Zap-Lok – A Mechanical Interference Connection to Overcome Today’s Offshore Installation Challenges
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1. Enabling Concept

1.1 Zap-Lok Mechanical Interference Connection and Internal Plastic Coating (IPC)

**Pipe Cross-Section**
- External Coating
- Lubricant
- Steel
- Internal Coating

**Diameter. (NPS):** 2 to 16-inch (50-400mm)
**Wall thickness:** Up to 1.000” (25.4mm)
**Material:** Grade B to X70; SMLS, HFI or ERW
**Service:** Sweet and sour crude, gas, condensate, water, steam
**Pressure:** As per line pipe material specification
**Corrosion Barrier:** Epoxy / Phenolic – up to 2% H₂S, CO₂, Acids, SRBs
1. Enabling Concept

1.2 Zap-Lok / Internal Plastic Coating (IPC) Design

Design Schematic

**Traditional Design**

- Parent Pipe
- 3LPE
- CWC

**Zap-Lok IPC Design**

- IPC
- Parent Pipe
- 3LPE

*Raw Material Cost Comparison (DDU)*

**25km x 10 ¾” OD, API 5L Gr. X52 HFI PSL2, SG 1.25**

*Zap-Lok / IPC*: 17.5mm wt, 3LPE, TK70

*Traditional*: 12.7mm wt + 3mm CA, 3LPE + 40mm CWC

*Cost [USD]*

- **Pipe**
- **Zap-Lok ends**
- **IPC**
- **3LPE**
- **CWC**
Zap-Lok connectors enable the end user to consider smaller vessels of opportunity as the amount of offshore work is reduced, i.e. only one connection station no field jointing stations are required. Considering a standard S-Lay construction method, the mobilization / demobilization costs and day rates are dramatically reduced.
1. Enabling Concept

1.4 Modular Pipelay System (MPS)

<table>
<thead>
<tr>
<th>Pipe OD (in)</th>
<th>Pipe Stored on Back Deck (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>800 m²</td>
</tr>
<tr>
<td>6</td>
<td>26</td>
</tr>
<tr>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>16</td>
<td>7</td>
</tr>
</tbody>
</table>

- Control Cabin, Workshop Container, Hydraulic Power Units
- Pipe Lifting System
- Pipe Storage Racks
- Pipe Conveyor
- Pipe feed table
- Zap-Lok Press
- Tensioner
- Integral A-frame & Modular Stinger
1. Enabling Concept

1.4 Modular Pipelay System (MPS)

The Remacut Modular Pipelay System (MPS)

- Fully automated
- Fully North Sea compliant
- $4-6m per system including stinger (not shown here)
1. Enabling Concept

1.4 Modular Pipelay System (MPS)
1. Enabling Concept

1.5 Tie-back Cost Summary – DP2 S-Lay

25km x 10 ¾” OD, API 5L Gr. X52 HFI PSL2, SG 1.25

Zap-Lok IPC BOD: DP2 supply vessel (modified S-Lay) using Zap-Lok connector and MPS
Traditional BOD: DP3 pipelay barge (S-Lay) using girth welding

Additional OPEX Benefits
- Increased flow rates
- No corrosion
- No MIB
- No waxing
- No scaling
- No inhibitors
- No erosion
- Reduced pigging
- LOP costs dramatically reduced
- CAPEX and OPEX reduced
## 2. Zap-Lok Mechanical Interference Connection

### 2.1 Operating Envelope

<table>
<thead>
<tr>
<th>Test</th>
<th>Average Result</th>
<th>Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial Tension</td>
<td>70% UTS</td>
<td>ASME B31.4 / B31.8, ISO 21329 (app. Level 4)</td>
</tr>
<tr>
<td>Axial Compression</td>
<td>&gt; 95% UTS</td>
<td>ASME B31.4 / B31.8, ISO 21329 (app. Level 4)</td>
</tr>
<tr>
<td>Internal Pressure</td>
<td>&gt; 95% UTS</td>
<td>ASME B31.4 / B31.8, ISO 21329 (app. Level 4)</td>
</tr>
<tr>
<td>Bending</td>
<td>&gt; 95% UTS</td>
<td>ASME B31.4 / B31.8, ISO 21329 (app. Level 4)</td>
</tr>
<tr>
<td>Fatigue – in air</td>
<td>DnV D Class weld curve</td>
<td>BS 7608 F2 / DNV C1, ISO 21329 (app. Level 4)</td>
</tr>
<tr>
<td>Fatigue – in water</td>
<td>DnV C2 Class weld curve</td>
<td>BS 7608 F2 / DNV C1, ISO 21329 (app. Level 4)</td>
</tr>
<tr>
<td>Stress Corrosion Cracking</td>
<td>No reduction in strength</td>
<td>NACE MR0175 / NACE TM0177 – Method A</td>
</tr>
<tr>
<td>Crevice Corrosion</td>
<td>No reduction in strength</td>
<td>1 month exposure at 130°F and 500psi in brine with 1,000ppm acetic acid, 30% CO₂, 70%N₂</td>
</tr>
<tr>
<td>Electrical Resistivity</td>
<td>±1μΩ / connection</td>
<td>N.B. 10A, 25mV FSD</td>
</tr>
</tbody>
</table>
2. Zap-Lok Mechanical Interference Connection

2.1 Operating Envelope

**Make-Up Loads - Static**

Stresses during mandrel insertion

Stresses following pin insertion.

12-inch, 0.500” wt, Grade X65
2. Zap-Lok Mechanical Interference Connection

2.1 Operating Envelope

Installation Loads - Dynamic

Bending to 140m radius

Bending to 67m radius

Bending to 30m radius.

12-inch, 0.500” wt, Grade X65

- Pin wrinkling
- Separation of pin from bell
- Hoop stress and bending moment on pin end
2. Zap-Lok Mechanical Interference Connection

2.1 Operating Envelope

Service Loads - Static

Pressure to Failure

Tension to Failure

Bending and Tension

12-inch, 0.500” wt, Grade X65
2. Zap-Lok Mechanical Interference Connection

2.1 Operating Envelope

**Service Loads - Dynamic**

![Graph showing stress range vs. number of cycles](image)

DNV-RP-C203 and Zap-Lok S-N Curves in Seawater with CP vs. Weld Curves
1. Zap-Lok Mechanical Interference Connection

2.2 End Preparation

- Mobile plant reduces handling costs – 3 x 40ft ISO containers
- Safe production of ends with Zap-Lok experts and local labour
- High production rate of 2,000-3,000m/12hr shift
- QC checks conducted at plant ensuring consistency of shipped product.
- Repeatability of production method permits CAR insurance on connection.
2. Zap-Lok Mechanical Interference Connection

2.2 End Preparation
➢ Tuboscope inspectors complete 100% visual and dimensional inspections using calibrated equipment during end equipment.

➢ 100% MPI and 10% UT are generally conducted for offshore products.

➢ 3 x control burst tests are completed on joints taken from each mill heat.
2. Zap-Lok Mechanical Interference Connection

2.4 Installation Equipment

8000-16 press
2. Zap-Lok Mechanical Interference Connection

2.5 Jointing

16-inch, 0.843” wt, Grade X65
2. Zap-Lok Mechanical Interference Connection

2.6 Installation Quality Control
2. Zap-Lok Mechanical Interference Connection

2.7 Certificates of Conformity

- BV witnessed certificate of conformity demonstrating onshore compliance with ASME B31.4

- Lloyd’s Register Energy conformity certification for offshore compliance as per DNV-OS-F101
3. Internal Plastic Coating (IPC)

3.1 Flow efficiency & Corrosion Coatings

- **Smoothness**
  - Limited design life
  - Thickness: 40-125μm
  - Air-cured
  - Sometimes holiday checked
  - 4-5 yr life in harsh conditions

- **Consistent surface**
  - 20-50 year design life
  - Thickness: 150-500μm
  - Heat-cured
  - Rigourously holiday checked

**Starting Point:**

- Corrosion Coatings
- Provide
- Flow Efficiency

But not vice versa
3. Internal Plastic Coating (IPC)

3.2 Manufacture

1. Pre-cleaning
2. Thermal cleaning
3. Internal shot blasting
4. Primer and pre-heat
5. IPC application
6. Thermal cure
7. Quality control
8. External Varnish
9. Bundling and shipment
3. Internal Plastic Coating (IPC)

3.2 Manufacture
3. Internal Plastic Coating (IPC)

3.3 Reductions in CAPEX and OPEX

Pressure Rating: \[ MAOP = f \times SMYS \times \frac{2(t_{\text{press}}+t_{\text{corr}}+t_{\text{stab}})}{OD} \]

For onshore applications, by applying IPC the corrosion allowance, \( t_{\text{corr}} \), can be removed entirely such that we only need to consider wall thickness for pressure containment, \( t_{\text{press}} \), thus saving raw material costs.

For offshore applications, again no corrosion allowance is required. The interesting trick here is to maintain a large wall thickness, i.e. increase \( t_{\text{stab}} \), to give the required on-bottom stability as we know this will not be corroded or eroded. This enables the design engineer to negate the requirement for CWC therefore reducing CAPEX.

Flow Efficiency: \[
\frac{dV}{dt} = -0.965 \left( \frac{gD^5h_L}{L} \right)^{0.5} \log \left[ \frac{\varepsilon}{3.7D} + \left( \frac{3.17u^2L}{gD^3h_L} \right)^{0.5} \right]
\]

Valid for turbulent flow where \( Re > 2,300 \)

We can see that the above equation that the volume flow rate of a fluid is proportional to the surface roughness \( \varepsilon \). Specifically \( \dot{V} \propto \log \varepsilon \).

Generally speaking for 6-12” pipe we can see that the differential in steel surface roughness (45\( \mu \)m) to that of IPC (1.5\( \mu \)m) leads to flow improvements of around 20% for crude to 30% for gas transmission. These ameliorations increase production rates and lead to reduction in raw material costs – reducing CAPEX.

It should be mentioned here that IPC also eliminates the requirement for corrosion inhibition – reducing OPEX.
# 3. Internal Plastic Coating (IPC)

## 3.4 Line Pipe Coating Performance

### Coating Performance Table

<table>
<thead>
<tr>
<th>Coating</th>
<th>TK-44LP</th>
<th>TK-70</th>
<th>TK-70XT</th>
<th>TK-15</th>
<th>TK-15XT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>107°C (225°F)</td>
<td>107°C (225°F)</td>
<td>107°C (225°F)</td>
<td>149°C (300°F)</td>
<td>149°C (300°F)</td>
</tr>
<tr>
<td>Flexibility (Ring Crush)</td>
<td>&gt;19 mm (0.750 inch)</td>
<td>&gt;25.0 mm (1.0 inch)</td>
<td>&gt;12.0 mm (0.5 inch)</td>
<td>&gt;2.28 mm (0.09 inch)</td>
<td>&gt;3.71 mm (0.146 inch)</td>
</tr>
<tr>
<td>Abrasion resistance</td>
<td>0.0018 mm/1000 cycles</td>
<td>0.0018 mm/1000 cycles</td>
<td>0.00106 mm/1000 cycles</td>
<td>0.0102 mm/1000 cycles</td>
<td>0.0071 mm/1000 cycles</td>
</tr>
</tbody>
</table>

### Coating Details Table

<table>
<thead>
<tr>
<th>Coating</th>
<th>Temperature</th>
<th>Pressure</th>
<th>Liquid Phase</th>
<th>Gas Phase</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>TK-44LP</td>
<td>121°C (250°F)</td>
<td>5,000 psi</td>
<td>Water / Hydrocarbon</td>
<td>50% CO₂/50% CH₄</td>
<td>16 hours</td>
</tr>
<tr>
<td>TK-70</td>
<td>135°C (275°F)</td>
<td>5,000 psi</td>
<td>H₂O / Hydrocarbon</td>
<td>50% CO₂/50% CH₄</td>
<td>16 hours</td>
</tr>
<tr>
<td>TK-70XT</td>
<td>135°C (275°F)</td>
<td>5,000 psi</td>
<td>Water / Hydrocarbon</td>
<td>50% CO₂/50% CH₄</td>
<td>16 hours</td>
</tr>
<tr>
<td>TK-15</td>
<td>149°C (300°F)</td>
<td>9,000 psi</td>
<td>Water / Hydrocarbon</td>
<td>100% CO₂</td>
<td>120 hours</td>
</tr>
<tr>
<td>TK-15XT</td>
<td>149°C (300°F)</td>
<td>9,000 psi</td>
<td>Water / Hydrocarbon</td>
<td>100% CO₂</td>
<td>120 hours</td>
</tr>
</tbody>
</table>
Conclusion

**Technical**
- Zap-Lok connectors, having gained full industry acceptance, qualification and significant track record enable end-users to dramatically reduce installation costs of in field gathering systems.
- IPC is a fully qualified and proven system that gives lifetime corrosion integrity to in-field flowlines enabling the modified design techniques to be used to provide a more cost effective pipeline basis of design.
- The combined Zap-Lok technology is best suited to shallow water installations (up to 200m), encompassing relatively sour service where it is an ideal option for most applications.

**Commercial**
- Zap-Lok combined with Internal Coatings cab provide can significant savings on raw material costs, for offshore line pipe.
- These cost savings are amplified to give Capex installation cost savings that can be achieved using vessels of opportunity and modular pipelay (handling) systems for installation.
- Opex costs are dramatically reduced through improvements in hydraulic efficiency, elimination of inhibitors, and reduction in corrosion, erosion and therefore maintenance.
Questions?
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