Society for Underwater Technology

Name Robby O'Sullivan
SUT Perth
Lifecycle of Flexible Flowline and Risers Course
November 2023

Strohm

Lifecycle of Thermoplastic Composite Pipe (TCP)

Contents

Strohm

Strohm

A Brief History of TCP

2007

Joint Industry Program launched to develop a deepwater riser concept and test feasibility

2009

Founding of Airborne Oil & Gas (rebranded to Strohm in 2020)

First pilot line for continuous TCP manufacturing

2010

Full-scale production site for TCP in IJmuiden (Port of Amsterdam)

2012

First commercial delivery of offshore downline

HPE steps in as investor

2014

Launch of the Recommended Practice for TCP: DNVGL-RP F119

Shell, Chevron and Evonik on board as strategic investors

2015

Airborne Oil & Gas independent company

2016

Subsea 7 on board as strategic investor Track record on all products except TCP Riser

2017

Qualified in accordance with DNVGL-RP F119

Saudi Aramco Energy Ventures on board as strategic investor

Opening of regional offices in US & KL

2018

Aker Solutions on board as strategic investor

Full breakthrough of TCP in the market place: record number of projects including flowlines

2019

Sumitomo on board as strategic investor

First TCP in GoM on Shell's flagship project Perdido

2020

Airborne Oil & Gas rebrands to Strohm

2022

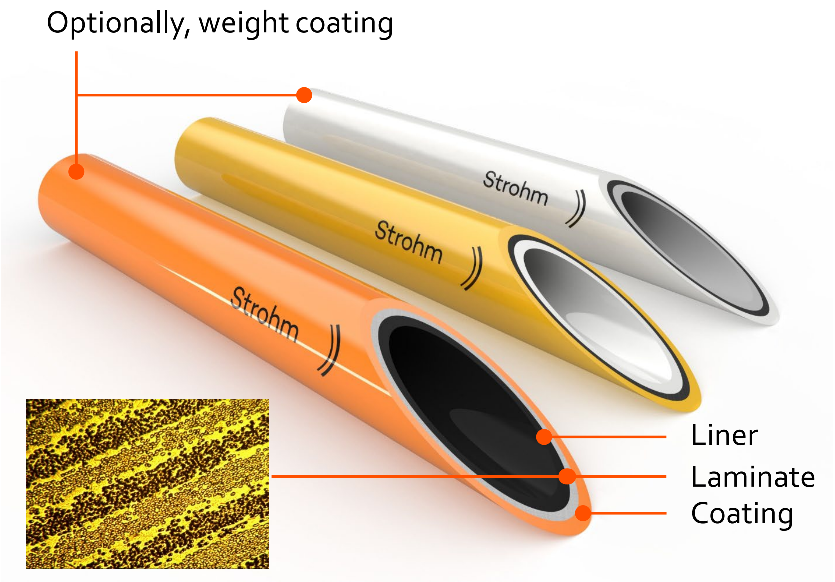
HydrogenOne on board as strategic investor

Strohm commitment to Energy Transition

Contents

Thermoplastic Composite Pipe

TCP is a fully bonded 3 layer pipe



- Two components, a fibre and polymer, selected and optimized for each application
- Liner and protective coating for robust offshore and subsea application
- Melt-fused composite laminate based on glass or carbon fibre with same polymer as liner & coating, to form a solid wall

- Flexible and spoolable in long lengths
- No metals – no corrosion and chemically resistant
- On-target weight – stable and light, reducing transportation and installation cost

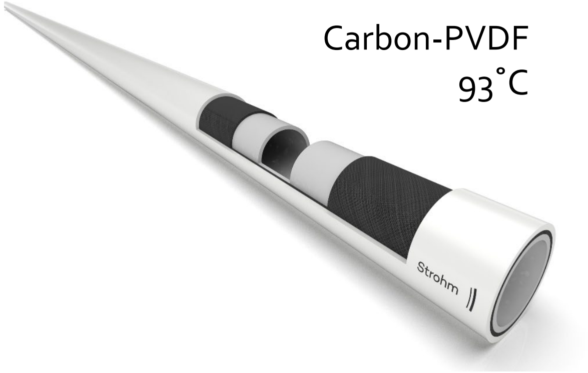
Thermoplastic Composite Pipe

3 Polymer Material Grades for increasing levels of performance specification

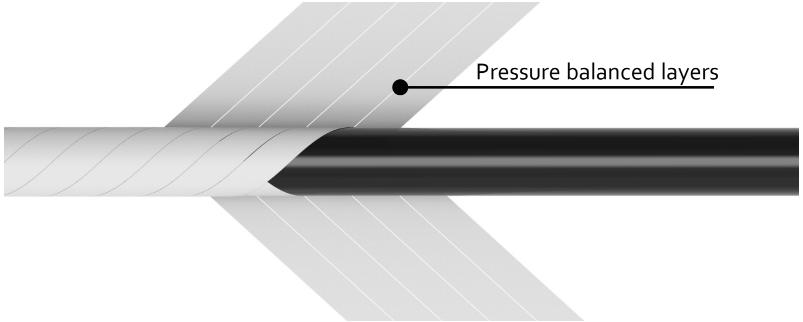
- Fully qualified to 60 Degrees C, option to 65 Degrees C (150 F)
- Medium pressure (5,000 psi)
- Low permeation
- High chemical resistance
- Weight coating option
- Flowlines and jumpers

- Up to 80 Degrees C (180 F)
- High pressure (10,000 psi)
- Low permeation
- Flowlines and jumpers

- Highest temperature up to 93 Degrees C (200 F)
- High pressure (10,000 psi)
- Highest chemical resistance
- DNV qualification complete 2022
- Weight coating option

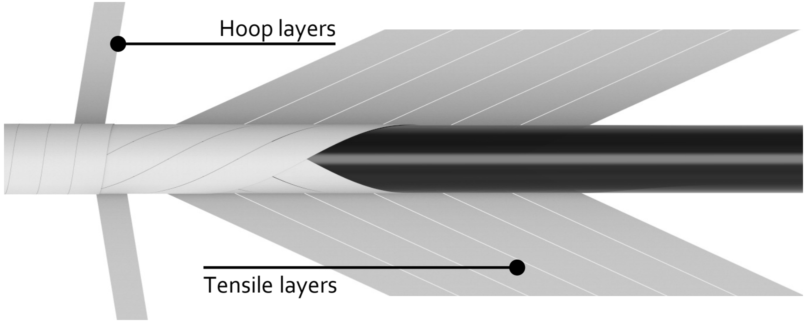


Thermoplastic Composite Pipe (TCP): Concept



Static Flowline & Jumper Design

- Flexible fibre angle design
- High internal and external pressure strength
- Lower tensile strength
- Small MBR: D/d 30
- Flexible



Dynamic Riser Design

- Fibres in all load directions
- High internal and external pressure strength
- High tensile strength
- Larger MBR: D/d 50
- Fully elastic

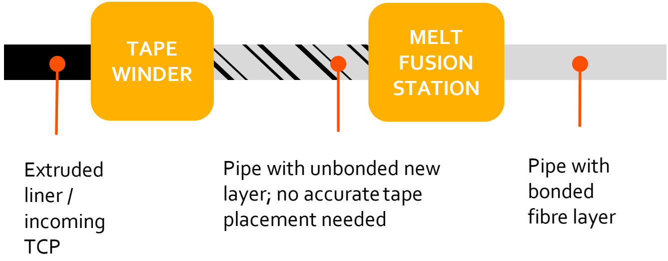
Overview of TCP Product Families and TRL level

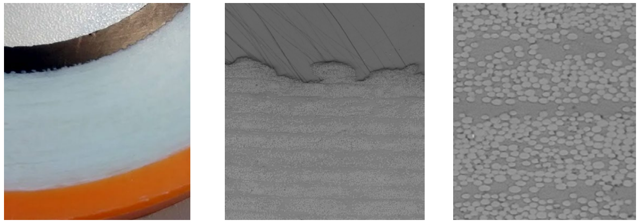
Sustainable pipeline solutions supporting the energy transition

Traditional Energy applications		Renewable Energy applications
Jumper & Flowline **All services, 60°C**	**TRL-7**	**Hydrogen** **CCUS** **Water**
Jumper & Flowline **All services, 80°C**	**TRL-6**	**Hydrogen** **High pressure** **Dynamic**
Jumper & Flowline **All services, 93°C - 121°C** **Risers**	**TRL-4**	**CCUS** **High pressure** **Dynamic**

TCP Manufacturing

Proprietary melt fusion technology produces fully bonded pipe





Contents

Design and Qualification for Application

TCP pipe is custom design for the specific project requirements

Application

Installation preferences

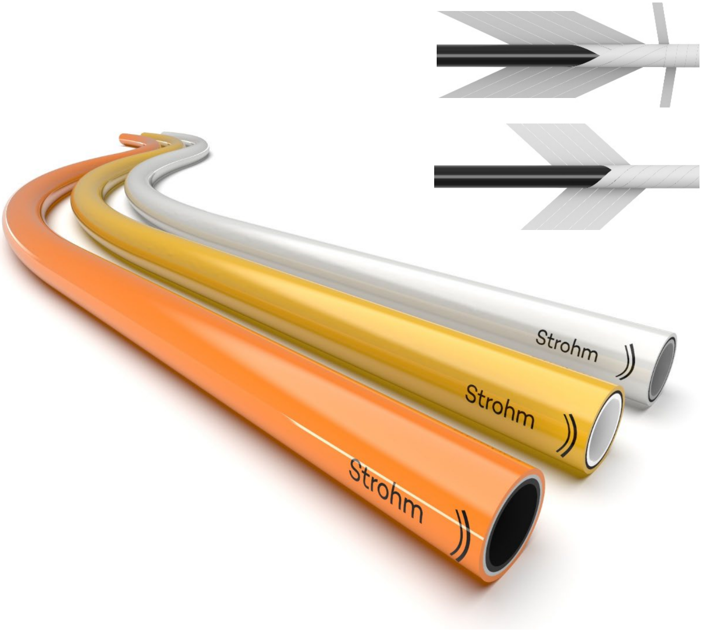
Track Record & qualification

Technology Readiness Level

All qualification work is directed to complete pilots in order to achieve TRL-6

Track record for any given material is considered suitable when the stress state is not fundamentally different:

- Same application but different water depth
- Different fluid but similar or less severe than what was tested



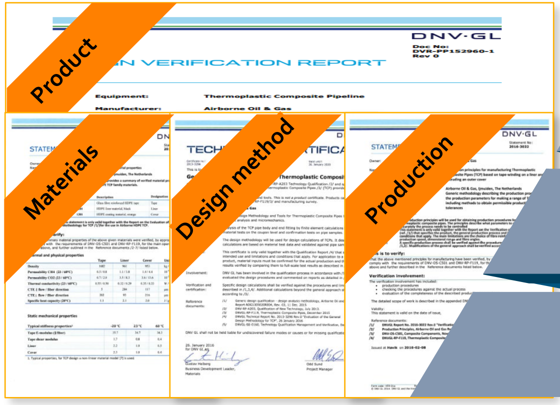
Qualification approach

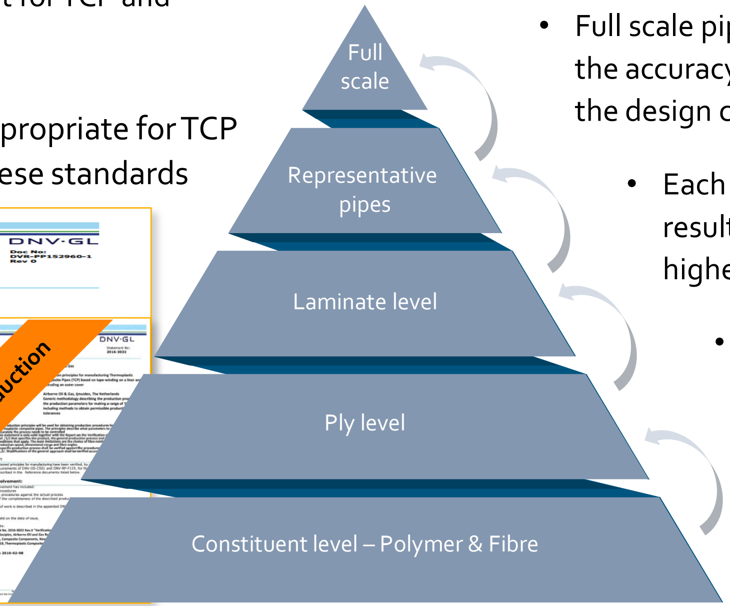
TCP is designed with the through life conditions included

DNV-ST F119 Standard

- Standard specifically meant for TCP and offshore use

- API 17J and 17B are not appropriate for TCP
- TCP do no comply with these standards





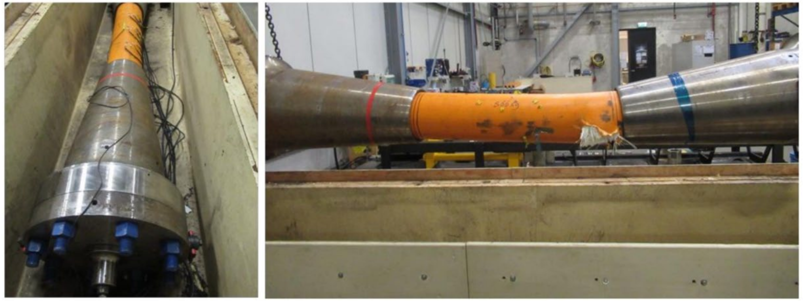
DNV-ST F119 Qualification approach

- Full scale pipes are tested on critical load cases to prove the accuracy of the design predictions, hence proving that the design covers all single and combined load cases well
  - Each step includes validation, proving that the results from the lower level can be used for the higher level
    - Material performance is measured and tested with infield conditions of fluid, temperature etc
      - Tested material performance is translated to validate a model based on fibre and polymer

From design model to validation test

Virtual testing is validated by full scale testing, confirming that the predictive engineering approach yields accurate results – done for <u>all</u> critical load cases

Qualification testing – internal pressure burst

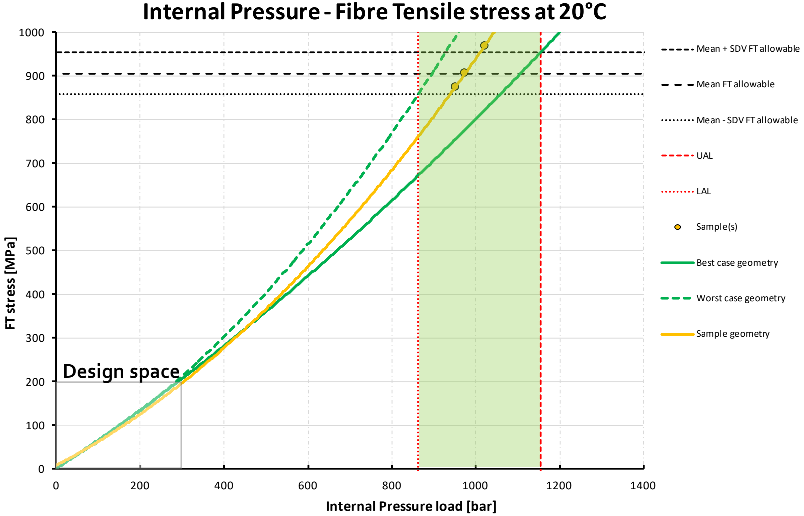


Failed sample after the IP test, where the failure is caused by fiber failure in tension leading to burst of the pipe sample.

Sample nr.	Failure pressure [bar]	Failure mode	Test Temperature [°C]	Acceptance	Result
S6220	1020	Burst	RT	863 (LAL) ≤ P [bar] ≤ 1154 (UAL)	**PASS**
S6656	972	Burst			
S6657	950	Burst			

1000 bar = 14,500 psi

Predictive engineering



- ✓ Failure governed by the fiber tensile strength
- ✓ Good correlation between the finite-element predictions and experimental observations

Contents

TCP Design Differentiators: No Steel

The absence of steel in TCP leads to numerous fundamental design differences when compared with traditional flexible pipe

No Corrosion

- No pitting corrosion, stress corrosion cracking, hydrogen induced cracking.
- Higher tolerance to seawater, H_2S, CO_2

Reduced Weight – Design Considerations

- Lower riser topside payload
- Reduced subsea connector loading
- On-bottom stability – weight coating or external

No Fatigue

- Order of magnitude increase in TCP fatigue endurance relative to steel

TCP Design Differentiators: Other

Fully Bonded Pipe Construction

- No annulus ➔ No gas venting requirement
- No collapse failure mechanism due to rapid gas depressurisation

Smooth Bore Pipe

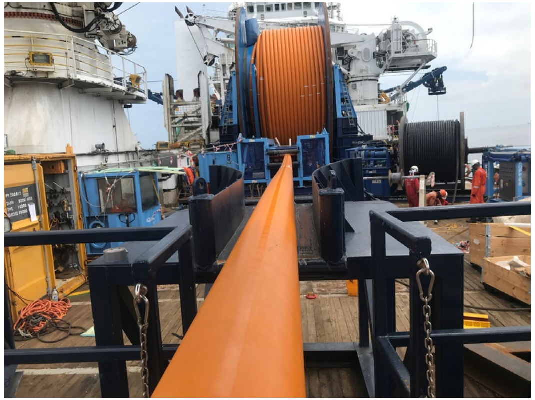
- Smaller diameter requirement to satisfy flow assurance requirements

Polymer based laminate strength layer

- Mechanical resistance is temperature dependent
- Temperature is a key design parameter in pressure and tension capacity

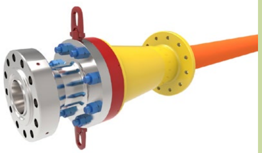
TCP Installation Differentiators:

The absence of steel in TCP leads to numerous fundamental installation differences when compared with traditional flexible pipe



Reduced weight – Installation Considerations

- Smaller cranes for loadout and transportation
- Lower spec vessels – horizontal lay flowlines
- Cradle installation for jumpers



Simplified End fitting can be post - installed

- Jumper on Demand concept
- Optimised j-tube pull in

TCP Jumper on Demand concept

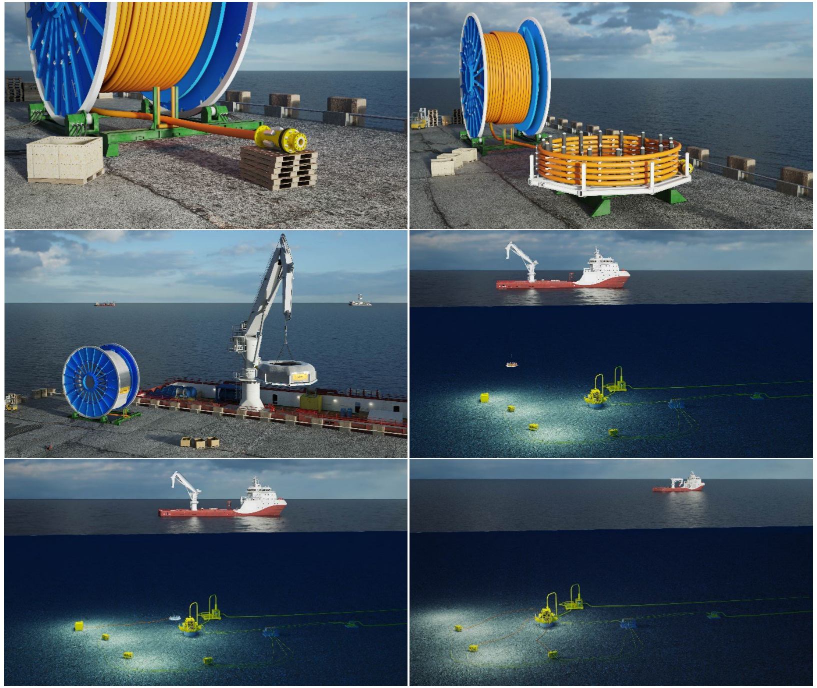
The concept for ultimate flexibility combined with lowest as-installed cost and highest local content

Preparation:

- TCP is manufactured in long length and shipped to near location
- TCP is cut to length and terminated onsite
- TCP is spooled onto subsea pallet
- Local content opportunities in end-fitting and ancillary supply and termination

Installation:

- Installation through MSV
- De-risking of project schedule
- Lowest cost



Life of field: repair

Event response procedures

Event initiation and inspection

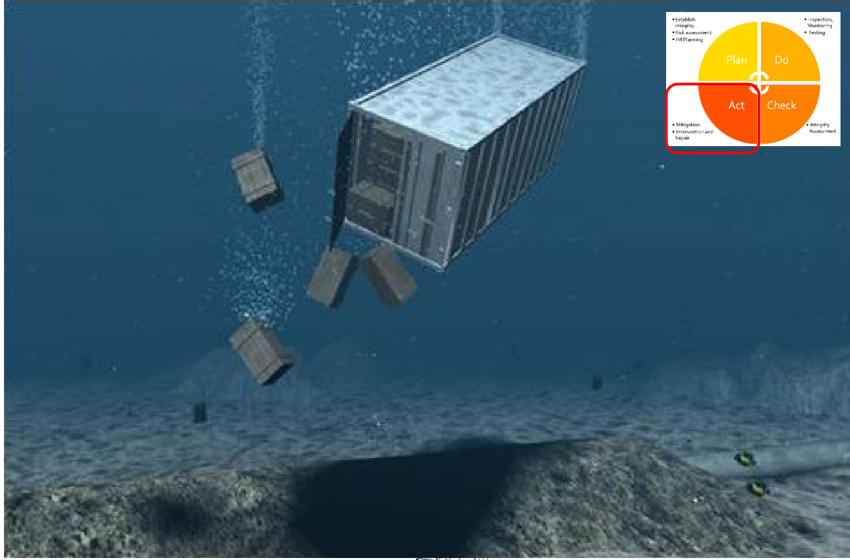
- Identification through monitoring event (e.g. loss of pressure)
- External visual inspection, ROV
- Internal inspection, caliper pig, digital x-ray

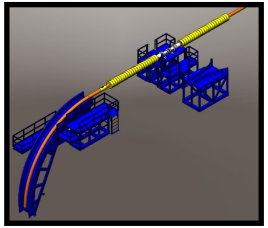
Repair options

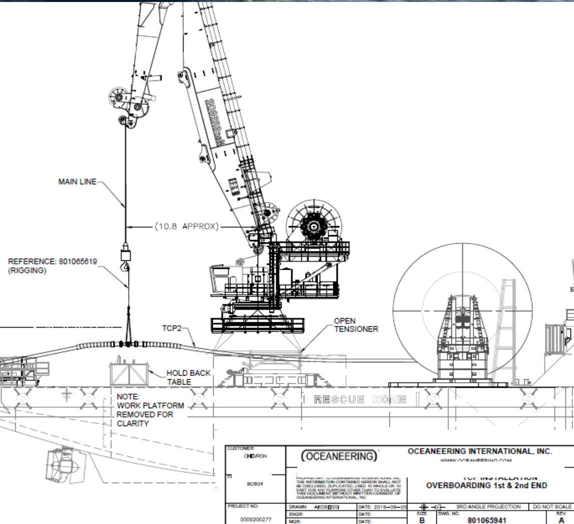
- Coating damage: coating repair / plidco clamp
- Through-wall damage: re-termination with inline connector or two standard end fittings

Strohm support

- Detailed installation, maintenance & repair manual
- 24/7 service support
- Trained & experienced field service staff





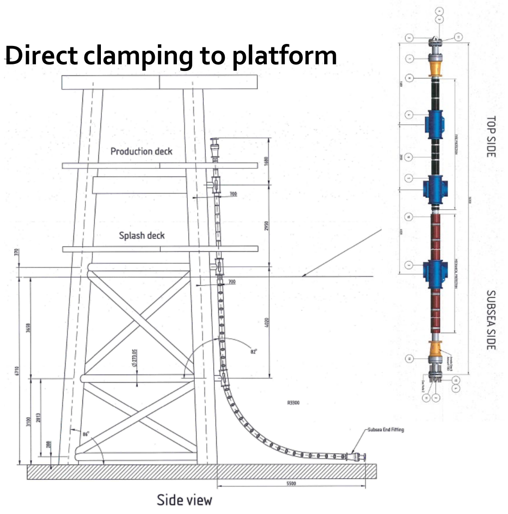


A flexible solution for platform interface

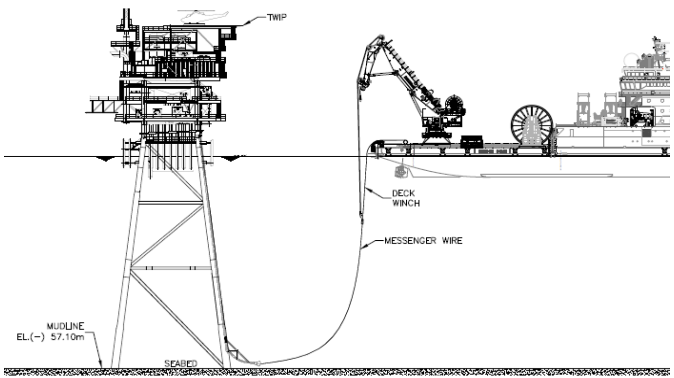
TCP can be terminated offshore enabling light weight J-tubes

- Pull-in through J-tube can be done with a combination of Chinese finger or internal pulling device, enabling much smaller J-tubes
- Alternatively TCP can be pre-terminated, or directly clamped to platform

Direct clamping to platform



J-tube pull through



“On our project we could reduce the J-tube size from 20 inch to 10 inch, for a 8 inch flowline”

TCP Riser: The Best Solution for Deepwater

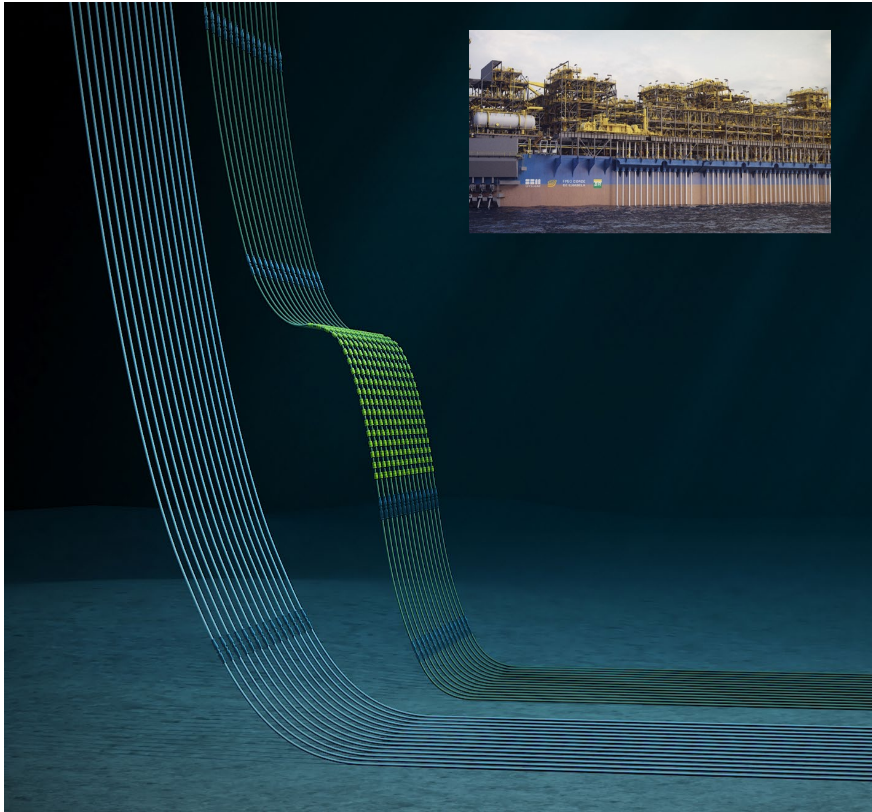
Free hanging catenary, no corrosion, lowest total installed cost and longest service life

The TCP Riser enables the cost effective, robust and simple free hanging catenary configuration:

- No corrosion, no stress corrosion cracking
- No buoyancy elements required
- Single water column connection, two sections
- Superior fatigue performance
- Significant top tension reduction

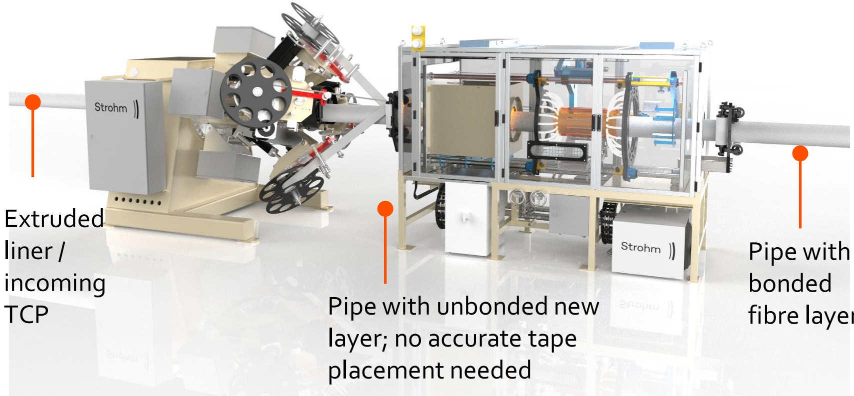
June 2021, Strohm, Petrobras and Shell signed a JIP contract for the development, qualification and piloting of the TCP Riser for deepwater application

> "We see the full TCP Riser as the ultimate solution for deepwater pre-salt fields"
>
> Strohm client, national oil company



Strohm

TCP Manufacturing Differentiators:



Simplified manufacturing process
- Compact machinery with limited setup time
- Shorter jumpers are cost effective to manufacture

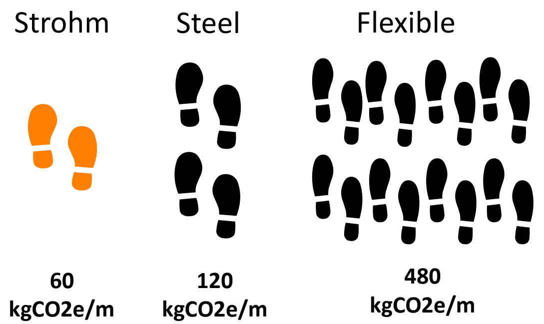
Contents

TCP supports the Energy Transition

From decarbonization to CCUS and H2: TCP is the best pipeline solution

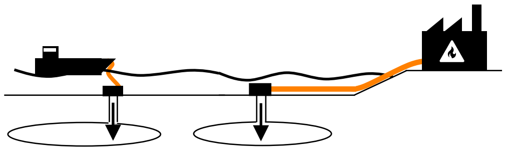
Decarbonisation

- TCP has the smallest CO_2 footprint of any pipeline[3]
- CO_2 footprint becoming a key parameter besides CAPEX: TCP targets both



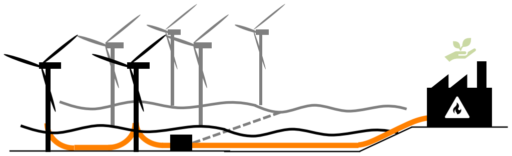
CCUS

- TCP is chemically resistant to CO_2 and can allow for high water content & other impurities
- TCP does not suffer from running ductile failure as steel
- TCP can be used for static and dynamic offloading applications



H2

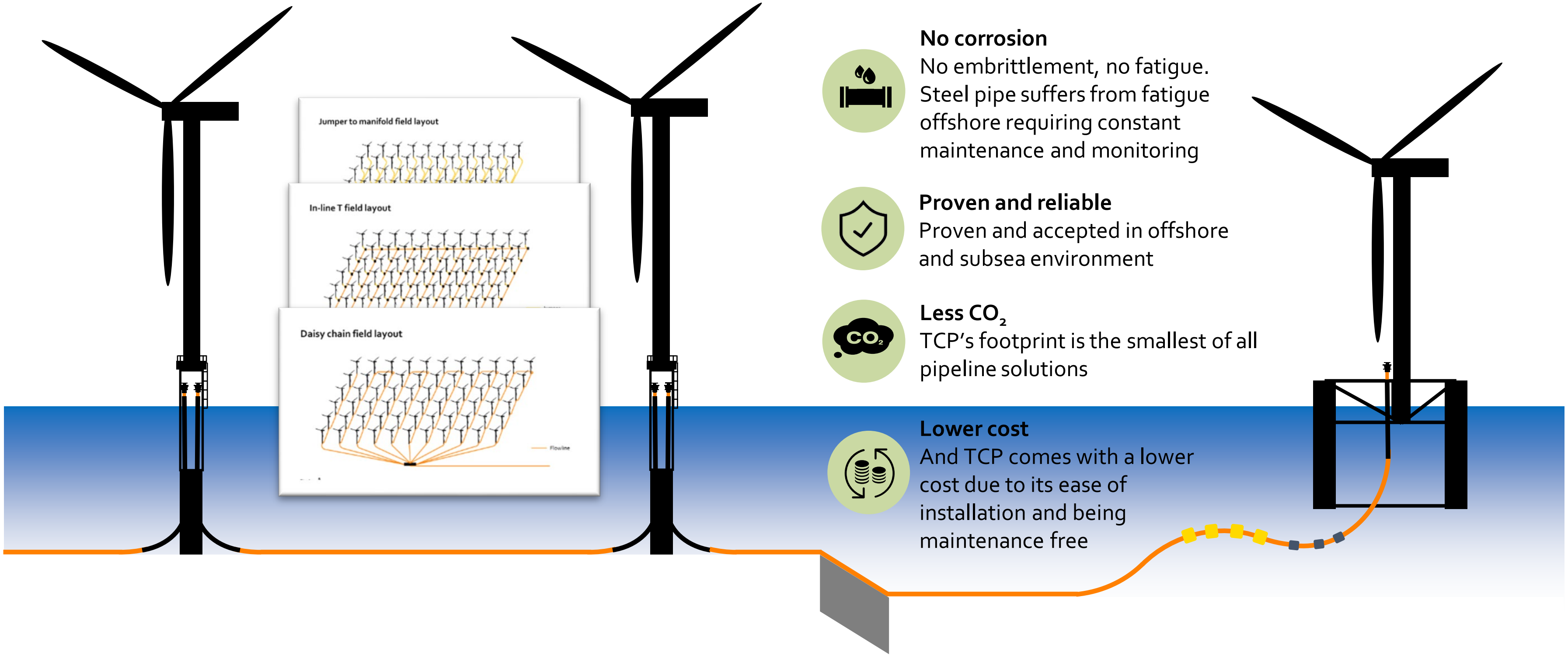
- TCP has the lowest LCOE[1]
- No embrittlement,
- No fatigue, can handle pressure fluctuations due to intermittency
- Direct WTG[2] pull in
- Permeation barrier
- Both bottom fixed and floating wind



1: Levelized cost of energy: source strategic shareholder input
2: Wind Turbine Generator
3: Based on EGF/PE, 7.1 inch TCP and estimated equivalents

The market needs a solution and TCP is preferred

TCP with a large track record, provides solutions for all offshore green hydrogen developments



No corrosion
No embrittlement, no fatigue. Steel pipe suffers from fatigue offshore requiring constant maintenance and monitoring

Proven and reliable
Proven and accepted in offshore and subsea environment

Less CO_2
TCP's footprint is the smallest of all pipeline solutions

Lower cost
And TCP comes with a lower cost due to its ease of installation and being maintenance free

Contents

Summary and Conclusion
Key Takeaways

SUT
Society for Underwater Technology

- **Comprehensive qualification program and track record**
- **DNV STF 119 is governing standard**
- **TCP is a viable alternative for Flexible Pipe**
    - No Steel = No Corrosion
    - Not susceptible to Fatigue
    - Fully bonded pipe – no annulus
- **Jumper on Demand offers cost and schedule flexibility**
- **Ideal for Energy Transition applications**
    - Compatible with CO_2 and H_2S Transportation

No corrosion. Lower cost. Less CO_2.