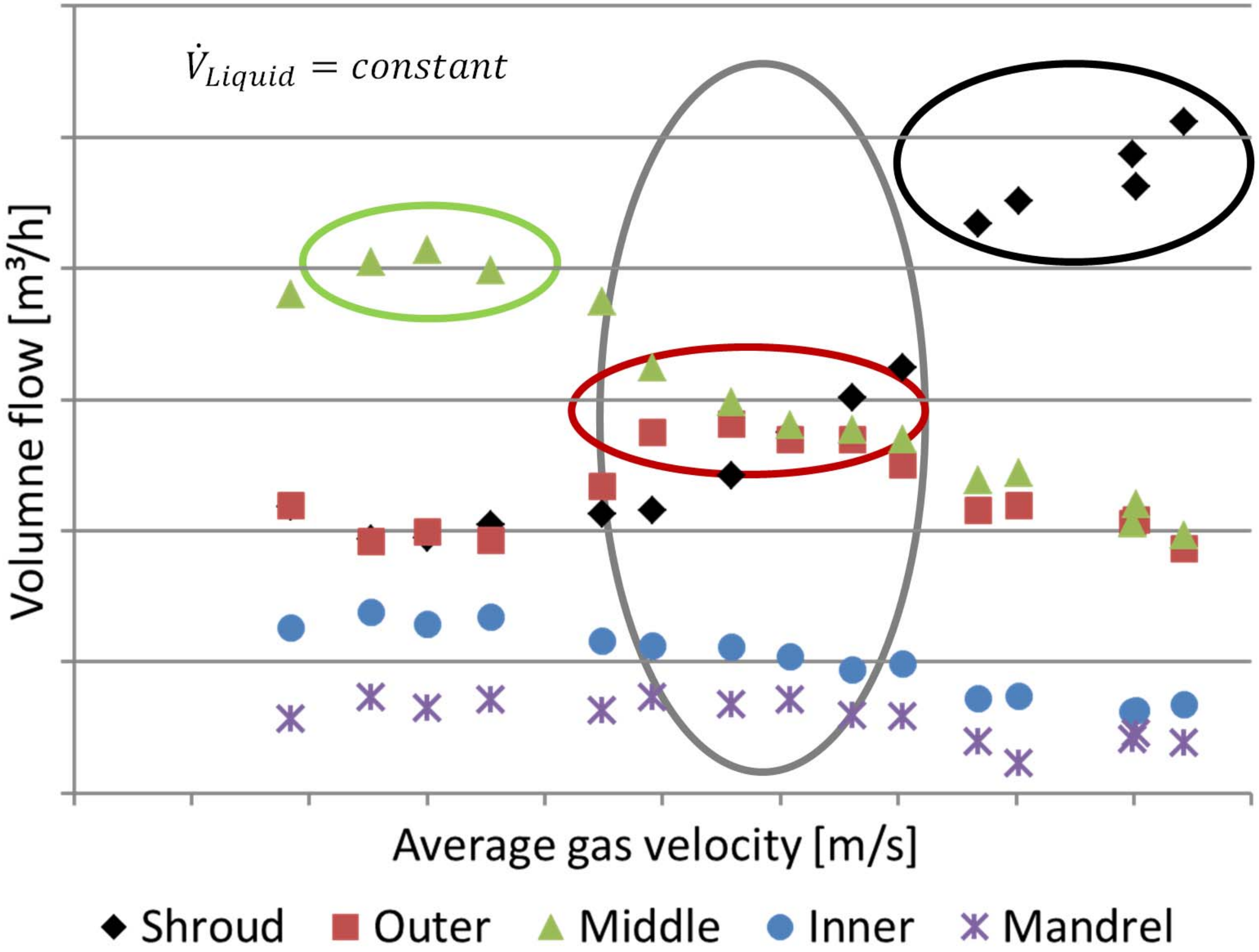
Liquid collectors, at two positions, arranged in same way. Additional collectors at:

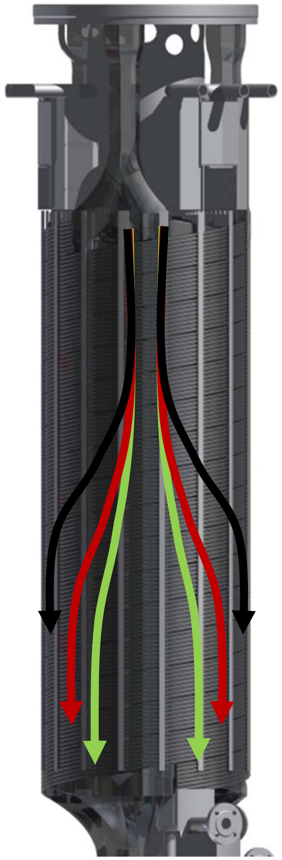
- Mandrel
- Shroud



Exemplary results

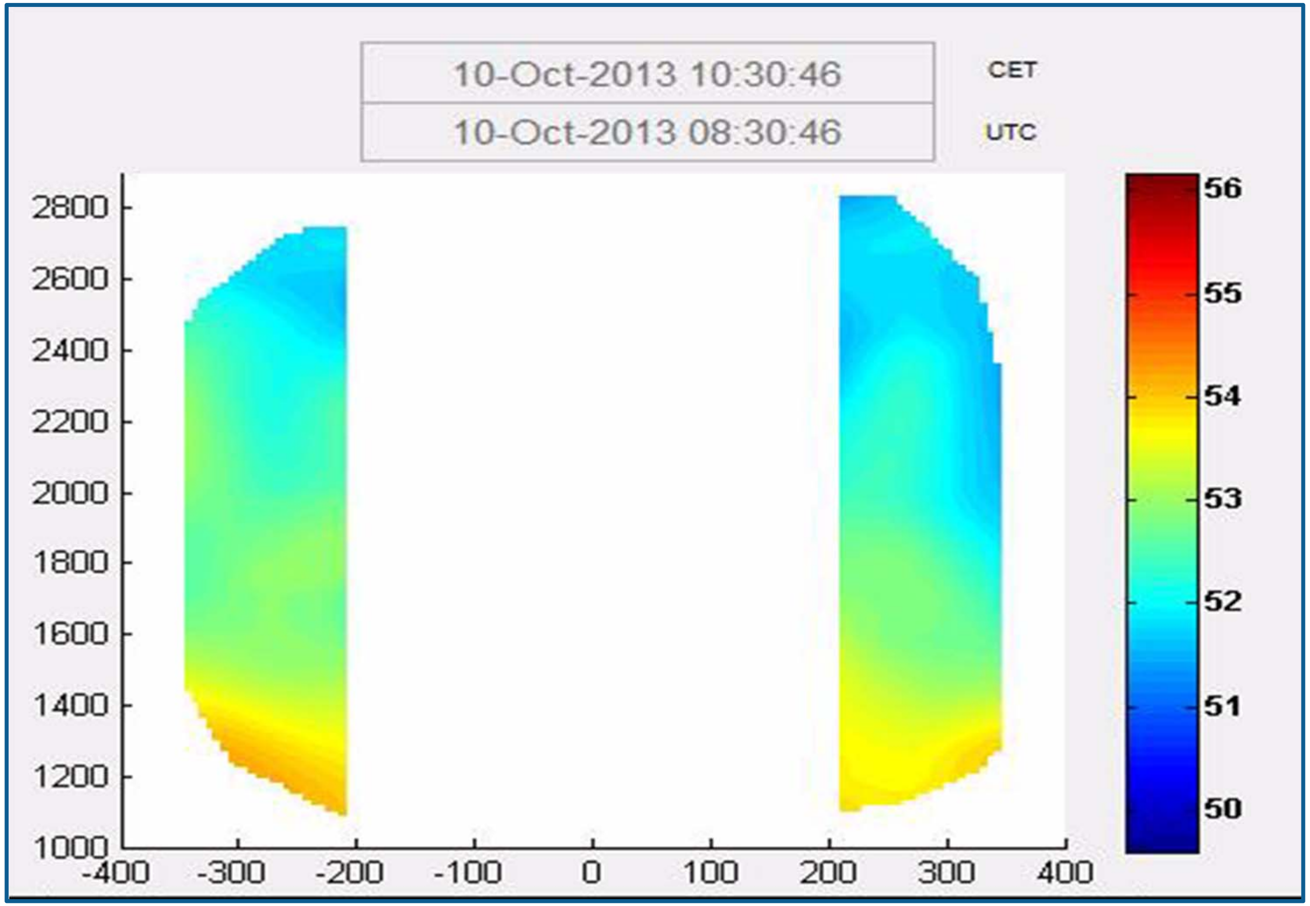
Liquid outlet distribution vs. average gas flow





Exemplary results

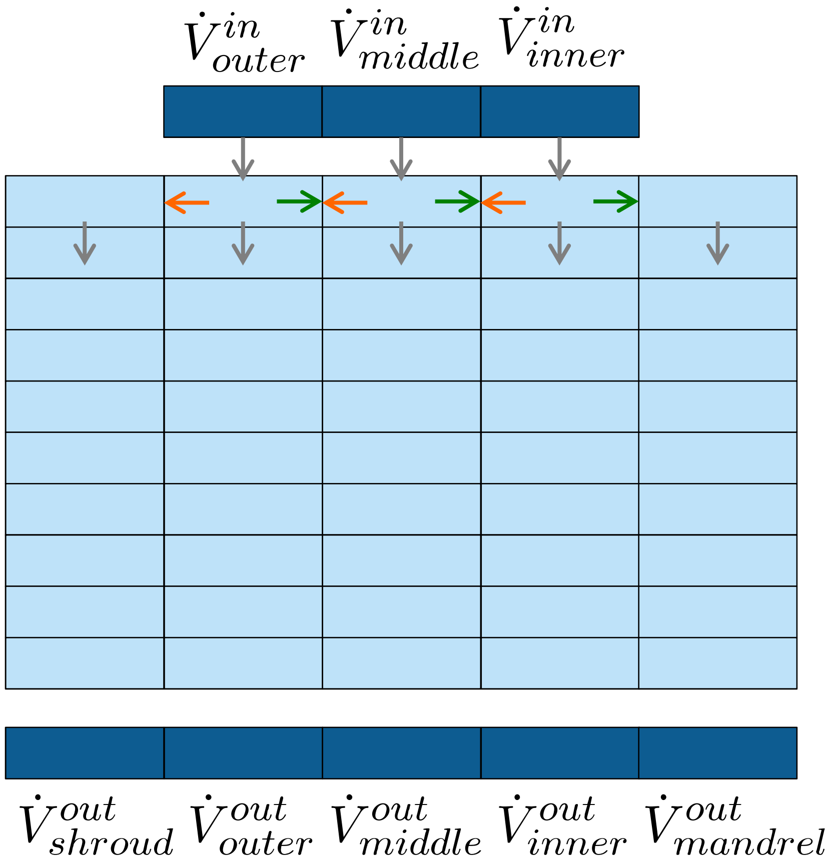
3D-temperature measurements

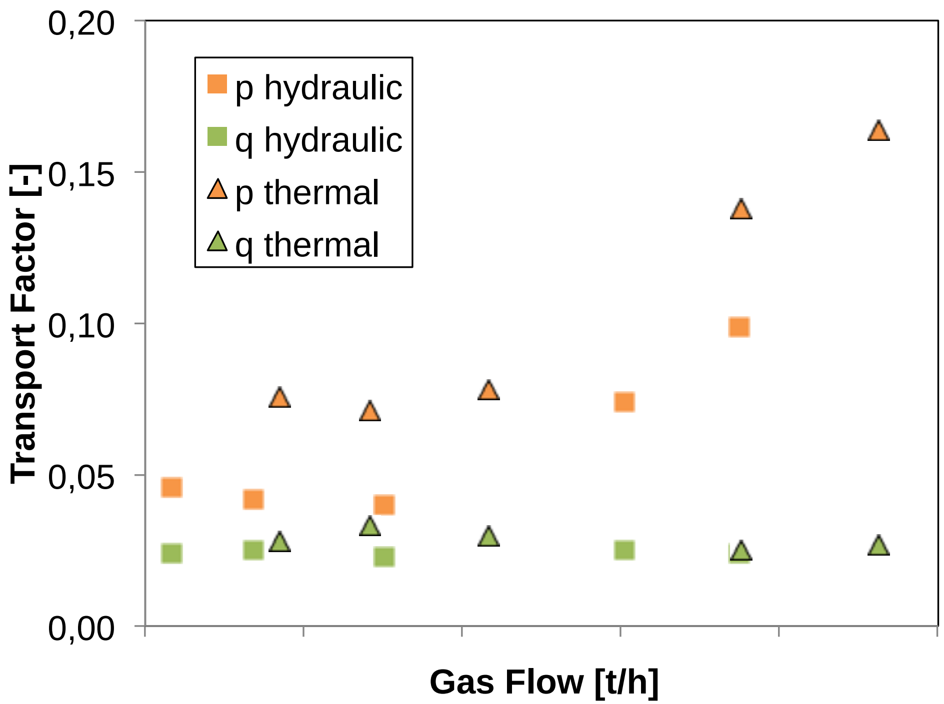


→ Increasing transport to outer layer can also be seen by 3D-temperature measurements

Exemplary results

Cell model





A cell model is set-up and adapted to the measured liquid distribution

→ Determination of the transport coefficient at various conditions.

Outlook

→ Pilot plant was operated for more than 10 months, over 150 measurements were performed

→ Results are compared to world-scale plant measurements

→ Development of empirical correlations not fruitful:

- no homogeneous geometry of bundle
- very complex transport and heat transfer phenomena

→ Development of heterogeneous 2D CFD model based on OpenFOAM

→ Verification of 2D CFD model with pilot plant results

Thank you for your attention!!!

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