OIL & GAS

Subsea Facilities – Technology Developments, incidents and future trends

Presentation of the report

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25. March 2014
Content of the Presentation

- Background
- Norwegian trends versus other regions
- Incidents
- Integrity Management
- Future trends, developments and challenges
- Recommendations for improvement of knowledge sharing
Content

- **Background**
  - Norwegian trends versus other regions
  - Incidents
  - Integrity Management
  - Future Trends, developments and challenges
  - Recommendations for improvement of knowledge sharing
Contributions

- Svein Gundersen
- Kari Lønvik
- Christian Markussen
- Per Wallin
- Bente H. Leinum
- Bjørn Søgård
Background

- New and more challenges characterised by:
  - Increasing number of new subsea wells and also many subjected to life extension
  - Higher pressures and temperatures
  - More remote locations
  - More and more major developments reaches service life
  - New actors on NCS with operator responsibilities for subsea facilities
  - Many projects in planning and implementation stages leads to PSA’s expectation to high activity in evaluations of older facilities as well as installations of new
Purpose of document

- Shall raise awareness to the challenges in the industry
- Serve as a guideline to new operators and suppliers entering into NCS
- Capture lessons learned from about 30 years of subsea development
- Highlights applied technologies and guidelines for different selection criterions
- Serve as a guideline for operating a subsea field with organisational aspects as well as degradation mechanisms
- Share experience with incident databases and suggested improvements

- The document is written to be educational
Content of document

- Technology - Historical trends, future trends, developments and challenges both on NCS and globally
- An overview of the most serious incidents on NCS and globally
- Overview and outlook - NCS and globally
- Integrity management
- Degradation mechanisms and failure modes
- Inspection, maintenance and monitoring methodologies
- Recommendations for improvements and knowledge sharing
Defining the objects
Content

- Background
- **Norwegian trends versus other regions**
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Norwegian trends versus other regions

- Based on examination of equipment databases
Expenditure subsea versus rest of oil and gas industry NCS

Upstream expenditure growth forecast for subsea vs rest of oil and gas industry at NCS, mill US $
As of 2013 - Rystad

Annual average growth 13%
Annual average growth 3%

2012-2020
Typical NCS solutions versus GoM
Tree concept selections versus start-up years, Norway
New subsea trees on stream World Wide
Subsea trees, Geographical area

![Bar chart showing the number of subsea trees by geographical area: NCS, N Sea, UK, GOM, Australia, Brazil, West Africa. The chart indicates a higher number of subsea trees in Brazil and West Africa compared to other regions.](image-url)
Tree type per geographical area

Geographical Area

- NCS
- N Sea, UK
- GOM
- Australia
- Brazil
- West Africa

Number of XT's

- VXT
- HXT
- Mudline XT

Quest Offshore
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Incidents

- Incident and accident databases

  WOAD
  - Worldwide Offshore Accident Databank

  Health and Safety Executive

  Norsk olje & gass

  Subsea installation Network
  - Lessons Learned database
Information extracted from incident databases

- It is considered highly important to establish the root cause and the trend in order to be able to implement correct actions to prevent future incidents.

- Uncontrolled hydrocarbon leakage may have serious consequences. Other fluids such as control fluid and chemicals may have impact on the environment in form of pollution and on the operation of the installation.

- The general observation is that:
  - The amount of information in the databases varies and is relatively limited, at least what is public available
  - It is limited information available whether the leakages have occurred due to operation outside the design and/or operation envelope
  - The information indicates that leakages often occurs when there is a transient situation such as drilling, work-over or other intervention activities

- Comment: From an environmental perspective, it is more useful to track consumption of hydraulic fluid pr. well rather than number of hydraulic leaks
Information extracted from incident databases

In the search for information on the largest accidents and release of hydrocarbons from subsea facilities, public sources from the national safety authorities have been sought after and reviewed.

The content of these sources varies and clear information on volumes, type of leakage, root cause etc. is not easy to retrieve.

However, the information in the databases shows that releases from subsea production systems are relatively few and small compared to releases from other activities e.g. installation, work over and drilling. The reviewed statistics are based on;

- PSA “Hendelsesdatabasen” (Incident database)
- Bureau of Safety and Environmental Enforcement (BSEE) Statistic for releases in the Gulf of Mexico and the Pacific
- HSE supplies data from the British sector
Leaks in Norway

![Bar chart showing the cause of accidents. The chart indicates that the majority of accidents are of unknown causes.](chart.png)
Leaks in UK

HCR – The Hydrocarbon release Database System
### Bureau of Safety and Environmental Enforcement (BSEE)

<table>
<thead>
<tr>
<th>LOSS OF WELL CONTROL ***</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013 ytd</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GOM</td>
<td>PAC</td>
<td>GOM</td>
<td>PAC</td>
<td>GOM</td>
<td>PAC</td>
<td>GOM</td>
</tr>
<tr>
<td>Flow Underground</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Flow Surface</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Diverter Flow</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Surface Equipment Failure</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>LOSS OF WELL CONTROL (TOTALS)</strong></td>
<td>7</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td><strong>COMBINED TOTAL FOR THE YEAR</strong></td>
<td><strong>7</strong></td>
<td><strong>8</strong></td>
<td><strong>6</strong></td>
<td><strong>4</strong></td>
<td><strong>3</strong></td>
<td><strong>4</strong></td>
<td><strong>7</strong></td>
</tr>
</tbody>
</table>

*Source: BSEE Database as of 16-Aug-2013*

Loss of well control during the years 2007 to 2013 in the GOM and PAC.
General experience from incident database

- Root cause very hard to find
- In many cases it is not clear to distinguish if the leakage came from subsea or topside facilities
- The impression is that in many cases the incident is entered in as an incident and information not updated when the incident is rectified
- Some are comprehensive in report format and several reports has to be examined in detail in order to make a conclusion
Most serious incidents

- From reviewed databases:
  - NCS
    - In 2013 a bleed valve was set in the open position by a mistake, the estimated oil spill was 2.5 tonnes. /28/ Hendelsesdatabasen
    - In 2003 the largest uncontrolled oil spill from a NCS subsea installation happened when 500 - 800 m$^3$ of oil leaked out due to rupture in connection between manifold and production line to platform. /51/www.ptil.no/news/....
    - From July 2002 until January 2003 approx. 30 m$^3$ was released due to wrong operation of a valve on the manifold. /28/ Hendelsesdatabasen
  - UK
    - 1993 there was a leakage from a wellhead in the UK sector where approx. 13.5 m$^3$ of oil leaked out. The cause was mechanical failure during shut down of the well. /1/ Health Safety and Environment in UK
    - In 1996 a XT was leaking and approx. 41.6 tonnes of gas leaked out. The operational causation in the HCR Database is “Dropped object”. /1/ Health Safety and Environment in UK
    - In 1996 a leak was discovered during final commissioning of a subsea manifold. The root cause was identified as hydrogen embrittlement (HISC). /50/ Foinaven superduplex......
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- **Integrity Management**
  - Future trends, developments and challenges
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Integrity Management

This section of the report describes several aspects of integrity management as:

- System Integrity
- Subsea Integrity Management (SIM)
- Life Cycle Information (LCI)
- Barriers
- Threats
- Safety philosophy
- Integrity management process
- Guidelines and standards for establishing a SIM system
- Main challenges related to Integrity Management in operation
The management of a subsea production system to ensure that it delivers according to the design requirements and national regulations, and does not harm life, health or the environment, throughout the required field life.

This implies that the operator needs to establish, implement and maintain a management system that ensures the integrity of the system throughout its service life.

Subsea Integrity Management (SIM)

- Concept, design and construction (incl. pre-commissioning)
- Operation (incl. commissioning until decommissioning)
- Risk Assessment and Integrity Management (IM) Planning
- Inspection, monitoring and testing
- Integrity Assessment
- Mitigation, intervention and repair
Degradation mechanisms and failure modes

- Description of Failure modes
- Degradation mechanism
- Examples of time dependent degradation mechanisms, 15 mechanism described and explained, some also illustrated with photos

<table>
<thead>
<tr>
<th>Degradation mechanism</th>
<th>Prediction models available</th>
<th>General Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ corrosion</td>
<td>/5/, /6/, /7/</td>
<td>CS: Models available. Flow induced shear forces can enhance the corrosion by removing protective corrosion films accelerating the corrosion. CFD can be used to determine area with high wall shear stress locally. Causes metal loss. CRA: Considered fully resistant to CO₂ corrosion. Wall shear stresses not relevant.</td>
</tr>
</tbody>
</table>

Note: CS – Carbon / Low alloy steel CRA – Corrosion resistant alloys

Example from the report
Examples from report and degradation mechanism

- Degradation mechanisms for *elastomers* and *thermoplastics* in subsea applications
- 15 mechanism described and explained

<table>
<thead>
<tr>
<th>Degradation mechanism</th>
<th>General Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creep / Compression sets</td>
<td>Creep is an increase in deformation with time at constant pressure. Compression set is if the part of deformation is still present after realising the pressure.</td>
</tr>
<tr>
<td>Volume swell</td>
<td>Absorption of fluids over time that may result in volume increase and deformation and weakening of the elastomer if unconstrained or induce stress if constrained (e.g. seal).</td>
</tr>
<tr>
<td>Seal shrinkage</td>
<td>Seal shrinkage can be caused by extraction of plasticisers and additives by contacting fluids or chemical reactions and post curing. Furthermore, loss of possible plasticisers will change the mechanical properties, e.g. the low temperature properties of the elastomer may be deteriorated.</td>
</tr>
</tbody>
</table>

Example from the report
Example of degradations

Example of coating breakdown after approx. 15 years in water

Example of totally consumed galvanic anode at end of service life
## Example of threats, 69 threats listed, documented and explained

<table>
<thead>
<tr>
<th>Threat group</th>
<th>Threat – Examples</th>
<th>Threat description – Examples</th>
<th>Failure mode</th>
</tr>
</thead>
</table>
| **DFI Threats** | Design            | • Lack of understanding of relevant design standards  
• Details of interfaces not ready during design  
• Lack of experience/ Newcomer in the market  
• Lack of knowledge  
• Stretching of technology, different interpretation of qualified design (U)  
• Improper/Unfortunate design  
• Unfamiliar with project specific design requirements  
• Basis of design incomplete, inconsistent or subjected to late changes  
• Incorrect materials selection  
• Inability to capture effect of bitumen on armour stress (U)  
• Design shortcoming  
• Incomplete 3rd party verification (not able to pick-up failure or shortcomings in design due to splitting of verification scope between various suppliers(U)  
• Lack of analysis tools | Burst  
Metal loss  
Leak  
Cracking  
Yielding  
Collapse  
Loss of function  
Material ageing |
| Manufacturing |                  | • Newcomer in the market  
• New materials with unknown performance for the application in question  
• Lack of resources for manufacturing follow-up  
• Construction yards with lack of experience with relevant authority regulation and project specific specifications and standards  
• Challenges implementing project specific regulations and requirements  
• Smaller deliveries – less focus from fabrication yard  
• Culture awareness  
• Lack of qualification of manufacturer  
• Lack of traceability of raw materials  
• Use of inexperienced personnel due to high activity  
• Shortcoming and damage during manufacturing |
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Future Trends, developments and challenges

- Reference is made to OG21 and TTA4, Future technologies for production, processing and transportation
OG21 and TTA4, Future technologies for production, processing and transportation

Technology gaps and prioritised areas

![Diagram of technology gaps and prioritised areas](image-url)
Standardisation

- There is no doubt there is a big upside to standardization, both commercially and from a quality point of view.
- Standardization must go beyond materials and components.
- Suppliers are more industrialized than the operators

Image: Aker Solutions
A Report on Norwegian Subsea Standardization

An industry collaboration to improve quality, reduce costs and delivery times through increased subsea standardization.
“Standardization enables reduced costs. There is a potential for further cost reductions in equipment, project processes and documentation for subsea developments”

Focus Areas Selected

1. Unified Specifications and QA/QC for subsea forgings
2. Subsea component catalogue with configurable solutions
3. Universal Workover systems
4. Brownfield subsea re-engineering
5. Standardized subsea documentation
6. Compliance with established equipment standards
Standardisation

- There an upside in using standardised building block design. A careful adoption of this has to be taken seriously. A concern has been raised by engineers:
  - Low acceptance for improving design, resulting in replication of former problems
  - Limited availability of preferred materials within time frames, resulting in alternative material with unknown track record
  - Less time and focus on manufacturing/fabrication follow up
  - Less acceptance for engineering support to supply/sourcing management
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Recommendations for improvement of knowledge sharing

- Knowledge sharing, across competing companies, buyers and sellers is not easy.
- There exists and will be commercial reasons for why players in the industry will not make incidents available to public. In this context there may be a dispute between equipment vendor and buyer, or it can be an ongoing arbitration between insurers and the party setting up the claim, as well as a party’s reputation.
- It would be of great benefit for the industry to have the data as comprehensive as possible to allow trending and establishing root causes.
- From PSA it is defined in the “Styringsforskriften” what information that shall be reported and what form(s) to fill in. However all the necessary information is not always provided and then it might end up not being reported.
Recommendations for improvement of knowledge sharing

- The subsea industry is today an international industry where the technology and techniques used are universal. The applied technology is based on the same design codes and the service contractors and equipment vendors’ are delivering all over the world.
- A majority of the upstream oil and gas producers also operate internationally.
- It is recommended and considered of utmost usefulness and of importance, with respect to HSE and equipment development, that the industry takes further responsibility for knowledge sharing.
- First step could be that PSA more clearly define the minimum data set that should be reported according to “Styringsforskriften”.
- Furthermore, the information provided should be more transparent through international databases where useful information can be retrieved.
Conclusion

- Based on the data from incident databases, there is no evidence that the incident frequency is increasing due to the age of the subsea facility.
- Most failures are due to quality issues resulting in early life failure or more random failures.
- Traditional bathtub curve effect is not seen at late life operation.
- Many of the incidents occurs during transitions in operating modes. We view this that human error is an factor.
- There is not data to draw any conclusions about incident frequency related to new operators on the NCS.

Dilemma: The more detailed and useful a database is, the less open it would be to the public domain.
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