Subsea Flowlines - Advanced Flow Management & Reuse
Are flowline costs significant?

Long step-out 45%

Short step-out 30%

Is there an opportunity to lower flowline cost through technology & by applying The Circular Economy?
Flowline Technology
Cost Assessment 6-inch x 10 km

**Carbon Steel**

- Reel No Re-Use w/ Insulation: 100%
- Composite: 107%
- Composite: 79%
- Thread & Couple w/ Insulation: 67%
- Thread & Couple w/ Flow Coat: 67%

**CRA Mechanically Clad**

- Reel No Re-Use w/ Insulation: 100%
- Composite: 109%
- Mechanical Connector Re-Use w/ Insulation: 81%
- Mechanical Connector Re-Use w/ Flow Coat: 81%

- Reel No Re-Use w/ Insulation: 100%
- Composite: 109%
- Mechanical Connector Re-Use w/ Insulation: 85%
- Mechanical Connector Re-Use w/ Flow Coat: 85%

- Reel No Re-Use w/ Insulation: 100%
- Composite: 109%
- Mechanical Connector Re-Use w/ Insulation: 78%
- Mechanical Connector Re-Use w/ Flow Coat: 78%

- Reel No Re-Use w/ Insulation: 100%
- Composite: 109%
- Mechanical Connector Re-Use w/ Insulation: 76%
- Mechanical Connector Re-Use w/ Flow Coat: 76%

- Reel No Re-Use w/ Insulation: 100%
- Composite: 109%
- Mechanical Connector Re-Use w/ Insulation: 51%
- Mechanical Connector Re-Use w/ Flow Coat: 51%

- Reel No Re-Use w/ Insulation: 100%
- Composite: 109%
- Mechanical Connector Re-Use w/ Insulation: 40%
- Mechanical Connector Re-Use w/ Flow Coat: 40%

- Reel No Re-Use w/ Insulation: 100%
- Composite: 109%
- Mechanical Connector Re-Use w/ Insulation: 37%
- Mechanical Connector Re-Use w/ Flow Coat: 37%

- Reel No Re-Use w/ Insulation: 100%
- Composite: 109%
- Mechanical Connector Re-Use w/ Insulation: 33%
- Mechanical Connector Re-Use w/ Flow Coat: 33%

- Reel No Re-Use w/ Insulation: 100%
- Composite: 109%
- Mechanical Connector Re-Use w/ Insulation: 30%
- Mechanical Connector Re-Use w/ Flow Coat: 30%

➢ 20km sees a further small reduction on re-use
Flow Assurance

Conventional approach:
- Keep fluids hot (high levels of insulation)
- Chemically treat with inhibitors (umbilicals and service flowlines)

The Aim:
- Eliminate insulation
- Minimise chemical injection

Possible Solutions:
- Cold flow – modify fluid behaviour to avoid deposition and blockage in conventional pipeline systems
- Advanced surface preparation – modify pipeline inside surface to prevent deposit adhesion and blockage
Internal Surface Coatings

To realise flow assurance benefits:
1. Low surface energy
2. Low surface roughness

Advanced polymer coatings are under development
- Presents an opportunity to learn from other industries

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whitford</td>
<td>PTFE</td>
<td>Low surface energy and surface roughness; likely to have good flow assurance properties.</td>
</tr>
<tr>
<td>Victrex</td>
<td>PEEK</td>
<td>Low surface energy and surface roughness; likely to have good flow assurance properties.</td>
</tr>
<tr>
<td>Tuboscope</td>
<td>Epoxy</td>
<td>Corrosion coating; limited flow assurance benefit. Field proven for down-hole service</td>
</tr>
<tr>
<td>Bredero</td>
<td>Epoxy</td>
<td>Flow coating; limited flow assurance benefit. Field proven for gas pipeline service.</td>
</tr>
</tbody>
</table>

Different technology readiness

- Composite pipe offers similar internal surface & benefits
Internal Coatings - Conclusions

Coatings exist which have the potential to eliminate insulation and flow assurance chemicals.

Coatings also protect the pipe against corrosion

Coatings could simplify upset operations

However:

- Currently no field proven systems. Behaviour of coatings under pressure is a major uncertainty.
- Significant application-specific research and testing is needed.
- May imply increased risk of blockage as a trade off for reduced CAPEX
- Reliance solely on internal coatings requires intervention strategies.
- Not suitable for conventional welded construction
Mechanically Connected Pipelines

Not a new idea

Joint Industry Projects:
- 2H Threaded Riser and Flowline JIP (2000)
- DNV Mechanically Connected Pipelines 2016/17

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<tr>
<td>Zap-lok</td>
<td>Friction Stab</td>
<td>Extensively tested; Field proven. Current w.d. limit 100m. Further development needed for deeper water.</td>
</tr>
<tr>
<td>VAM TTR</td>
<td>Threaded + coupled</td>
<td>Extensive use downhole – avoids welding if use more connections; suited to coating application.</td>
</tr>
<tr>
<td>Marine Direct</td>
<td>Stab + ferrule make-up</td>
<td>Weld on connector, preloaded BX seal hubs. In detail design; qualification planned</td>
</tr>
</tbody>
</table>

Strength and fatigue better than welded pipe.
Mechanically Connected Pipelines - Conclusions

**Advantages:**
- Internal coatings
- Recovery and re-use
- Higher strength steel (T&C)
- Reduced CAPEX

**However:**
- Reliability concerns
- Long term integrity management
- Connector/pipe interaction
- Limited Track record for flowlines
Composite pipe

An interesting alternative to steel pipe.

Qualified products from Airborne & Magma

**Advantages:**
- Flow assurance
- Corrosion
- Suitable for Reuse
- Install by CSV
- Lower cost tie-ins

**However:**
- Limited to 6 or 8-inch diameter
- Limited supply chain
- Limited track record
- Hydrodynamic stability
Most existing flowlines will be decommissioned in-situ

Drivers for Re-use for future developments:

- **Commercial arrangements**
- **Pipe not returned to shore between deployments**
  - Implies cost effective offshore inspection/certification can be developed to assure next user of retrieved condition
- **On bottom pipeline design is adopted**
  - Reduces cost of first use
  - Reduces cost of retrieval
  - Requires agreement with fishermen
- NNS Steel pipes are stable within displacement limits
- CNS Steel pipes are stable within displacement limits
- SNS Steel pipes are not stable
- Effect of insulation
- Composite pipe is not stable
On bottom design – Lateral Buckling

Welded Pipe
- Probability of failure due to local buckling is acceptable in most cases
- Fracture limit state dependent on D/t ratio and temperature

Mechanically Connected Pipe
- Capacities of connectors exceed pipe
- Strain concentrations
Cost Assessment

- Identify cost impact of advanced internal coatings, alternative flowline technologies & reuse

- Parameters
  - OD = 10-inch/8-inch/6-inch
  - Length = 10km & 20km
  - Carbon Steel or CRA Clad pipe or Composite pipe
  - Welded, Mechanical connected & Thread & Coupled
  - External Insulation with internal Corrosion Coat or internal Advanced Flow Coat
  - 1, 2 or 3 uses
  - Re-use cases: Smart operational monitoring & offshore inspection
  - Pipe not returned to shore between uses – recovered to shore after last use

- Typical Operating Conditions
  - Temperature = 80°C
  - Pressure = 345 Bar (5ksi)
  - Water Depth = 100m
Cost Assessment 10-inch x 10km

Carbon Steel
*No Composite Option

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- Thread & Couple w/ Insulation
- Mechanical Connector Re-Use w/ Flow Coat
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<tr>
<td>1</td>
<td>100%</td>
</tr>
<tr>
<td>2</td>
<td>82%</td>
</tr>
<tr>
<td>3</td>
<td>77%</td>
</tr>
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CRA Mechanically Clad
*No Composite Option

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<td>72%</td>
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✔ 20km sees a further small reduction on re-use
Cost Assessment 8-inch x 10km

Carbon Steel

CRA Mechanically Clad

- 20km sees a further small reduction on re-use
Cost Assessment 6-inch x 10 km

Carbon Steel

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CRA Mechanically Clad

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20km sees a further small reduction on re-use

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Conclusions

1. Pipeline reuse appears to offer significant savings.
2. Mechanical connectors show promise. Potential to reduce costs & facilitate reuse but need to demonstrate similar reliability to welded joint.
3. Composite pipe also interesting, especially in smaller sizes. Ideally suited to reuse. Address stability.
4. Advanced coatings could offer CAPEX & OPEX reductions but at relatively early development - composite pipe.

However

1. All technologies need further investment
2. Commercial models for re-use also required
Contact locations

For more information go to

www.crondall-energy.com