Heat traced pipe-in-pipe for S or J-lay – proof of concept test results

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Overview

• Introduction

• Electrical heat tracing / EHTF Technology (ITP Interpipe)

• Prototype + flowloop test results

• Conclusions and outlook
Introduction

• Increasingly difficult oil and gas discoveries are considered for development

• Economics drive long distance tie-backs

• Hydrate management issues

Solution:
Electrically Heat Traced Flowlines (EHTF)
Electrical heat tracing

• Temperature management using electrical heating is not new:
  • Direct electrical heating (DEH) developed since the 1990s and installed on 14 pipelines (110 km).
  • high power requirement, typically limited to maximum 50 km for 18” pipe

• Alternative: electrical heat tracing for Pipe-in-Pipe
  • Based on existing highly insulated PiP technology
  • Resistance wires added on the inner pipe
  • Power Consumption: 5 – 15 kW/km (5-20 times lower than DEH)
  • Range: 20 – 50 km/kV, much lower than DEH

• EHTF concept (ITP Interpipe) for S-lay
  • Individually heat-traced segments in set in parallel
  • Three phase AC power connections by Deutsch (qualified for Ormen Lange)
EHTF construction

- Prefabricated Pipe-in-Pipe joints
- Inner pipe connection - single weld
- Pipe-in-Pipe sleeve mounted over weld
- Cavity filled with fast curing resin (~ minutes)
Proof of concept testing - objectives

• Operating experience with the Deutsch connector and DTS monitoring with OMNISENS fibre optic

• Measuring U-value of the fully installed system (including the sleeves)

• Test operation in heated mode – temperature maintenance / control

• Assess the impact of an electrical connector failure – can we still operate?
Flow loop at Shell Technology Centre

• Low pressure air-water loop at Shell Technology Center Amsterdam
• Three 10 m long EHTF sections were constructed by ITP: 4” – 6” PiP with a single phase Deutsch electrical connector per section.
• Installation as in the field: welded inner pipes, covered by sleeves and filled with resin.
• Temperature monitoring using thermocouples (inside pipe and sleeves) and fibre optic cables supplied by OMNISENS
Experimental setup / operation

• Guard heaters mounted on each side to compensate heat losses at the ends
• Temperature measurements using thermocouples and fiber optic cable (internal and external)
• Power supplied through the loop control unit (220 V)
• Tests during shut-in conditions – no flow, pipes filled with water, air or a mixture.
• Temperature control using a TIC unit as programmed in the control system (on/off switch)
Results – fully air / water filled heating

• Results indicate fast heat up and cool down when filled with air at atmospheric pressure. Much slower warm-up when filled with liquid (higher energy content).

• Excellent match between FO and TC data – substantially added value in revealing the profile vs. point data (thermocouple).

• With air: heat up performed to 45 °C, several cool down cycles ran with temperature maintenance, e.g. at 40 and 30 °C. Sleeve joints result in strong drop in fluid temperature: local heat loss is considerably higher despite PiP sleeve.

• With water: constant temperature profile along the pipeline length (also at sleeved PiP) – stronger natural convection taking place. Unable to reach temperature above 32C due to higher heat loss compared to air testing and the low voltage (220V).
Results – air filled: cool down

- Cool down from 40 to 30 °C with temperature maintenance:
  - Gradual and even drop of the temperature
  - 7 hour cool down period
  - Sleeve sections consistently at lower temperature but remain above ambient temperature (10 °C)

- Heat transfer analysis used to determine overall U-value ~ 0.3 W/m²K for the main pipe. This is consistent with the expected design value.

- FO cable clearly shows the evolution throughout the pipeline
Results – water filled: cool down

- Long cool down time due to the high heat capacity: more than 70 hours
- Two cool down cycles performed
- Flat temperature profile during cool down gradually moving closer to the ambient temperature
- Estimated U value: 0.55 W/(m².K)
Failure mode: one pipe not heated

- Heating central EHTF section switched off

- Gradual warm-up, slower due to reduced power input

- Central pipe also warms up: convective transport of heat into the central pipe due to natural convection. The heat flow is able to cross the sleeves and flow into the highly insulated pipe-in-pipe sections.

- Central pipe is 5 °C colder than the heated sections, but considerably above ambient temperature (7 – 9 °C)
Inclined experiment – 2 degrees

• Fully liquid filled: temperature gradient appears (top warmer)
• Half liquid filled + degraded mode: no natural convection in the gas filled section, so it cools down to ambient temperature in 48 hours
Measured overall U values

• Fully air filled system: $0.3 \, \text{W}/(\text{m}^2\cdot\text{K}) \leftrightarrow$ Fully water filled system: $0.55 \, \text{W}/(\text{m}^2\cdot\text{K})$

• With air: no convection (low sleeve temperature), so U value $\sim$ U value individual PiP section
• With water: natural convection: so U value $\sim$ U value of the assembly

• Knowing the field joint length ($\sim 2 \, \text{m}$) results in estimate for its U value: $1.55 \, \text{W}/(\text{m}^2\cdot\text{K})$

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U_{\text{overall}} \times L = U_{\text{joint}} \times L_{\text{joint}} + U_{\text{line}} \times L_{\text{line}}
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• Considering then a field joint length of 48 m (as installed offshore) gives an overall U value of $0.35 \, \text{W}/(\text{m}^2\cdot\text{K})$ for the entire assembly
Conclusions

• Proof of concept achieved through flowloop testing – Technology Readiness Level 5 (API): basic technological components integrated and tested in a simulated environment

• Total installed U-value of 0.35 W/m².K when using quad joints

• Uniform temperature profile in liquid filled sections – cold spots at the sleeves for gas, though well above ambient temperature

• Unheated section kept warm by neighbouring sections if sufficient liquid is present, high pressure gas may also be effective.

• Fibre optic system (DTS) visualized the temperature profile with good accuracy