Subsea Integrity Monitoring – Naxys Acoustic Leak Detector for major operator's deep water project
Content

- Business Case
- Recommended practice
- Sensor coverage
- Installation & Interface
- Performance Leak Detection
- Regulations
- Condition Monitoring
Subsea Leak Detection

**CAPEX**
- Risk reduction
- Reputation
- Cost of lost production
- Availability
- Performance/production
- OPEX
- CAPEX

**OPEX**

**INCENTIVE**
- Risk reduction
- Reputation
- Cost of lost production
- Availability
- Performance/production
- OPEX
- CAPEX

**PUSH**
- Regulations
- Polluter pays
- Public
- Insurance?
RECOMMENDED PRACTICE
DNV-RP-F302

SELECTION AND USE OF SUBSEA LEAK DETECTION SYSTEMS

APRIL 2010

Offshore leak detection
Sensor coverage is described as:

— regional coverage, meaning that they can cover the entire field development or more
— area coverage, meaning that they can cover a large area of the field but not full field coverage
— local coverage, meaning that they will cover an area close to the sensor.

The accuracy of the placement, the range covered and positioning parameters vary from technique to technique. Some techniques require contact with the leaking medium, and can detect a leakage in their vicinity but cannot determine the location of the leak. Sensors using these principles are named point sensors. These sensors may be an option for monitoring of high risk leak points. Some of the sensors can also be used for additional purposes, including condition monitoring. This can potentially result in early warnings and allow the operators to take actions before an incident escalates into a leak. In the table below (subsea techniques) "leak positioning" refers to the capability of a single sensor. System configuration and processing software may enable leak positioning.
**SUBSEA LEAK DETECTION**

**POINT SENSING**

Direct contact with the leaking medium is required.

**LIMITED/LOCAL AREA**

Limited detection range to a few meters

**WIDE AREA & Condition Monitoring**

Covers an extended area e.g. entire subsea structure and adjacent infrastructure

NAXYS A1 delivered since 2014

NAXYS A3 delivered since 2010

NAXYS A10 delivered since 2006
NAXYS A1 - POINT SENSOR

LEAKAGE TREND MONITORING:

LEAKAGE STATUS:
• OK
• WARNING
• ALARM

Informed Decisions
• Availability
• OPEX
**SUBSEA LEAK DETECTION**

**POINT SENSING**

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NAXYS A1 delivered since 2014

NAXYS A3 delivered since 2010

NAXYS A10 delivered since 2006
TECHNOLOGY – SUBSEA SENSING

• One monitoring system for:
  ▪ Subsea Leak Detection
  ▪ Vibration Monitoring
  ▪ Machinery and process monitoring
• Stand-alone & non-intrusive

LEAK DETECTION
• Early detection
• Wide area coverage
• Directional
• High sensitivity

VIBRATION DETECTION
• Early detection
• Structural, Flow lines, Riser

MACHINE & PROCESS MONITORING
(Compressor, Pump, Transformer, ...)
Acoustic & Electric monitoring
Continuous & synchronous
Early detection of changes/faults

NAXYS A10E
Installation & Interface
A10 on Aasgard Subsea Compressor System
Naxys A10 mounted on a manifold
3 alternatives for mounting Naxys A10 onto a manifold

Landed onto any horizontal surface having a footprint of 1 m diameter. Suitable for retrofit installation by ROV.

Docking station (cross) pre-welded onto subsea installation. Suitable for new structures, installation dry or by ROV.

Docking station (guide post) pre-welded onto subsea installation. Suitable for new structures, installation dry or by ROV.
Naxys system overview

TOPSIDE

• Early warning
• User-friendly interface
• Status:
  - OK
  - Warning
  - Alarm
• Trend values

Field-proven interface to major system integrators

SCM

Download
• Calibration
• Configuration
• Software updates

Status Message
• Ethernet (SiIS Level 3)
  - RS485
  - CAN
  - IWIS
  - Modbus/TCP
  - FTP
  - UDPIP

A10 installed subsea and connected to the Subsea Control Module (SCM)
**NAXYS SUBSEA SUPPORT UNIT**
POWER, CONTROLS, DATA MANAGEMENT, DATA TRANSFER

**POWER**
- Battery power
- Externally powered (e.g. from SCM)

**EXTERNAL DATA TRANSFER & COMMUNICATION**
- Through SCM
- Through ROV
- Cable to surface
- Acoustic communication to surface
- Pop-up buoy with satellite communication
- Retrieval of module and transfer of stored data

**COMMUNICATION, DATA PROCESSING & STORAGE**
- Instrument power & communication interface (4-20mA, CanOpen, RS485, Ethernet)
- Data processing (digitization, compression, etc)
- Storage of data
- Duty cycling control (user defined)

**POWER**

**EXTERNAL DATA TRANSFER & COMMUNICATION**

**COMMUNICATION, DATA PROCESSING & STORAGE**

**AUXILIARY INSTRUMENTS**
- ACCELEROMETER
- LEAK DETECTOR
- CONDITION MONITORING
- PRESSURE SENSOR
- PIG DETECTOR
- SAND DETECTOR
- ANY OTHER SENSORS
Leak detection Performance

“During commissioning of the ALD units on Ormen Lange template A and B we saw an impressive ability to detect and determine the direction of small and large simulated leakages”

Lars Kristian Asbjørnsen, Shell
NAXYS A10 – wide area coverage

DETECTION OF WATER INJECTION LEAKAGE TO SEA

Acoustic level

Warning and sector indication

Location of Naxys A10

Sector 1
No measurable impact of marine growth
4.1.3 Conclusions

The main conclusions from the tests with the ALD passive acoustic system are:

- The system detects both gas and crude oil leakages very well, and is well suited for area coverage.
- Gas leakages are in general easier to detect than crude oil leakages.
- The most important parameter for detection is the pressure difference across the leakage opening, due to the creation of acoustic noise. If the pressure difference is above around 5 bar, leakages are easily detectable within a range of at least 10 m.
- The detection is also dependent upon the distance to the leakage and the size of the leakage opening.
- Localization of the leakage is possible.
- Other leaking fluids should also be easily detected, as long as there is a pressure difference across the leakage opening that generates sufficient acoustic noise.

Table 4.6 Results from gas leakage experiments with nozzle sizes 0.17 and 2 mm and varying distance and pressure difference.

<table>
<thead>
<tr>
<th>Nozzle</th>
<th>Distance</th>
<th>AP</th>
<th>Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.17 mm</td>
<td>2 m</td>
<td>5 bar</td>
<td>Ok</td>
</tr>
<tr>
<td>0.17 mm</td>
<td>2 m</td>
<td>4 bar</td>
<td>Ok</td>
</tr>
<tr>
<td>0.17 mm</td>
<td>2 m</td>
<td>3 bar</td>
<td>Ok</td>
</tr>
<tr>
<td>0.17 mm</td>
<td>2 m</td>
<td>2 bar</td>
<td>Ok</td>
</tr>
<tr>
<td>0.17 mm</td>
<td>2 m</td>
<td>1 bar</td>
<td>Weak, but ok</td>
</tr>
<tr>
<td>0.17 mm</td>
<td>4 m</td>
<td>5 bar</td>
<td>Ok</td>
</tr>
<tr>
<td>0.17 mm</td>
<td>4 m</td>
<td>2 bar</td>
<td>Ok</td>
</tr>
<tr>
<td>0.17 mm</td>
<td>4 m</td>
<td>1 bar</td>
<td>Weak, but ok</td>
</tr>
<tr>
<td>2 mm</td>
<td>4 m</td>
<td>10 bar</td>
<td>Ok</td>
</tr>
<tr>
<td>2 mm</td>
<td>4 m</td>
<td>5 bar</td>
<td>Ok</td>
</tr>
</tbody>
</table>

Table 4.7 Results from crude oil leakage experiments with varying nozzle size, distance, and pressure difference.

<table>
<thead>
<tr>
<th>Nozzle</th>
<th>Distance</th>
<th>AP</th>
<th>Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7 mm</td>
<td>2 m</td>
<td>15 bar</td>
<td>Ok!</td>
</tr>
<tr>
<td>0.7 mm</td>
<td>2 m</td>
<td>10 bar</td>
<td>Ok</td>
</tr>
<tr>
<td>0.7 mm</td>
<td>2 m</td>
<td>5 bar</td>
<td>Not ok</td>
</tr>
<tr>
<td>0.7 mm</td>
<td>6 m</td>
<td>20 bar</td>
<td>Ok!</td>
</tr>
<tr>
<td>0.7 mm</td>
<td>6 m</td>
<td>10 bar</td>
<td>Ok</td>
</tr>
<tr>
<td>0.7 mm</td>
<td>6 m</td>
<td>5 bar</td>
<td>Very weak, but ok</td>
</tr>
<tr>
<td>0.7 mm</td>
<td>6 m</td>
<td>5 bar</td>
<td>Not ok</td>
</tr>
<tr>
<td>2 mm</td>
<td>2 m</td>
<td>5 bar</td>
<td>Ok!</td>
</tr>
<tr>
<td>2 mm</td>
<td>2 m</td>
<td>4 bar</td>
<td>Weak, but ok</td>
</tr>
<tr>
<td>2 mm</td>
<td>2 m</td>
<td>3 bar</td>
<td>Not ok</td>
</tr>
<tr>
<td>2 mm</td>
<td>6 m</td>
<td>5 bar</td>
<td>Ok!</td>
</tr>
<tr>
<td>2 mm</td>
<td>6 m</td>
<td>4 bar</td>
<td>Weak, but ok</td>
</tr>
<tr>
<td>2 mm</td>
<td>6 m</td>
<td>3 bar</td>
<td>Not ok</td>
</tr>
</tbody>
</table>
The Activities Regulation (Norway)
§ 57 Remote measuring of acute pollution
The operator shall establish a remote measuring system that provides sufficient information to ensure that acute pollution from the facility is quickly discovered and mapped so that the amount and spread can be determined.

It has recently been stated by the Norwegian authorities in relation to future production in the Arctic region that there is a need for “early warning system based on detecting leaks at the source.”
Inward Leak Detection

LEAKAGE: Water to Water
NOZZLE: 2mm and 1.5mm
DEPTH: 210m and 100m

LEAKAGE: Water to Gas
NOZZLE: 2mm and 1.5mm
DEPTH: 210m and 100m

Leakage location:
Azimuth: 55°
Elevation: 84°

Leakage location:
Azimuth: 55°
Elevation: 115°
Dual Use

Leak & Condition Performance Monitoring
Detection of flow induced vibrations and choke cavitation
Naxys monitoring Pazflor pumps (Total Angola)

DETECTION OF ABNORMAL CONDITION
Sub-synchronous frequencies detected for one of the Pazflor pumps when running close to 3600 RPM

The movie shows frequencies detected for one of the Pazflor pumps when running close to 3600 RPM. When shaft speed is close to 60 Hz, two peaks appear symmetrically around the shaft speed divided by two.

RECOMMENDATION TO OPERATOR:
Avoid specific shaft speed close to 60Hz/3600 RPM causing sub-synchronous vibrations.

"Detecting Sub-synchronous frequencies (SSF) noise is a very valuable feasibility of the Naxys acoustic system, because this is where a lot of mechanical troubles or Offset running condition manifest. SSF reveal a lot of fluid induced trouble/instabilities because the fluid is always rotating at approximately half of the rotating speed. So fluid excitations (and so system responses) are always at 0.5X and below."

Pierre-Jean BIBET, TOTAL E&P - MPP Specialist, Senior Rotating Equipment Engineer.
PUMP HARMONICS

Significant increase in 1st harmonic → INDICATES PUMP IMBALANCE

1st harmonic:
- Related to pump imbalance
- 2008: Low value, pump well-balanced

Clear 7th harmonic related to pump characteristics
a) No monitoring system to detect damaging pump condition. Operating with limited information

- Damaging operation mode not detected: Continued 100% production detoriates pump
- Severe damage to pump
- Uninformed operation of pump continous to detoriate pump. 50% production
- Unplanned pump trip
- Unplanned mobilization of spare pump
- Production regained

Production loss: $39.4 MM

b) Naxys monitoring system detects damaging condition and provides information that supports pump operation

- Damaging operation mode detected by Naxys monitoring system: Controlled operation of pump to non-damaging mode. Production reduced to 60%
- Planned mobilization of spare pump
- Planned replacement of pump
- Production regained

$25.7MM saved by utilizing Naxys acoustic & electric monitoring for informed decision support

Production loss: $13.7 MM

Assumptions:
Production 7000 bbl/day
Oil price: $50 per bbl.