3D Gamma Tomography Tool
cutting edge technology for hydrate plug detection

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Outline

• Introduction
• Flow assurance challenges and needs
• Initial Statoil and Tracerco cooperation on developing/testing detection tools
• Examples of field tests
• DiscoveryTM - Subsea Pipeline Visualisation
• Introduction to the technology
• Trials and scan images
• Summary and Conclusion
Introduction

• Hydrate restrictions in production systems
• No reliable detection tools, especially for subsea use
• Needs for high accuracy detection tools
• Cooperation between Statoil and Tracerco over last 10 years
  – To develop detection technology
  – Primary goal was FA applications
  – Application areas have expanded
Flow Assurance challenges

• Plug location
• Plug characteristics
  – Liquid pockets, wax depositions, hydrate restrictions, scale etc.?
• Information important for
  – Safety considerations
  – Evaluation of remediation solutions
Statoil's Flow Assurance Pilot

- Subsea template mimic
- Flowline mimic
- KO drum
- Gas/liquid separator
- Flare line
- Gas feed
- Fiber optics in all test sections
- 6" test section

Statoil's Flow Assurance Pilot
Statoil's Flow Assurance Pilot Plant

Tomography technique used during hydrate detection trials

Tomography map with liquid filled pipe section

Tomography map after draining
Tomography applications

Topside field measurements

100 mm
Single gamma applications

Subsea field trial

Graph 6: Density measurements on the “Wye” riserbase

Figure 1: Illustration of Tracerco Diagnostics Subsea Pipe Scan equipment

Picture 1: Tracerco Diagnostics Subsea Pipe Scan equipment
Discovery Pipeline Visualisation

- Tracerco Discovery™ is the world’s first Subsea CT Scanner, a revolutionary non-intrusive technology for inspection of subsea pipelines.
- It is specifically targeted for the inspection of unpiggable, coated pipelines.
Discovery Principle

Same principle as medical CAT scanner

• Reconstructs image of a target from a series of projections
• One gamma radiation source and a large number of detectors

The same concept has been taken from the medical field to design, implement and deploy a scanner for subsea pipelines
Discovery

Initial Prototype Results
Initial Lab Prototype Results

10-inch Pipe, 20mm wt, 50mm PU coating
Pipe-in-pipe Systems

Assess integrity of inner and outer pipes
Caissons and Pipe Bundles

Assess integrity of internal flowlines as well as the outer pipe

- Oil Riser
- Gas Riser
Discovery

The Instrument
Discovery – specification overview

• Completely non intrusive
  – No need to remove coating
  – No need to stop production

• Wide range of pipes
  – 6 to 27 inch.
  – Integrity and Flow Assurance
  – Pipe-in-pipe and caissons

• 10000 ft / ~3000m Depth

• X/Y resolution close to 1mm

• Real-time Data Acquisition on the vessel
  – Images continuously updated every 20-30 seconds
Discovery – specification overview

- **Crawler**
  - Instrument automatically advances on the pipe

- **Scanning speed**
  - ~2-3 ft/h for low resolution
  - ~0.5 ft/h for high resolution
Discovery

Underwater Trials
First Subsea Trial - Bergen, April 2013
2nd Subsea Trial – Scotland, 08/13
Customer Trial Results

• Test pieces supplied by customers, for proof of capability prior to offshore inspection project
Flow Assurance Trial 1
20-inch Pipe, 22mm wt, with brick, thermalite block, 2 sand bags, half filled with water

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
<th>Dimensional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Known feature</td>
<td>Object of size 100mm wide x 50mm high, density ~2.4g/cc</td>
</tr>
<tr>
<td>2</td>
<td>Known feature</td>
<td>Object of size 95mm wide x 210mm high, density ~0.9g/cc</td>
</tr>
<tr>
<td>3</td>
<td>Known feature</td>
<td>Freeform object of approx. size 100mm x 90mm high, density ~1.9g/cc</td>
</tr>
<tr>
<td>4</td>
<td>Known feature</td>
<td>Freeform object of approx. size 100mm x 90mm high, density ~1.9g/cc</td>
</tr>
<tr>
<td>5</td>
<td>Known feature</td>
<td>Fluid filled to approx. 50% of volume, density ~1g/cc</td>
</tr>
<tr>
<td>6</td>
<td>Unknown feature</td>
<td>Gas pocket of approx. size 70mm wide x 35mm high</td>
</tr>
</tbody>
</table>
Flow Assurance Trial 2

8-inch water injection line with plastic liner

- 273mm OD, 15.9mm WT
- 10mm internal plastic lining
- Manufactured blister to simulate damage
**Flow Assurance Trial 3**

<table>
<thead>
<tr>
<th>TEST</th>
<th>Detect small gas channel openings in blocked pipelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHY</td>
<td>Assess possibility of gas communication between different sections</td>
</tr>
</tbody>
</table>
| MODEL | • 12 inch Pipe-in-Pipe  
|       | • Blockage and gas as density-equivalent plastic. Then inserted in the pipe and scanned |

![Diagram showing outer and inner pipes with asphaltene or wax blockage and 6 gas channels from 0.25 to 2.2 in]

OUTER PIPE  
(12.7 in OD, 0.5 in Wall)  
INNER PIPE  
(8.7 in OD, 0.87 in Wall)  
ASPHALTENE OR WAX BLOCKAGE  
6 GAS CHANNELS from 0.25 to 2.2 in
Trial 3 – 30 seconds (1 lap)

Most channels detected **after just 1 lap!**
Trial 3 – 1 minute (2 laps)

Getting Sharper. Now all channels are visible.

MODEL

RECONSTRUCTION
Trial 3 – 5 minutes (10 laps)

Getting Sharper. All channels well visible.
Trial 3 – 12.5 minutes (25 laps)

All channels completely detected.
Flow Assurance Trial 4

TEST

Detecting gas pressure differences in blocked pipelines channels

WHY

Assess gas communication (HP/LP) between sections of pipeline

MODEL

• Same Pipe-in-Pipe
• Blockage and as density-equivalent plastic to asphaltene or wax.
• HP/LP gas as density-equivalent foam (0.1/0.2 g/cc)

HIGH PRESS.
GAS ~0.2 g/cc

LOW PRESS
GAS ~0.1 g/cc
Trial 4 – 12.5 minutes (25 laps)

Successful detection of gas density differences in channels.

MODEL
0.2 g/cc

RECONSTRUCTION
0.1 g/cc
Tracerco Discovery

Customer Trial Results – Pipeline Integrity
# Integrity Trial 1

<table>
<thead>
<tr>
<th>TEST</th>
<th>Detect wall loss on the inner walls of pipelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHY</td>
<td>• Assess safety margins</td>
</tr>
<tr>
<td></td>
<td>• Extend service life</td>
</tr>
<tr>
<td>MODEL</td>
<td>• 20 inch pipe, ~20mm wall</td>
</tr>
<tr>
<td></td>
<td>• Several defect profiles machined at different axial positions in the pipe</td>
</tr>
</tbody>
</table>
Integrity Trial 1

6+1 localized defects and 2 scallops to model wall loss
Trial 1 – 30 seconds (1 lap)

Early detection of most defects and scallops in **30 seconds**.
Trial 1 – 5 minutes (10 laps)

Image getting sharper. All defects clearly visible.
Trial 1 – 20 minutes (40 laps)

High resolution image. All defects visible and quantifiable.
Integrity Trial 2

‘Blind test’ with unknown defects in a 20-inch coated pipeline
Integrity Trial 3

<table>
<thead>
<tr>
<th>TEST</th>
<th>Detect voids and broken strands in flexible risers</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHY</td>
<td>• Assess safety margins</td>
</tr>
<tr>
<td></td>
<td>• Extend service life</td>
</tr>
<tr>
<td>MODEL</td>
<td>• 12-inch flexible riser</td>
</tr>
<tr>
<td></td>
<td>• 1 strand segment was removed from the outer tensile armor.</td>
</tr>
</tbody>
</table>
Trial 3 – 30 seconds (1 lap)

Indication of broken strand at the first lap (30 seconds).

MODEL

RECONSTRUCTION
Test 4 – 12.5 minutes (25 laps)

Image getting sharper. More detail on the inner carcass and all other layers.
Conclusion

• Tracerco and Statoil have cooperated to produce the world’s first Subsea CT Scanning device.
• Truly non intrusive technology
  – Through coating
  – No need to stop production
• Integrity and Flow Assurance
• Real time data
• Near mm accuracy
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