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

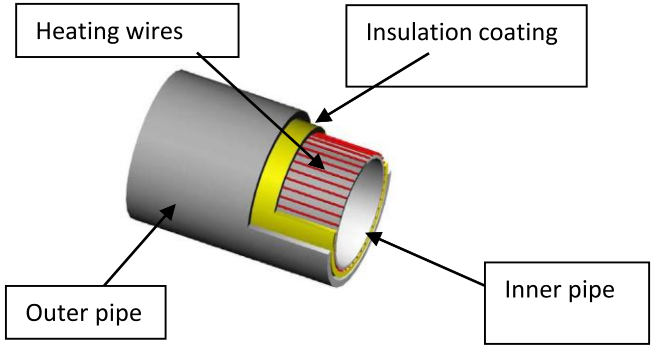
- Increasingly difficult oil and gas discoveries are considered for development
- Economics drive long distance tie-backs
- Hydrate management issues

Solution:
Electrically Heat Traced Flowlines (EHTF)

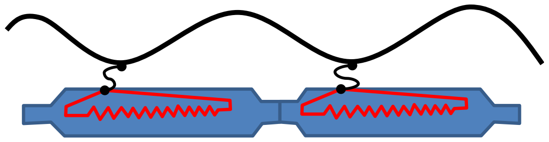
Electrical heat tracing

- 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

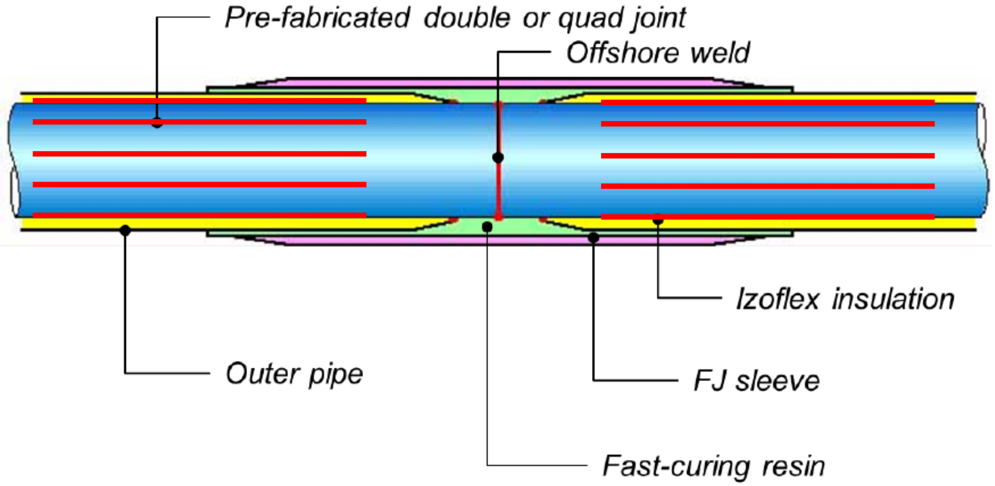


- EHTF concept (ITP Interpipe) for S-lay
  - Individually heat-traced segments in set in parallel
  - Three phase AC power connections by Deutsch (qualified for Ormen Lange)



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

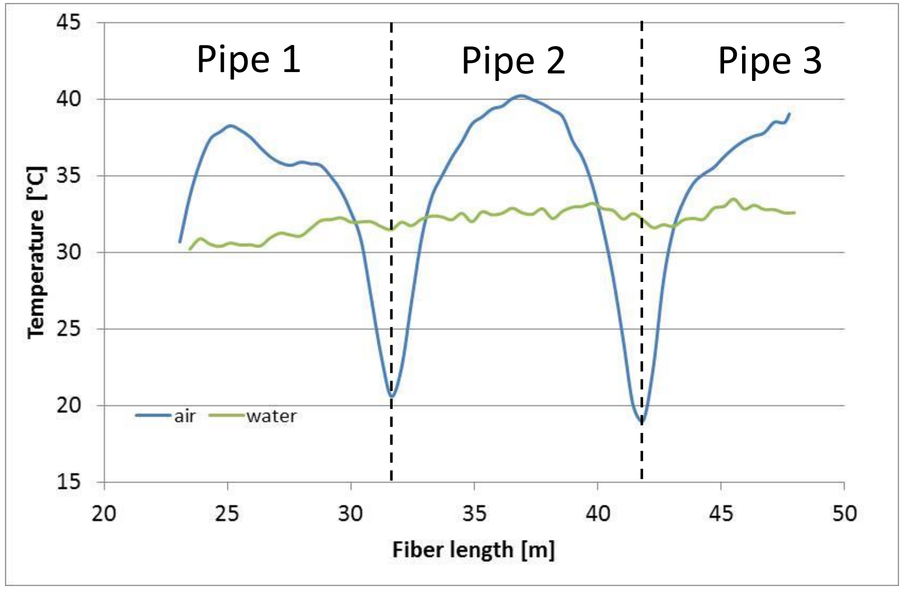
- Low pressure air-water loop at Shell Technology Center Amsterdam
- Three 10 m long EHTF sections were constructed by ITP: 4” – 6” PiP with a single phase Deutsch electrical connector per section.
- Installation as in the field: welded inner pipes, covered by sleeves and filled with resin.
- Temperature 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).

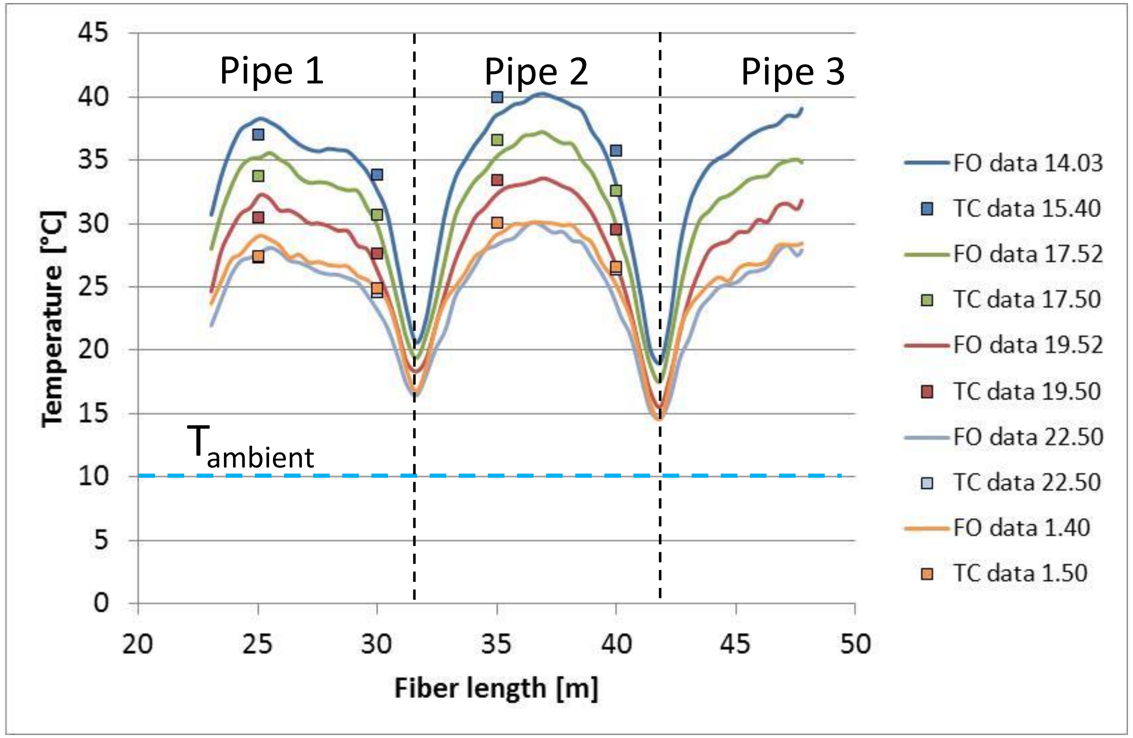


Results – air filled: cool down

- 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)

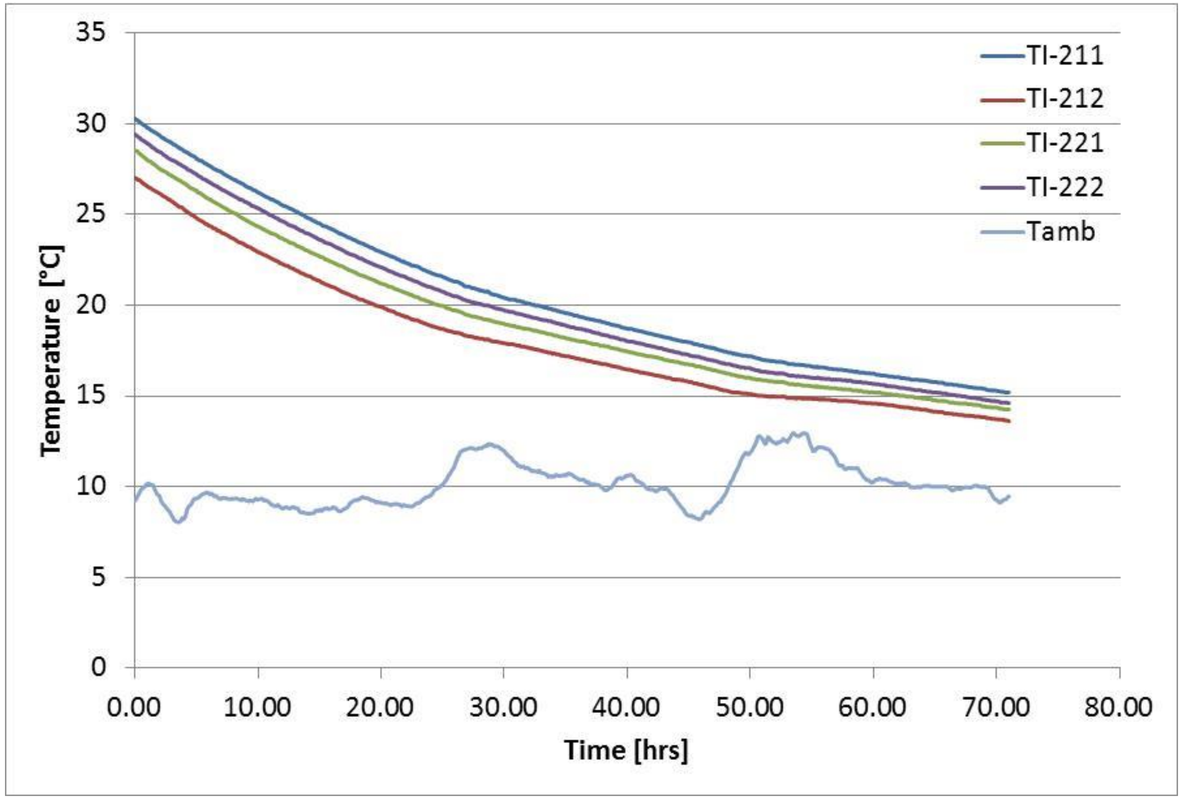
- Heat transfer analysis used to determine overall U-value ~ 0.3 W/m²K for the main pipe.
  This is consistent with the expected design value.

- FO cable clearly shows the evolution throughout the pipeline



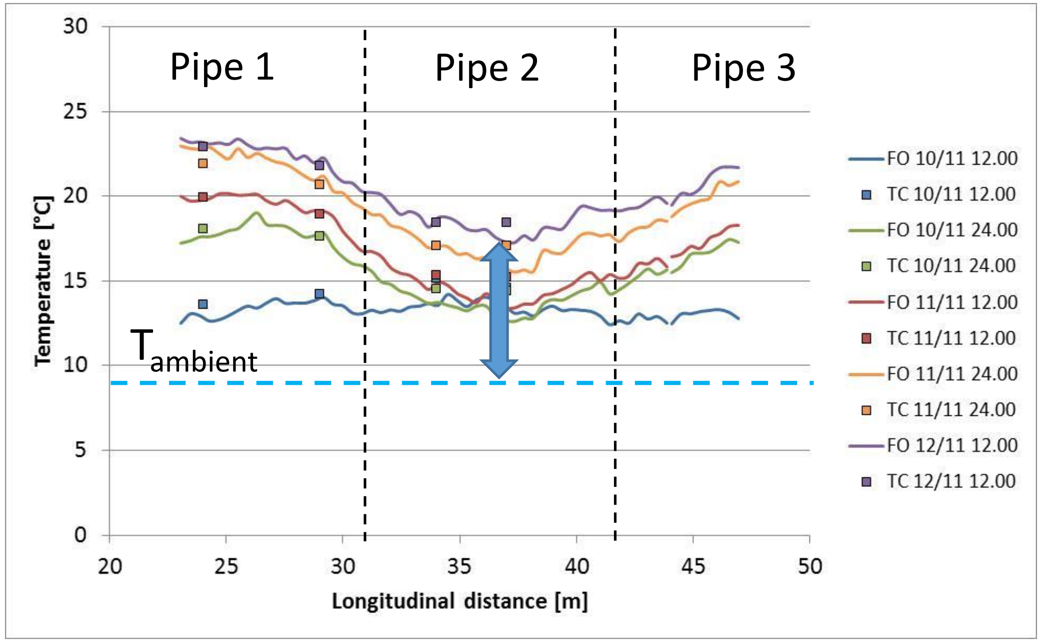
Results – water filled: cool down

- 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/(m^2.K)



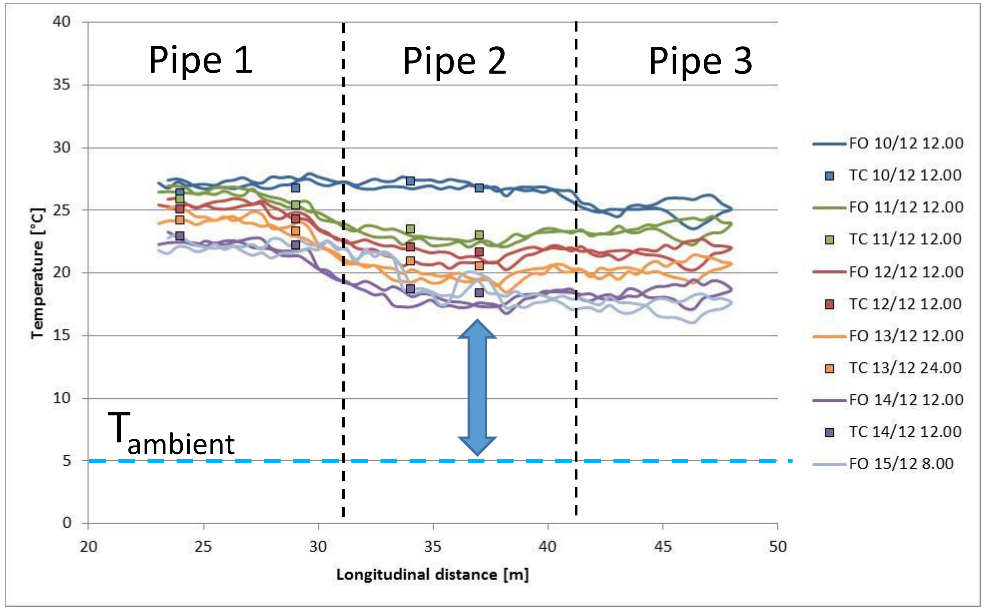
Failure mode: one pipe not heated

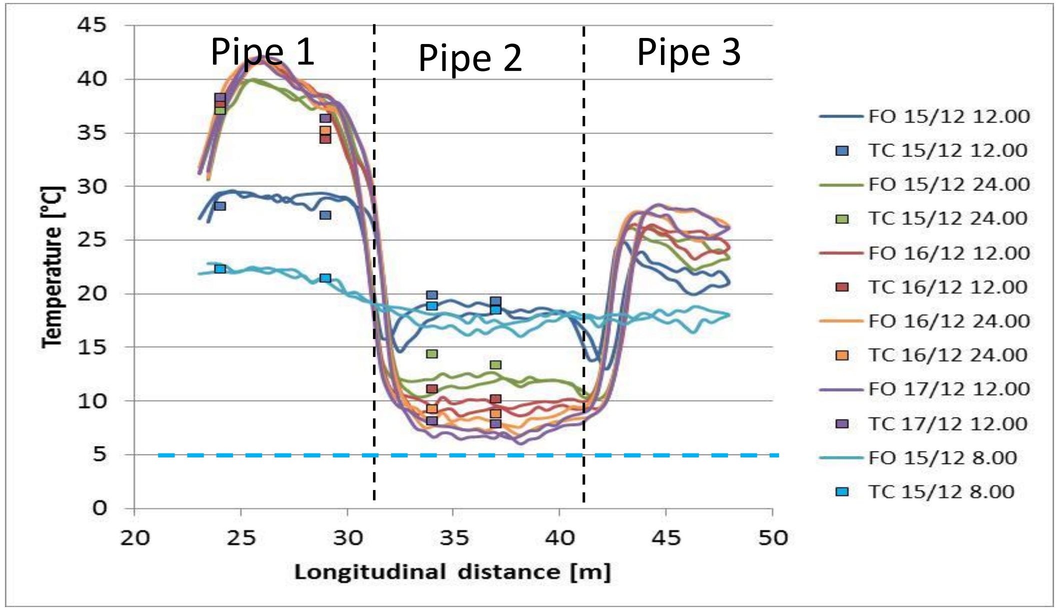
- Heating central EHTF section switched off
- Gradual warm-up, slower due to reduced power input
- Central pipe also warms up: convective transport of heat into the central pipe due to natural convection. The heat flow is able to cross the sleeves and flow into the highly insulated pipe-in-pipe sections.
- 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 W/(m^2.K) $\leftrightarrow$ Fully water filled system: 0.55 W/(m^2.K)

- With air: no convection (low sleeve temperature), so U value ~ U value individual PiP section
- With water: natural convection: so U value ~ U value of the assembly

- Knowing the field joint length (~ 2 m) results in estimate for its U value: 1.55 W/(m^2.K)

$$U_{overall} * L = U_{joint} * L_{joint} + U_{line} * L_{line}$$

- Considering then a field joint length of 48 m (as installed offshore) gives an overall U value of 0.35 W/(m^2.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 $W/m^2.K$ 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