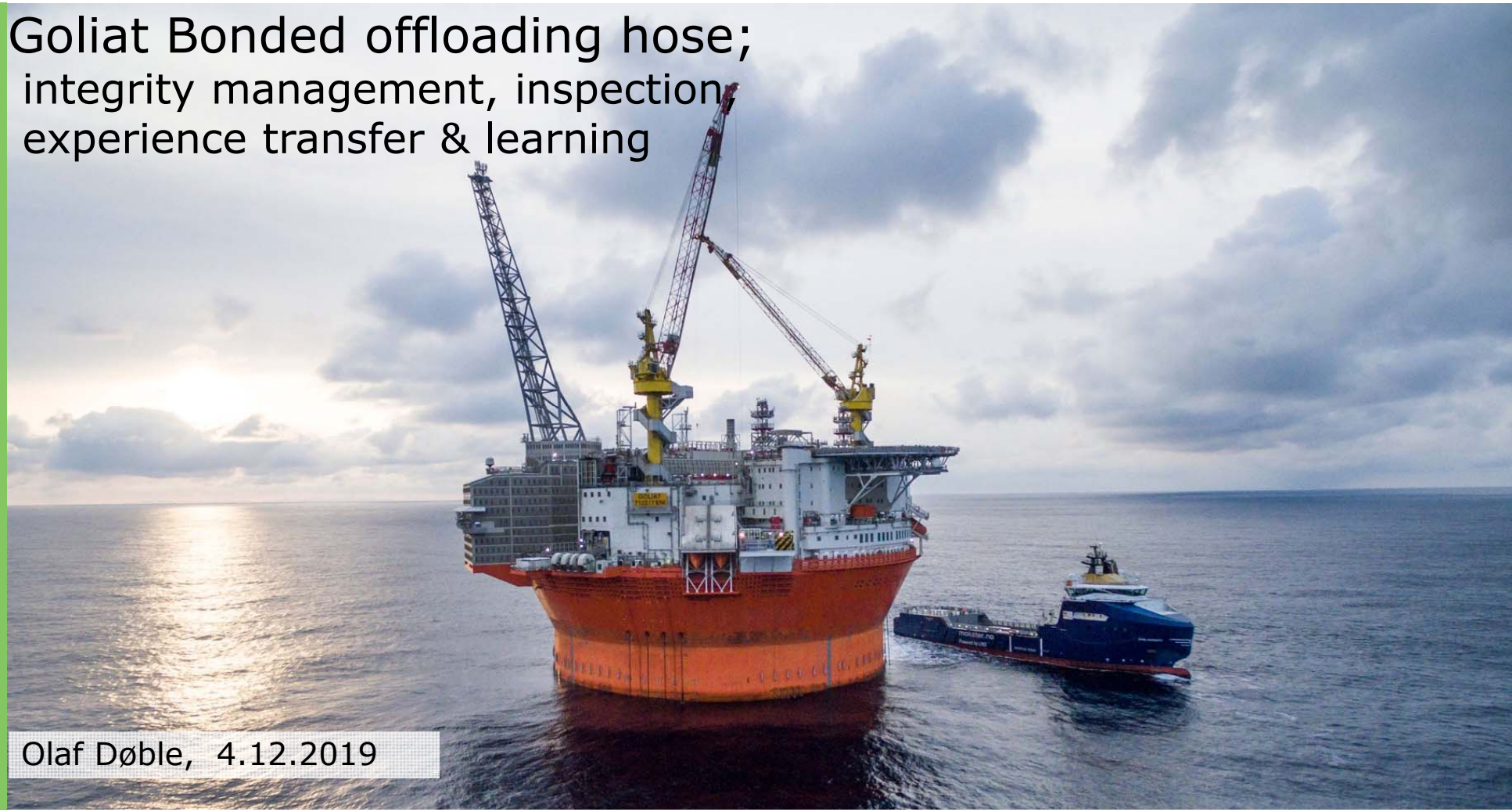
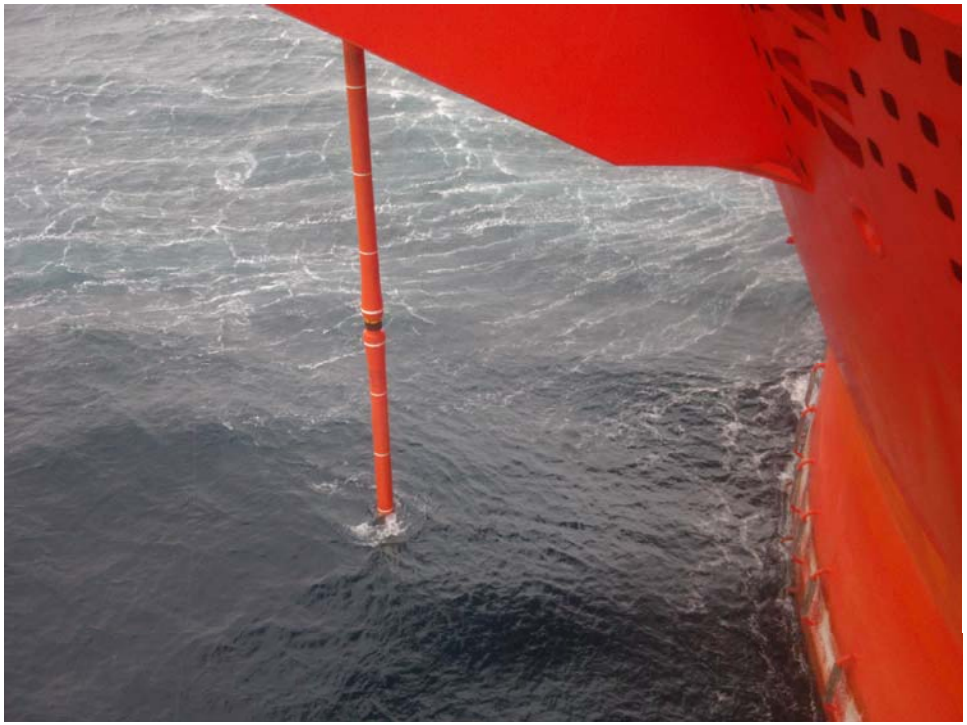
Goliat Bonded offloading hose;
integrity management, inspection, experience transfer & learning



Olaf Døble, 4.12.2019

Agenda

- The Goliat offloading hose
- Integrity management
- Inspection
- Failure case
- Experience transfer and learning



Goliat offloading hose

- API 17K
- Hose diameter 500mm (20”)
- 28 (29) elements
- 12,2 meter section
- Length 354 meter
- Design loads:
  - Internal pressure
  - External pressure
  - Tension
  - Temperature
  - Reeling
  - Bending moment
  - Lifetime-integrity
  - Fatigue of a complex build-up

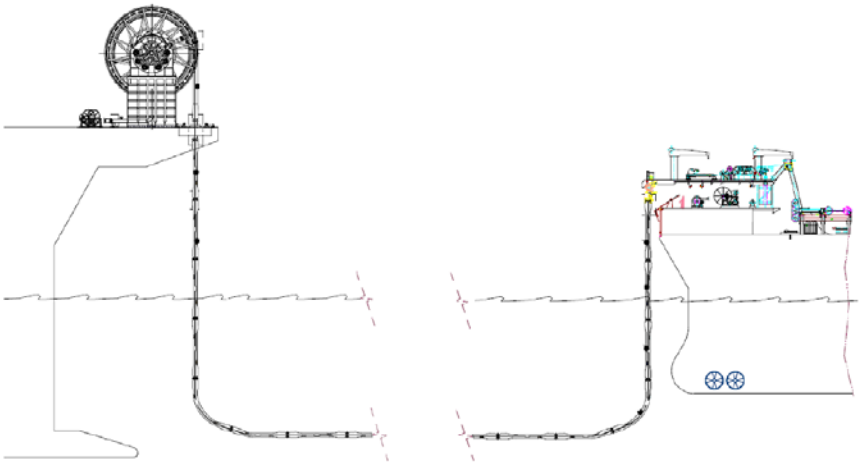
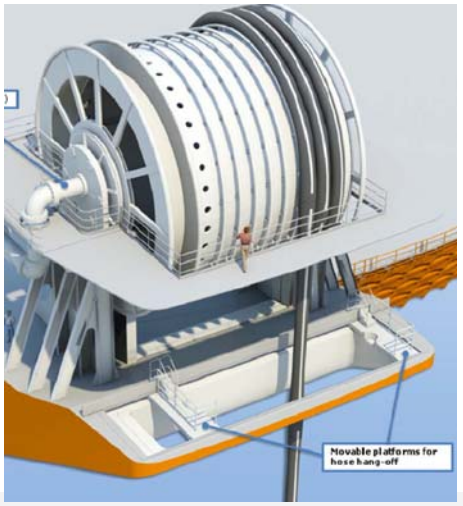


Figure 1 - Offloading system illustration.



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Integrity management planning

Offloading Hose Specification

- Inspection frequency shall be such that potential defects are identified before there is any risk of loss of integrity
- what can go wrong?

Failure modes

- External damage
- External wear
- Kinking and over-bending
- Tensile failure
- Corrosion

Failure drivers

- Handling
- Interference
  - FPSO bilge box
  - Mooring line
  - Tanker bow
- Corrosive media in the hose
- External environment
- Drifting objects on the sea

External damage	**In service**	• **Handling** • **FPSO bilge box interference** • **Tanker bow interference** • **Mooring line interference** • **Drifting object interference**
External wear	In service	• Handling • FPSO bilge box interference • Tanker bow interference • Mooring line interference • Drifting object interference
Kinking and over-bending	In service	• FPSO bilge box interference • Excessive loads during reeling • Excessive loads during hose replacement • Excessive tension
Crushing	In service	• FPSO bilge box interference • Drifting object interference • Excessive loads during hose replacement
Fatigue of metallic parts	In service	• Environmental loads
Fatigue in steel armouring	In service	• Environmental loads
Fatigue in metallic liner	In service	• Environmental loads
Fatigue in end fitting including welding to piping	In service	• Environmental loads
Fatigue in polymer parts of pipe	In service	• Environmental loads
Corrosion	In service	
Tensile failure (Excessive tension)	In service	• Tanker drive off
Burst or reduced pressure capacity	In service	• Excessive Pressure
Elastomer degradation	In service	• Temperature • Product fluid composition outside specification
Fatigue of connectors	In service	• Environmental loads

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Possible failure modes; extensive testing

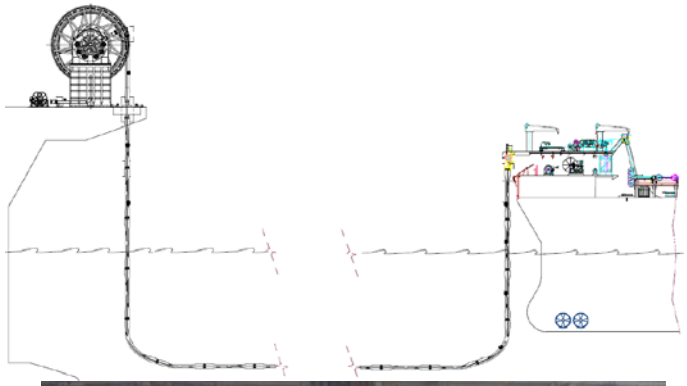
- Fatigue
- Kinking and overbending
- Crushing
- Tensile strength
- Tension and bending
- Burst pressure capacity
- Bonding failure
- Ovality

Fatigue test at Marintek

Tension and bending test at NLI

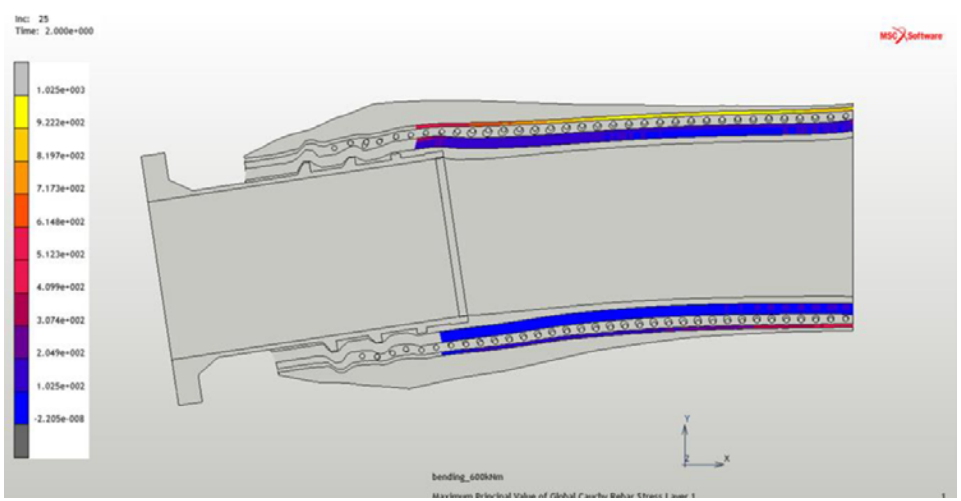
Inspection and monitoring

- External inspection with camera
- RFID identification (yellow ring)
- Internal inspection, camera/video
- Oil spill detection:
  - CCTV in tanker bow
  - CCTV in FPSO hang of area
- FPSO hang off loads
- Bow Loading System (BLS) tension
- Flow measurement on FPSO and shuttle tanker
- Visual inspection

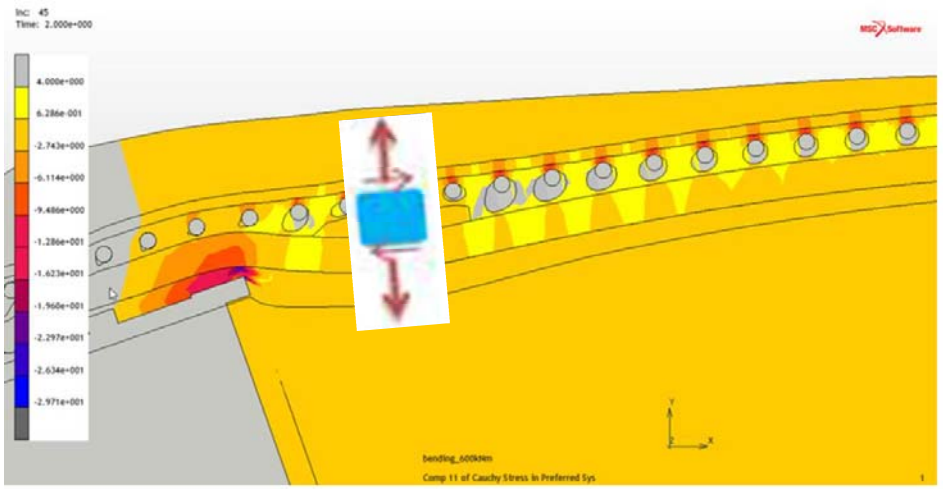


Damage mechanism

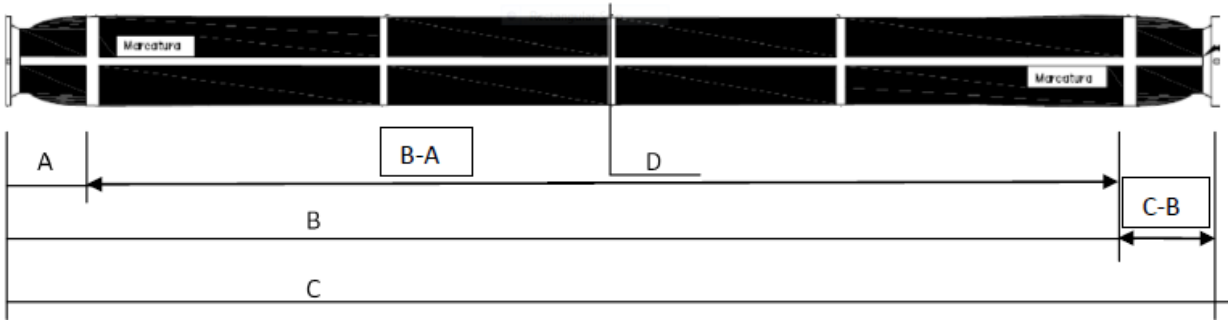
Stresses in outer steel cords at nipple end

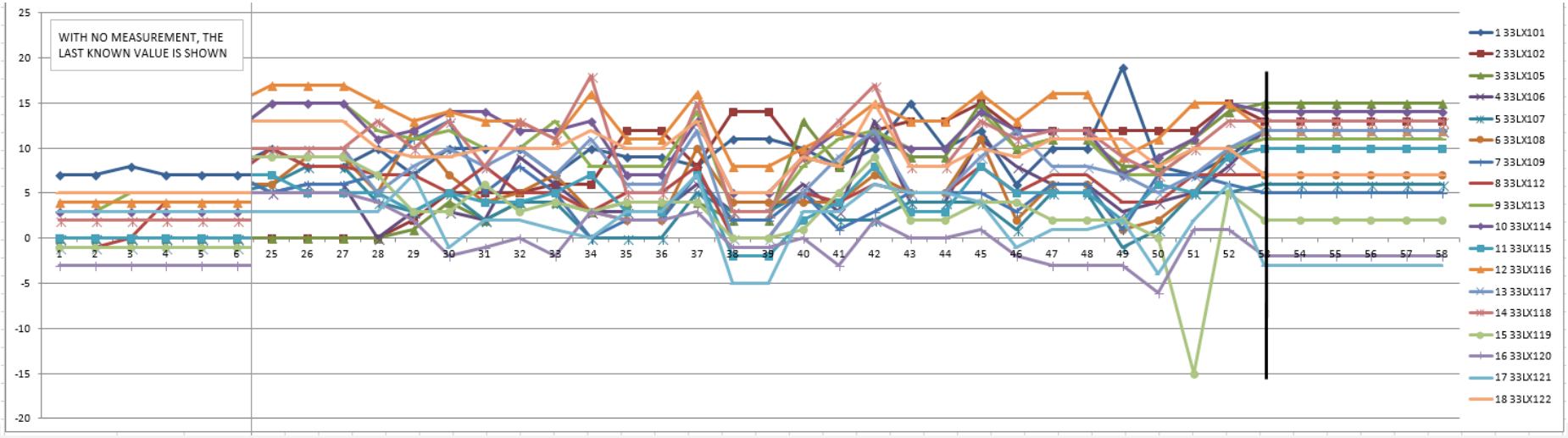


Radial stresses in rubber with beginning delamination outside nipple



Length measurement for segment 1-18





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Status today

- Stable situation since August 2017
- spare hoses available
- DNVGL involved and agreed with the modifications
- Well known replacement method
- Known failure mechanism
- Partial replacement possible without production interference, but subject to weather and preparation activity.
- 100% visual inspection
- Length measurement of the first 18 segments
- Knocking test randomly
- Decided to change supplier
  - Qualification of prototype is ongoing
  - Different design

Experience transfer and learning

- Technical
  - Reeling is now part of API 17K certification
  - Rubber creep can damage hose at the end-fitting
  - Long time vertical hanging out of the hose can contribute to creep at the hose ends
  - Action to reduce the load have shown effect
    - removed one hose element
    - reel out, transfer, reel in and store the hose with oil, not with water
  - 10 years lifetime of existing hose could not be obtained
  - Expensive and time consuming inspection with existing hose

- Competence
  - DNVGL, Contractors and suppliers
  - Experience personnel from 4subsea
  - Close cooperation with the partner Equinor; involved in meeting, invited to failure investigation etc.

Thank you for your attention!