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

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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
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:

— 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
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

\[ \dot{V}_{\text{Liquid}} = \text{constant} \]

- Increased flow at shroud
- Decreased flow in outer and middle section
- Almost constant flow in inner section and at mandrel

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TGTC-3 - Coil wound heat exchangers for LNG – Investigation of transport phenomena within the bundle
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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