Pressure Cycling of Dive Chambers

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Nov 2021

Discussion and Acknowledgements

We have been working with 4Subsea and DNV on pressure cycling of dive chambers, with the same goal – avoiding hydro testing and reducing overpressure testing gas to extend the life of the chambers.

Specific acknowledgements for work carried out to should go to:

Matthew Watson at Subsea7

Arnfinn Hansen at DNV

Hedda Sofie Sjøvaag at 4Subsea

Why do we test?

It’s the rules - We have to test our pressure vessels (PVHO).

The very testing that we were carrying out was likely to be reducing the life of the chambers.

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The Options

- Hydraulic Overpressure test

This brings lots of challenges, not least stripping out time (and subsequent rebuild) of the chamber and a lot of weight being added during the actual test.

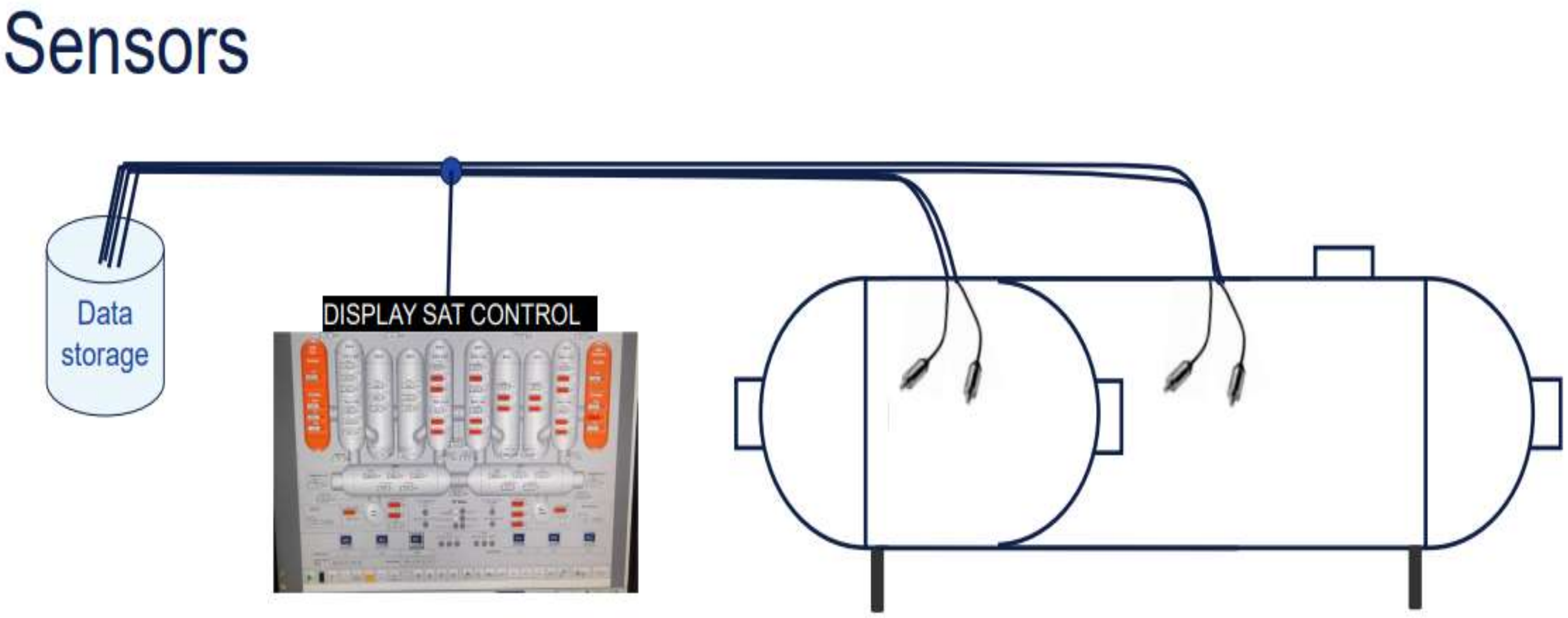
- Gas leak testing at MAWP and Eddy Current (ET) Testing to be carried out on the outside part of some pre-defined welds.

DNVGL-RU-OU-0375

- 1.3.1 Chamber and bells For systems having digital pressure monitoring with a record of the actual cycles experienced, testing shall be invoked when 20% of the design fatigue life have been reached for the worst-case chamber. For systems not able to provide documentation of the pressure cycling since new, testing shall be invoked at a 10-year cycling basis.

The Solution

- Use the data that we have.
- After all, how hard can it be? We already have the sensors, and the saved data.



The data.

- Seven Falcon is fully NORSOK compliant so there is a lot of data stored.
- We narrowed down the sensors to pressure and temperature.
- One day produces over 118000 outputs. This was a normal diving day!

118631	SDS/04TX081ZF02/Sensor.fValue;2014-12-19 01:39:07.000;0.40942099999999998
118632	SDS/04TX081ZF03/Sensor.fValue;2014-12-19 01:39:07.000;0.55973499999999998
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118634	SDS/04TX081ZP09/Sensor.fValue;2014-12-19 01:39:07.000;0.55225400000000002
118635	SDS/04TX081ZP06/Sensor.fValue;2014-12-19 01:39:07.000;-0.82000200000000001
118636	SDS/04TX081ZQ01/Sensor.fValue;2014-12-19 01:39:07.000;194.44444300000001
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118639	SDS/04TX082ZP50/Sensor.fValue;2014-12-19 01:39:07.000;-13.736110999999999
118640	SDS/04TX082ZP60/Sensor.fValue;2014-12-19 01:39:07.000;0.0
118641	SDS/04TX082ZP70/Sensor.fValue;2014-12-19 01:39:07.000;-0.34365299999999999
118642	SDS/04TX082ZP80/Sensor.fValue;2014-12-19 01:39:07.000;-0.114409
118643	SDS/04TX082ZT50/Sensor.fValue;2014-12-19 01:39:07.000;48.641379999999998
118644	SDS/04TX082ZT60/Sensor.fValue;2014-12-19 01:39:07.000;-46.0
118645	SDS/04TX082ZT70/Sensor.fValue;2014-12-19 01:39:07.000;48.428122999999999
118646	

4insight® Data Analytics

- Data Analytics.
- This is really where the project started to come together.

- DNV gave us options, we knew what we wanted, but didn’t really know how to get there.
- Enter 4Subsea. 4Subsea is a company in the Subsea 7 Group.
- And data is what they do!

- It’s not just as simple a drop the numbers into a chart.

Rainflow Counting

- When counting part cycles, the rainflow-counting technique in accordance with ASTM E1049-85 Standard Practice for Cycle Counting in Fatigue Analysis, shall be used.

The Rainflow counting method

1. Reduce the time history to a sequence of peaks and valleys.

2. Count number of half-cycles. Each half-cycle starts at a peak/valley and is terminated when either

- It reaches the end of the time-series
- It merges with a flow starting at an earlier peak/valley
- It meets a peak/valley which is larger/smaller or equal to the peak/valley the cycle originated from

3. Assign a magnitude to each cycle by calculating the pressure difference between its start and termination.

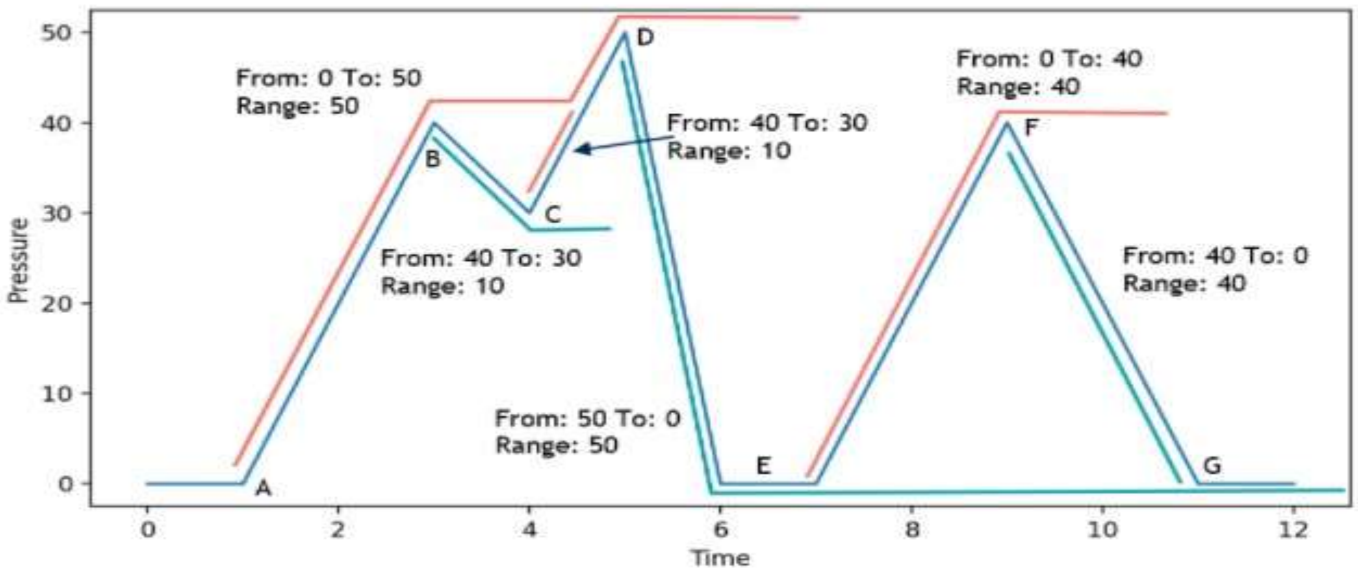
4. Organize half-cycles in bins of different pressure-range.

5. Use the pressure-range distribution to calculate total damage, as seen in "Damage calculation"

Example

1. Counting half-cycles originating from valleys (red marker):
   - A-D: half-cycle terminates at (E). (E) is of the same magnitude as (A).
   - C-B: half-cycle terminates as it merges with a flow starting at an earlier valley (A-D).
   - E-F: half-cycle terminates at (G). (G) is of the same magnitude as (E).

2. Counting originating from peaks (green marker):
   - B-C: half-cycle terminates at (D). (D) is of the larger magnitude as (B).
   - D-E: half-cycle terminates as it reaches the end of the time-series.
   - F-G: half-cycle terminates as it merges with a flow starting at an earlier peak (D-E).



Range	Cycles	Events
10	0.5 + 0.5	B-C, C-D
40	0.5 + 0.5	E-F, F-G
50	0.5 + 0.5	A-D, D-E

Calculation of damage

- In order to calculate the accumulated material damage caused by the part cycles, the following equation shall be used:

$$\text{Fatigue } Damage = \sum_{Pressure\ range} \frac{\left(\frac{Pressure\ range}{MAWP}\right)^{m} * Number\ of\ cycles}{C}$$

Where;

Pressure range is the maximum pressure for the part cycle

MAWP = Maximum Allowable Working Pressure

m = 1

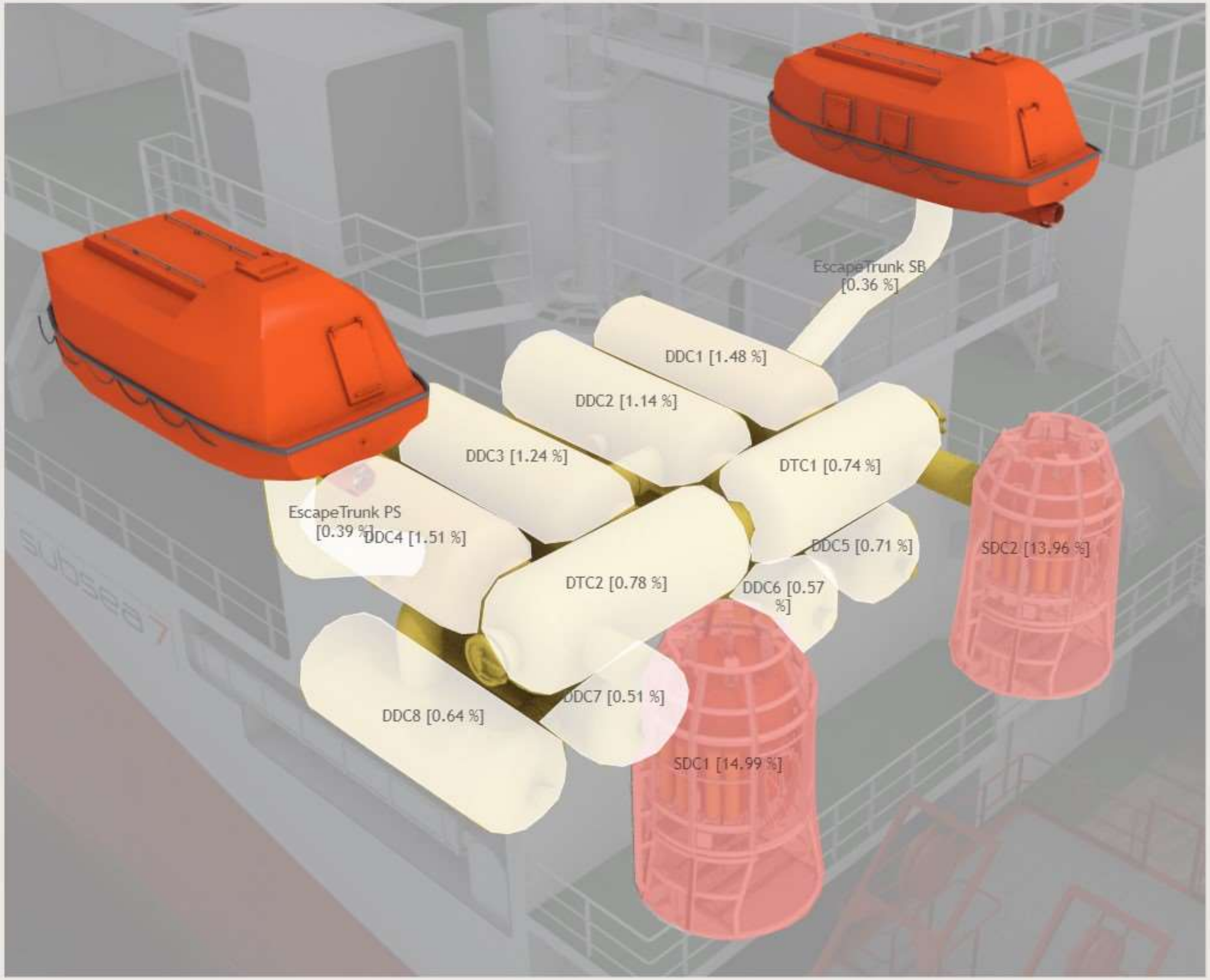
C = Number of fatigue cycles used for design

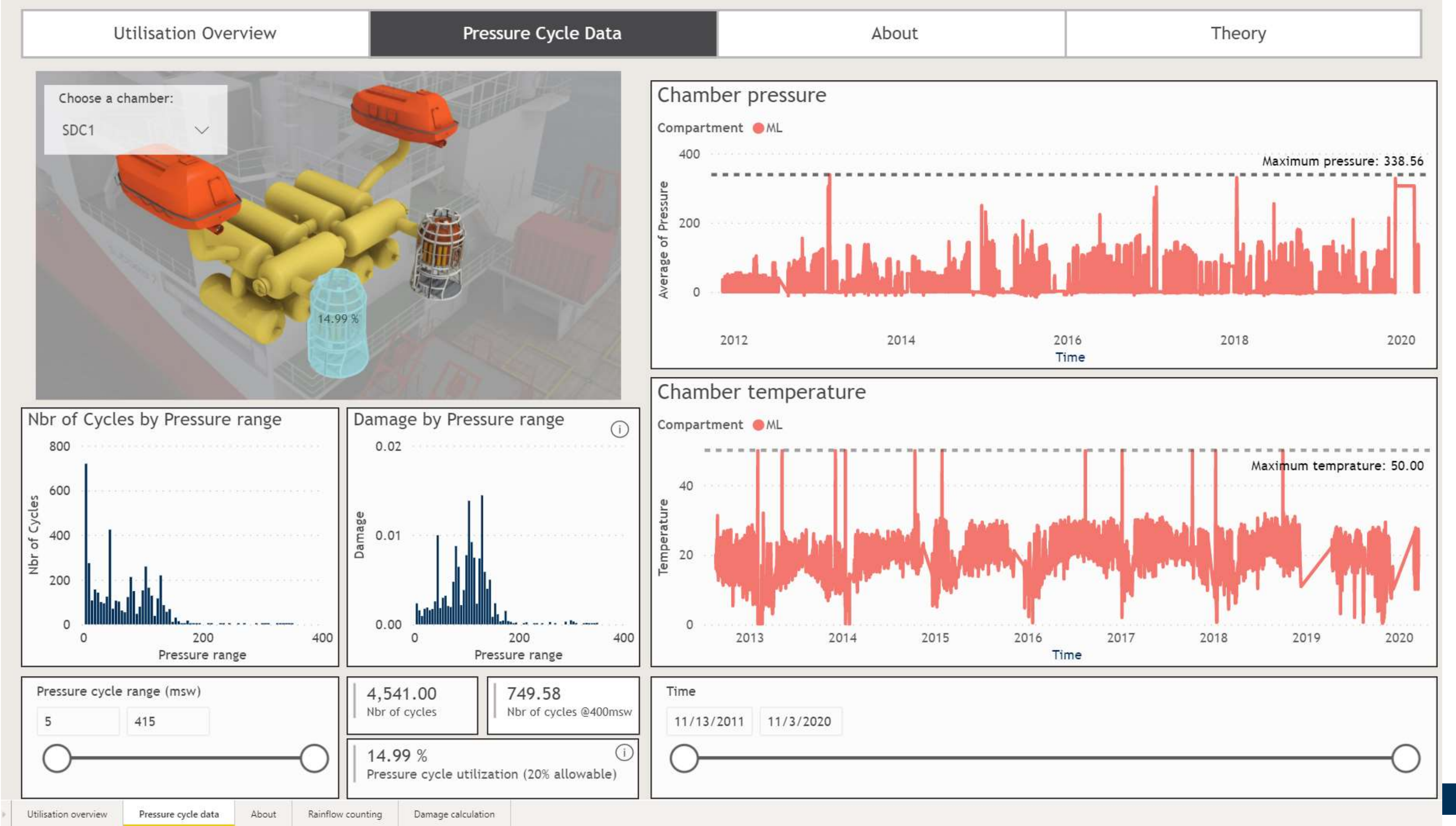
Utilisation Overview | Pressure Cycle Data | About | Theory

Chamber	Pressure Cycle Utilization (20% allowable)
SDC1	14.99 %
SDC2	13.96 %
DDC4	1.51 %
DDC1	1.48 %
DDC3	1.24 %
DDC2	1.14 %
DTC2	0.78 %
DTC1	0.74 %
DDC5	0.71 %
DDC8	0.64 %
DDC6	0.57 %
DDC7	0.51 %
EscapeTrunk PS	0.39 %
EscapeTrunk SB	0.36 %

Pressure cycle range (msw)

5 419





Utilisation Overview
Pressure Cycle Data
About
Theory
Choose a chamber:
SDC1
14.99 %
Chamber pressure
Compartment ML
Maximum pressure: 338.56
Average of Pressure
400
200
0
2012
2014
2016
2018
2020
Time
Chamber temperature
Compartment ML
Maximum temprature: 50.00
Temperature
40
20
0
2013
2014
2015
2016
2017
2018
2019
2020
Time
Nbr of Cycles by Pressure range
Nbr of Cycles
800
600
400
200
0
0
200
400
Pressure range
Damage by Pressure range
Damage
0.02
0.01
0.00
0
200
400
Pressure range
Pressure cycle range (msw)
5
415
4,541.00
Nbr of cycles
749.58
Nbr of cycles @400msw
14.99 %
Pressure cycle utilization (20% allowable)
Time
11/13/2011
11/3/2020
Utilisation overview
Pressure cycle data
About
Rainflow counting
Damage calculation

Conclusions

- We are able to accurately demonstrate the pressure cycles of our chambers.
- The vast majority are not even close to their 20% fatigue life ‘test’ point.

- This reduces testing – which we know can increase fatigue -ultimately increasing the life of the chambers.
- This reduces the need to use scarce resources, eg helium.
- It reduces personnel risk.
- It reduces equipment downtime.
- We can target specific testing to higher fatigue areas (specific welds).

THANK YOU

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