Mooring Line Integrity Monitoring

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Mooring Line Failures

- 107 mooring incidents from 73 facilities across the industry (1997-2012)
- 51 single line failures – 9 multiple line failures
- 38 pre-emptive replacement events – 9 reports of severe degradation
- 150 lines replaced/repaired 2001-2011 (Ref: OTC 24181)
Mooring Line Failures

Failures rate per line per year of exposure (1997 – 2014)

- Long term Mooring system design life: 15-25 yrs
- 1:50 chance of a failure per asset per year
- Considering 25 years of design life: chance of 50% failure during the lifetime of a mooring line

Ref: Underlying causes of Mooring line Failures
24th March 2015
Enhancing operational safety

Safety Barrier Principle

- Monitoring tension & fatigue
  - Extreme tensions and cumulative fatigue issue

- Detection of single mooring line failure
  - Preventative action to prevent multiple line failure

Consequences:

- Loss of production
- Environmental damage
- N-1 design
- Multiple line failure

Threats:

- Monitoring fatigue accumulation
  - Fatigue
- Corrosion
- Overload

Detection of large tension events

- Early detection of single line failure

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Pulse Mooring Monitoring Solutions

- Mooring line inclination
- Topside tension (Load cells)
- In-line tension (Inter-M Pulse)
- Excursion monitoring

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# How to Monitor?

Main mooring monitoring technologies - comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Inclination</th>
<th>In-line Tension</th>
<th>Load Cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Communication</td>
<td>Acoustic</td>
<td>Acoustic</td>
<td>Hardwired</td>
</tr>
<tr>
<td>Data Availability</td>
<td>On Demand</td>
<td>On Demand</td>
<td>Continuous</td>
</tr>
<tr>
<td>Direct Tension</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Battery Life</td>
<td>Dependent on operating mode</td>
<td>Dependent on operating mode</td>
<td>Unlimited</td>
</tr>
<tr>
<td>Reliability</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Serviceable</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Retrofittable</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

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Mooring Integrity Monitoring
Improving reliability

| Design          | • Assist with development of specification  
                        • Early involvement with project  
                        • System redundancy  
                        • Serviceable systems |
|-----------------|----------------------------------------------------------------------------------|
| Installation    | • Robust installation procedure  
                        • Use experience and best practice  
                        • Cable management  
                        • Smart integration |
| Operation       | • Ongoing maintenance & service plan  
                        • Data analysis and reporting  
                        • Not “fit and forget” |

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Questions on How to specify a mooring line monitoring system?