Non Intrusive Corrosion/Erosion monitoring

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Sensorlink

ISO 9001:2015 certified | IECEx certified | Achilles JQS qualified

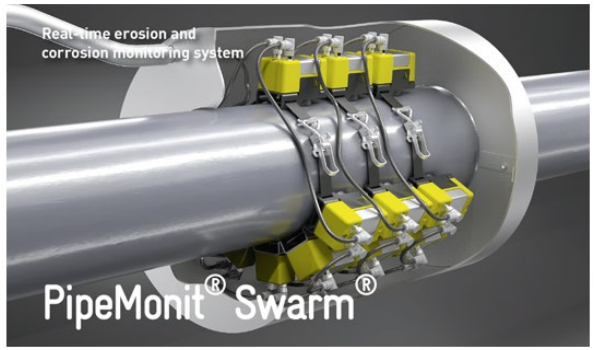
Monitoring vs inspection

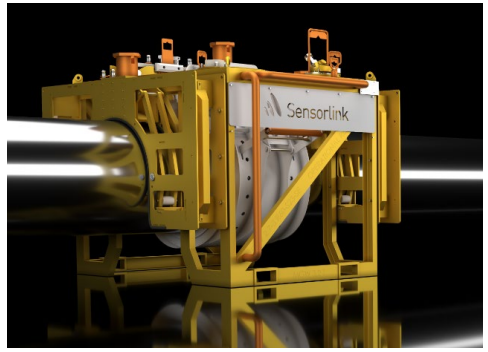
Inspection

- Gives a picture of the situation now, flaw finding
- Labor intensive, operator dependent
- Need to be repeated to give corrosion/erosion rate
- Repeatability not on the level of monitoring

Permanent Installed Monitoring Systems (PIMS)

- High quality continuous wall thickness measurements
- Excellent trending and process variable correlation/optimization
- Real-time and online follow up of known defects
- Eliminate the operator bias of manual inspection
- Repeatability 0.1-1 mils/2.5-25 µm

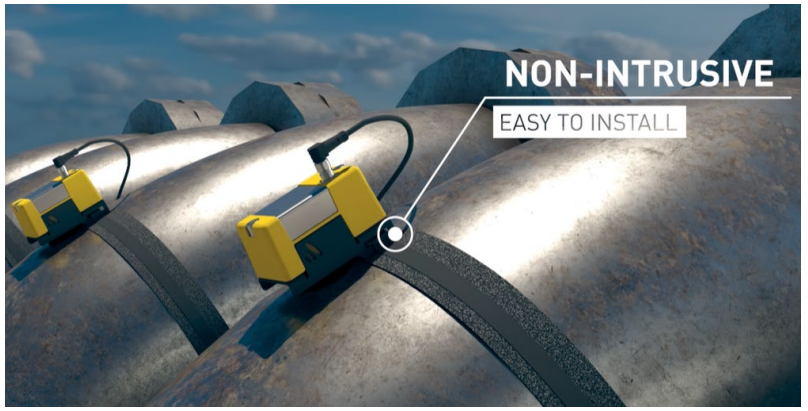




Corrosion/Erosion, why monitor?

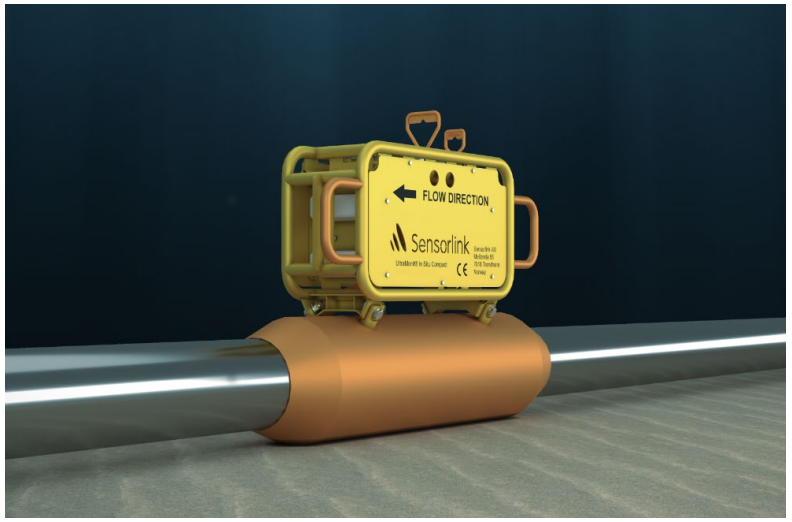
- General corrosion
  - To determine metal loss rate
  - To evaluate inhibitor effectiveness
- Pitting corrosion
  - To detect existence and severity
  - To evaluate growth rate
- Microbiologically-influenced corrosion (MIC)
  - Not monitored, but inspected
- Sand erosion
  - Verify effect of sand erosion on pipeline
- Overall goal
  - To verify the integrity of the process pipeworks

Corrosion cost



Cost of corrosion and erosion in O&G industry is:

- 1,4 billion USD
- 590 million USD for pipeline and facilities (refinery etc)



Goal for an oil and gas maker and asset owner:

- Optimize revenue by producing the full potential from your existing assets
- Securing safe operations to avoid serious incidents.

What Sensorlink Deliver:

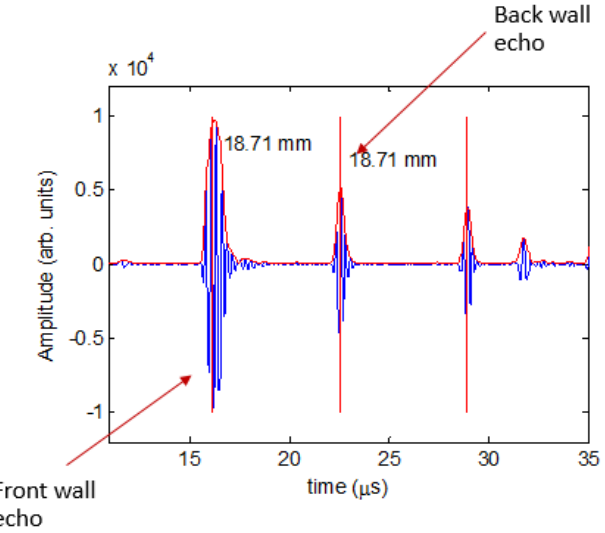
- A Non-Intrusive sensor to create an acceptable understanding of how the asset is managing the constantly changing corrosion and erosion demands being placed upon it from the inside.

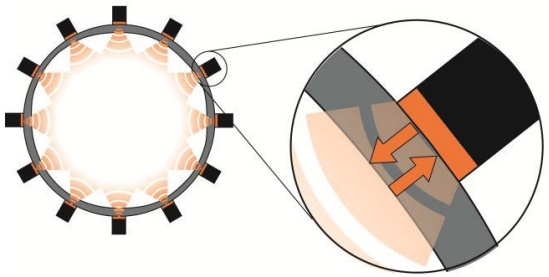
Subsea Instruments

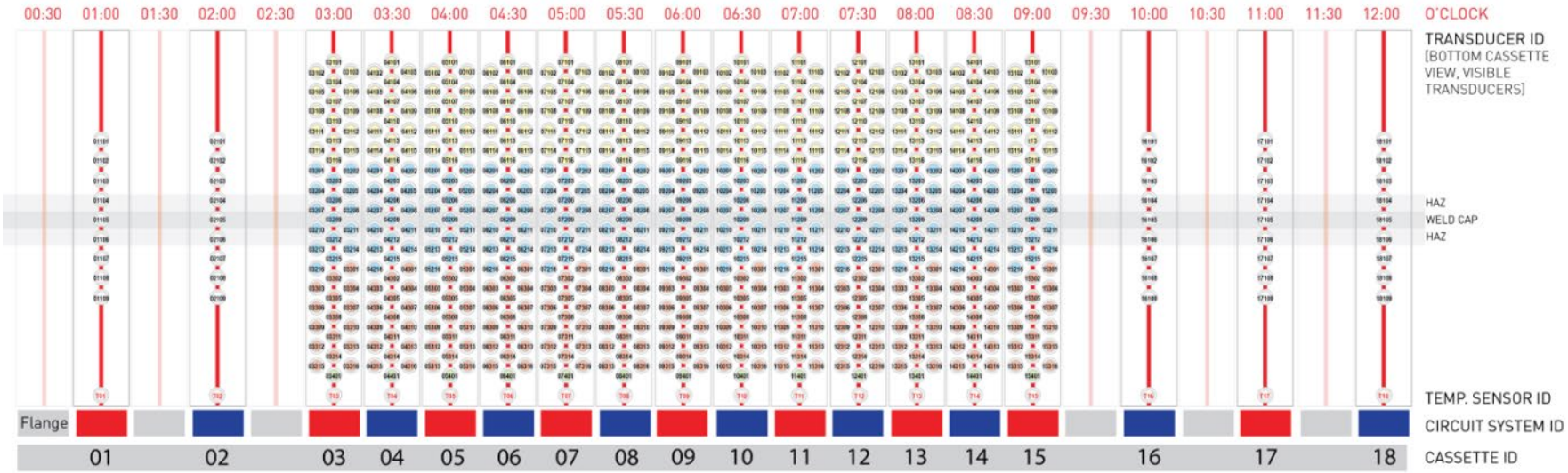
Technology

Wall thickness monitoring using Single Element Pulse/Echo Transducers

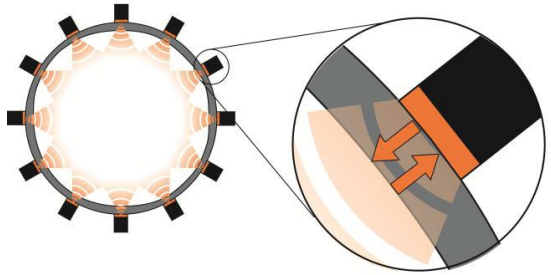
- Non-Intrusive
- Direct wall thickness measurement of pipe wall
- Not sensitive to pipe wall thickness
- Work through laminated layers
- Configurable sensor grouping to measure area of interest
- Functions on pipe walls with internal processing temperature from -40 to 150 degC
- Fixed sensors combined with advanced signal processing can detect wall loss from less than .1 mils (2.5 micrometres)



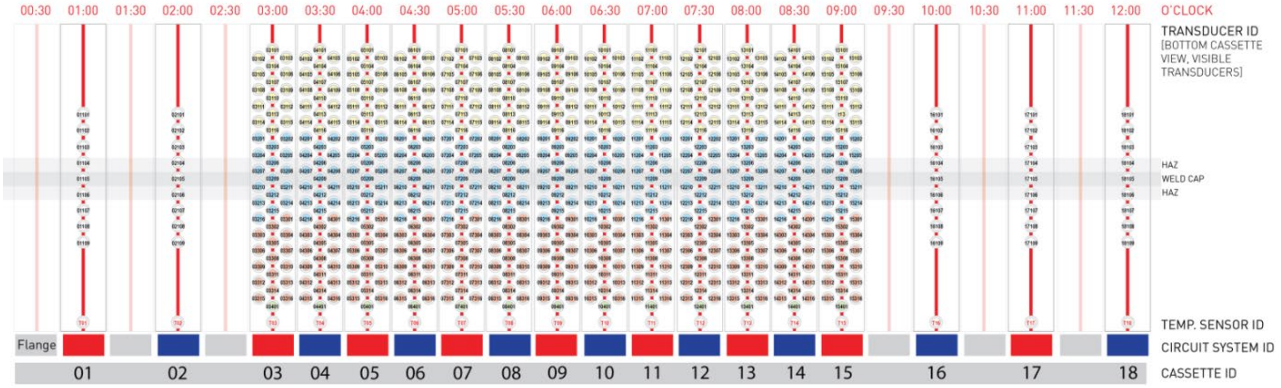




Sensor matrixes



Sensor matrixes to increase areal covereage and give better understanding



Industry leading Product Sensitivity/Accuracy

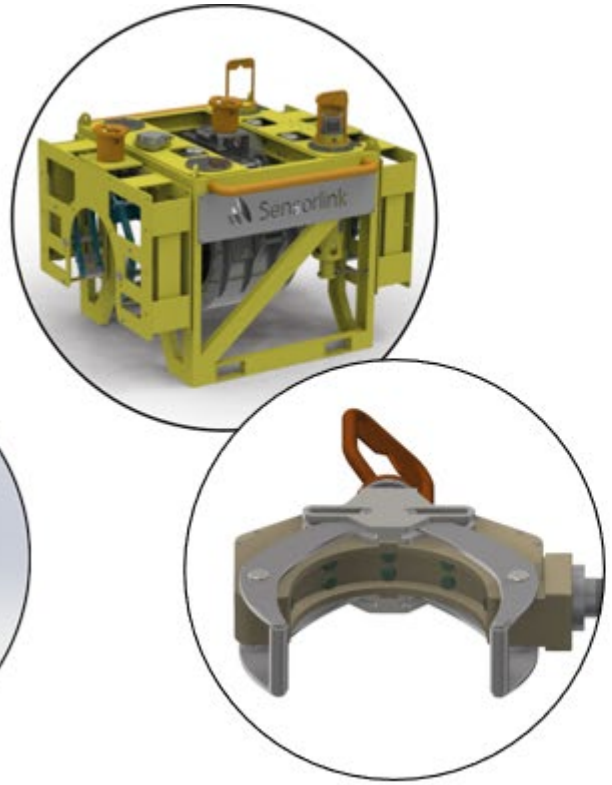
- Industry leading flexibility leads to:
  - Reduced
    - Frequent and costly manual inspections
    - Harmful and damaging leaks
    - Unplanned shutdowns and repairs
  - Improved
    - Safety
    - Asset performance
    - Savings from optimizing chemical injections with documented ROI within 5 years for subsea tools
    - Uptime through enhanced decision making
    - Most accurate data provides best data visualization and analytics

Different packaging same system

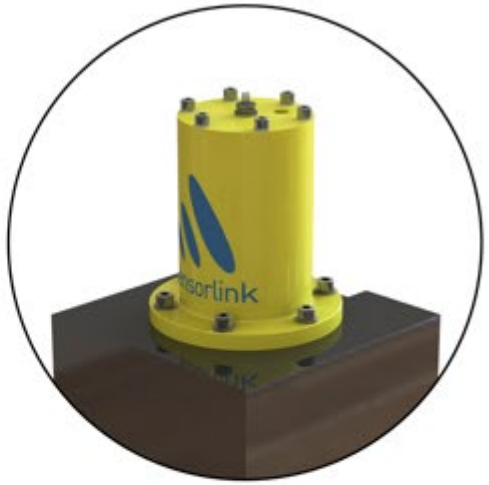
Fixed installations/ new pipelines

Retrofittable modular design

Retrofittable installations



Integrated modular design



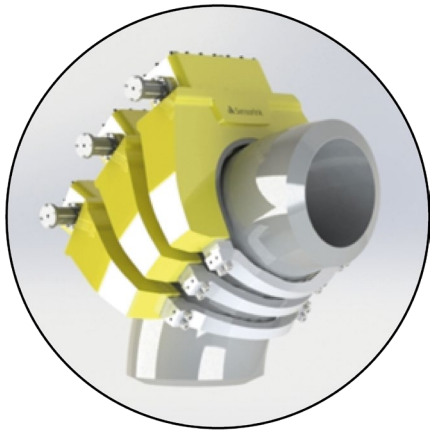
Fixed installations / new pipelines

- Designed for S-lay with rotation tolerance of 30 degrees
- Resolution from 0,0025mm
- Design life 30 years+
- Subsea data processing
- Transducer placement: contact
- Delivered to BP Shah Deniz 10 units (6 operational) installation depth down to 560m
- Delivered to Woodside Greater Enfield 2 units (both operational) installation depth down to 890m
- Coverage in different clock positions and longitudinal pending on customer requirements

- Designed for J-lay with rotation tolerance of 360 degrees
- Resolution from 0,0025mm
- Design life 30 years+
- Transducer placement: contact
- Subsea data processing
- Delivered to BP Tortue 2 units, installation depth down to 2860m
- Coverage in different clock positions and longitudinal pending on customer requirements

Retrofittable modular design

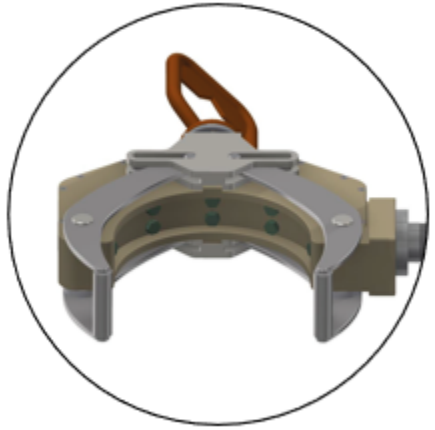
- Designed for topside installation
- Resolution from 0,0025mm
- Design life 30 years+
- Transducer placement: contact
- Subsea data processing
- Delivered to Chevron Gorgon 23 units (8 operational) installation depth down to 1890m
- Coverage in different clock positions and longitudinal pending on customer requirements



- Designed for topside installation
- Resolution from 0,02mm
- Design life 15 years+
- Transducer placement: stand off
- Subsea data processing
- Delivered to Chevron Gorgon 2 units (2 operational) installation depth down to 300m
- Coverage in different clock positions and longitudinal pending on customer requirements

Retrofittable installations

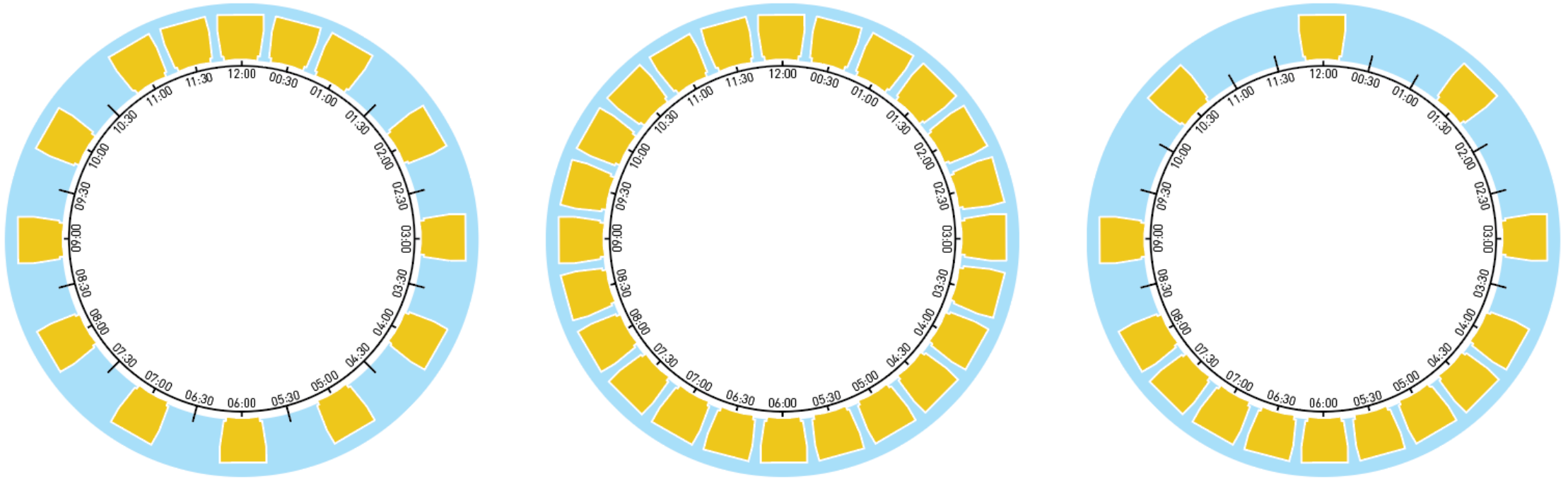
- Designed for subsea installation
- Resolution from 0,01mm
- Transducer placement: stand off
- Design life 30 years+
- Subsea data processing
- Delivered to Statoil, Chevron UK, Chevron Australia, Conoco Philips, Exxon Mobil with installation depth down to 850m
- Coverage in different clock positions and longitudinal pending on customer requirements



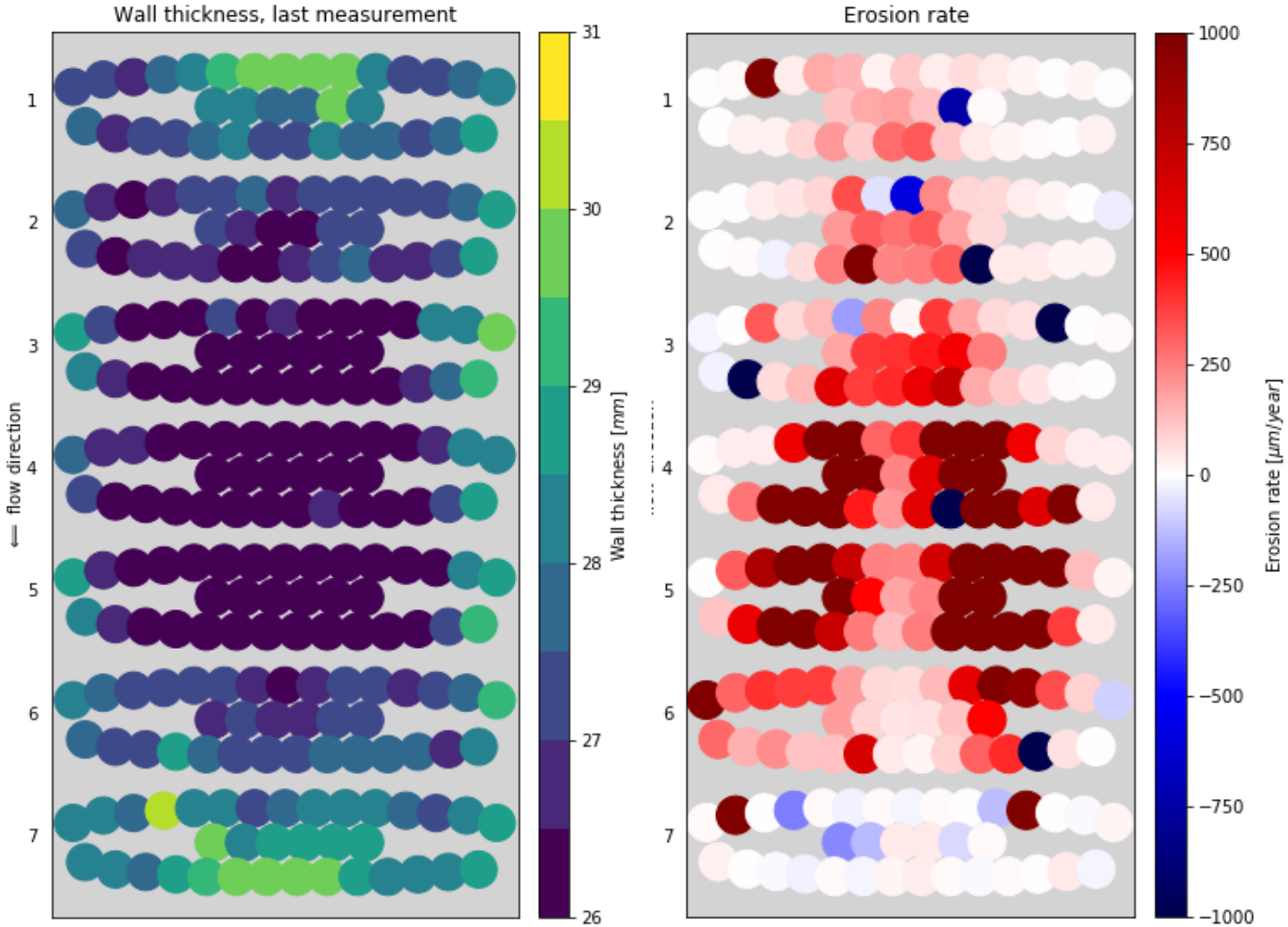
- Designed for subsea installation
- Resolution from 0,02mm
- Transducer placement: stand off
- Design life 15 years
- Subsea data processing
- Not delivered
- Coverage in different clock positions and longitudinal pending on customer requirements, note not completely around the circumference than two units are needed

Configurable Sensor Arrangement

- The number of sensors and positions can be configured to target project specific needs.



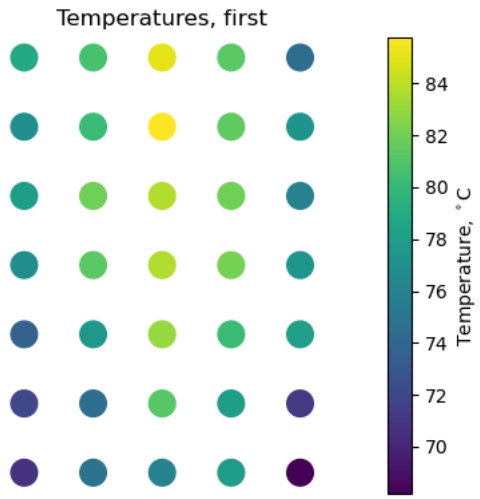
Data Presentation

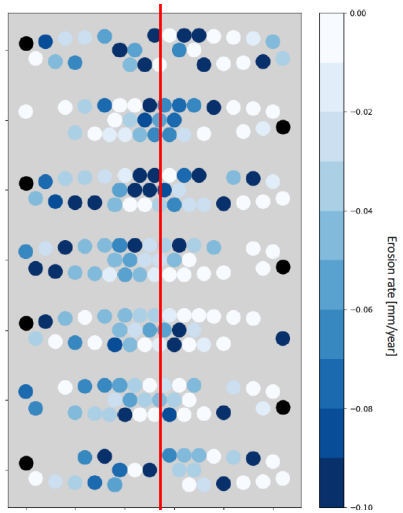


Simplified and accurate knowledge

- System detects
  - Highest erosion rates to the left side of the bend (almost double compared to the right side)
  - Measured temperature spread around both axis of the pipe/bend of ± 8 degC
  - Rapid changes in sand induced erosion detected

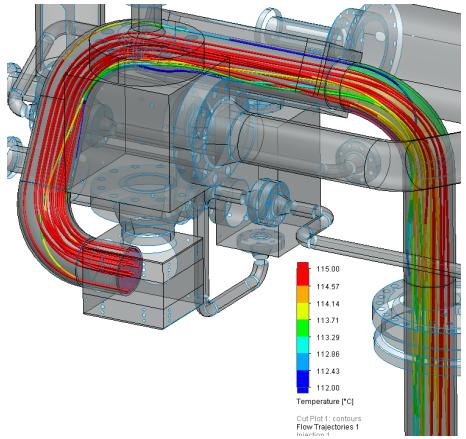
    Planned due to accuracy of system to be included in close loop control system of choke to allow for sand production in an accurate way

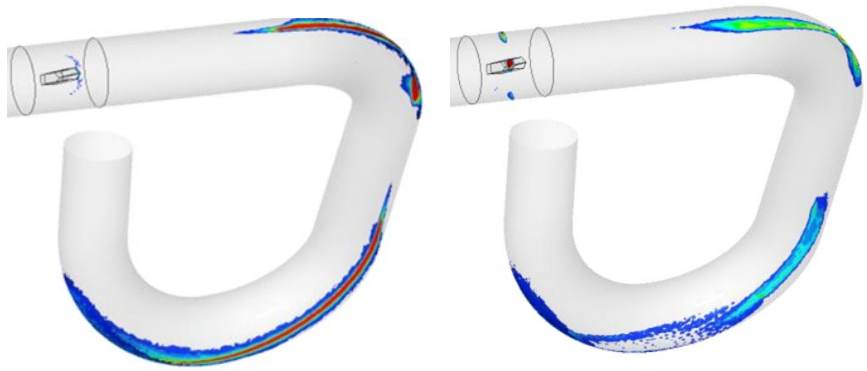




Simplified and accurate knowledge

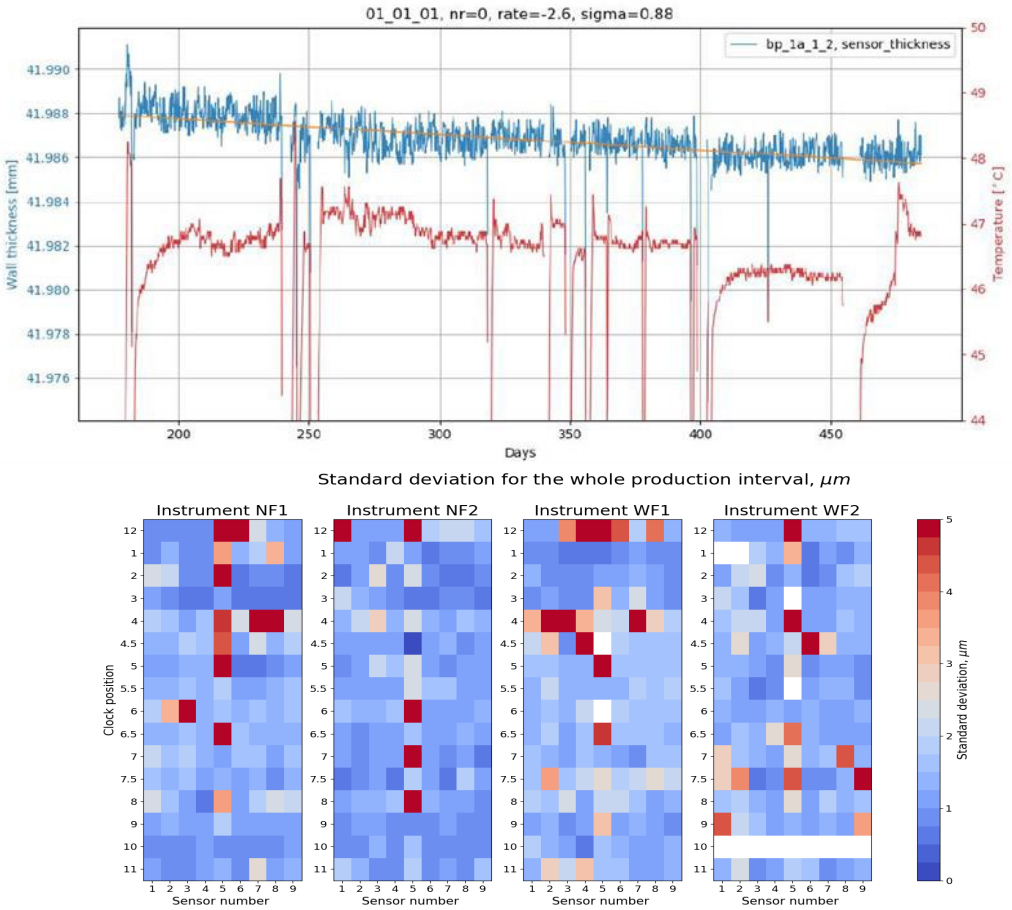
- Flow Assurance analysis
  - Estimated erosion/corrosion rate based on different sand particle size and or flow but likely case centred around 12 o’clock on the bend
  - Estimated uniform temperature spread around bend (± 3 degC)





Operational optimization = reduced OPEX

- System used for production optimization and control
  - Optimization
    - Monitored trend rate realises spread over production changes allowing for optimised production planning and inhibitor chemical use -> result maximized production output with minimized productional input[1]
      - Normal use for an asset is 50 to 100 ppm or roughly 200 to 500 litres of CI on a 30k (barrel production) per day subsea asset with a cost per litre of CI going from 2,30 to 5,7 USD/litre
        - Standard operating cost of Corrosion Inhibitors is between 21 000 USD and 1.3M USD per year
      - Optimization ongoing where the goal is to re-pay initial tool investment within 5 years of operation based on OPEX saving, goal still within reach.
    - Reduced need for subsea pipeline inspection with DP vessel and ROV. A cost per vessel can be USD 50.000-100.000 per asset/day pending on vessel type increasing further the ROI for monitoring



Possible to increase operational life?

- Operator had piggable lines but due to life extension of field wanted to have improved control over the corrosion rate in the pipeline at a defined hot-spot detected during pigging
- Pipeline had external FBE coating
- Retrofit installation conducted for two years to verify corrosion rate over different operation scenarios.
- Corrosion rate defined to be lower than pigging run estimate.
- Resulting in the operator continued safe operations
    - Sensorlink have done several of these short time installations for optimization and verification purposes

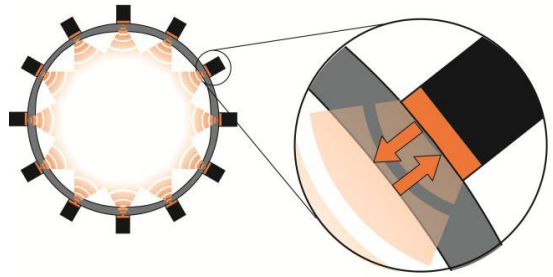
Communication interface

- Sensorlink have the following standard interfaces:
  - Modbus TCP/IP
  - Modbus RTU
  - Canbus over CiA 443 rev 3
- All data is processed subsea and transmitted topside without additional need for processing. This reduces surface or SCM traffic load by only exporting the key data routinely

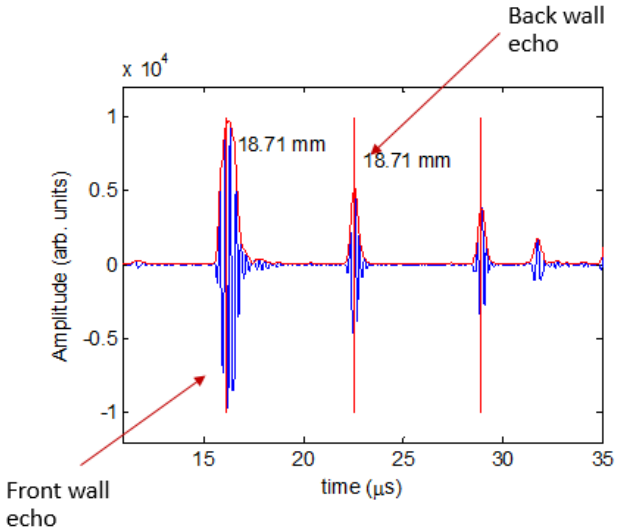
PipeMonit® Instruments (topside)

Technology

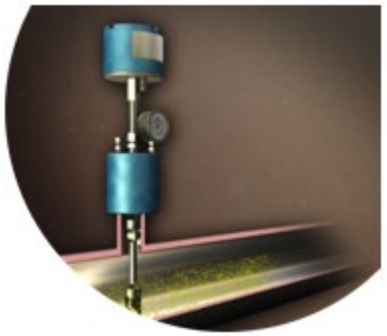
Wall thickness monitoring using Single Element Pulse/Echo Transducers



- Non-Intrusive
- Direct wall thickness measurement of pipe wall
- Not sensitive to pipe wall thickness from 3in to 200in
- Work through laminated layers
- Configurable sensor grouping to measure area of interest bends, T-joints, pipe spools, vessels etc
- Fixed sensors combined with advanced signal processing can detect wall loss from less than .1 mils (2.5 micrometres)
- Hazardous and non-hazardous area certified systems for zone 1
- Systems is developed based on subsea technology



Non Intrusive vs Intrusive Monitoring



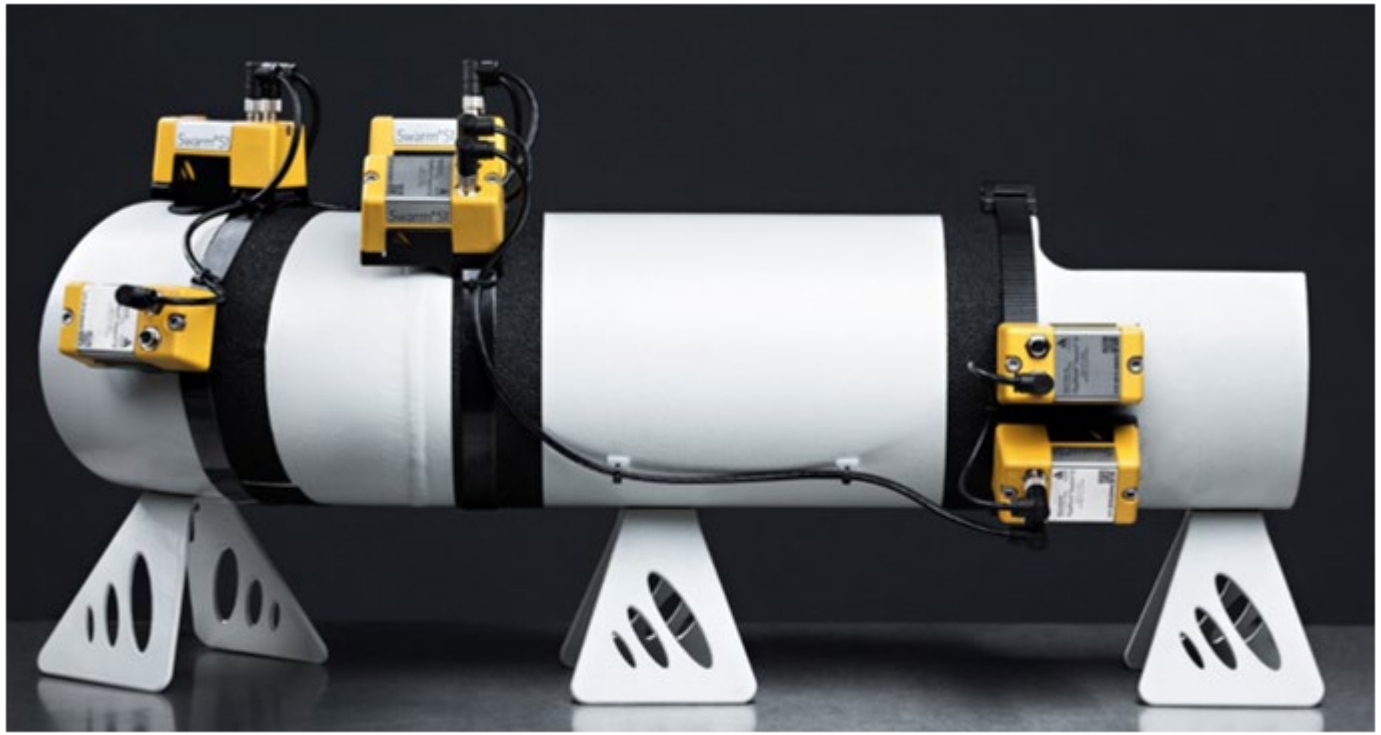
Intrusive probes and coupons

- In-direct measurement, measure wear on probe/coupon not on actual pipe, potential overrepresentation or under representation of wall loss
- Not possible to pig while inserted
- Wears out over time, must be replaced
- Requirement to be sent for weighing (coupons)
- Integrity of pressure system is jeopardized; fittings and valves has to be added
- Not possible to move after installed if not additional leakage points is added to the pipeline
- Potential HSE risks while doing maintenance
  - For example in pressurised systems hydraulic tools needed to change coupons have known HSE issues

Non-intrusive

- Direct measurement of pipe wall (effect measurement)
- Piggeable lines while installed
- No wear and tear, install and forget
- No maintenance, apart from battery change
- Non – intrusive no access holes or fittings, zero leak risk
- Retrofittable, movable allowing for installation where issues are located
- Reduced human exposure to operational HSE hazards
- Measure pipe temperature

PipeMonit® Swarm
for topside/landbased applications



- **Applications**
  - All land based/topside pipelines/flowlines/pressure systems with surface temperatures up to 500°C
- **PipeMonit®**
  - Non-intrusive measurement
  - Strap on installation, no gluing, welding or hot work requirements
  - Easy to retrofit or move
  - Pipe wall thickness measurement
- **System**
  - Ex / Non-Ex
  - Absolute accuracy 0.1-0.2 mm
  - Repeatability down to 0.0025mm *(1/30 of a human hair)*

Sensors optimized for different operations

SWARM S1

- for temp -40 to 125

- IP 67
- Repeatability 0,0025mm
- daisy chained for maximum of 250 S1 sensors per datalogger
- Datalogger communications via GSM, hard wire, Bluetooth
- Certification:
  - EX ib IIB T4 Gb

SWARM LT

- for temp -40 p to 150

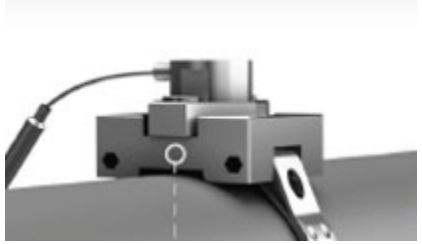
- IP 66
- Repeatability 0,0025-0,01mm
- Single channel sensor with a maximum of 4 sensors per datalogger
- Datalogger communications via ISA 100 and Bluetooth
- Certification:
  - Ex II 2G Ex ib IIB T4 Gb

SWARM HT

- IP 66 and 68
- Repeatability 0,01mm
- Single channel sensor with a maximum of 4 sensors per datalogger
- Datalogger communications via ISA 100 and Bluetooth
- Certification:
  - II 1 GD Ex ia IIC T* Ga

SWARM UHT

- for temp 350 to 550



- IP 66 and 68
- Repeatability 0,01mm
- Single channel sensor with a maximum of 4 sensors per datalogger
- Datalogger communications via ISA 100 and Bluetooth
- Certification:
  - II 1 GD Ex ia IIC T* Ga

Dataloggers optimized for different operations

Swarm S2 datalogger

-Ambient temp -40°C to 70°C
-Data output options:
  -Bluetooth
  -Wireless ISA 100 (soon WiHART and also LoRa)
  -GSM
  -Modbus TCP/RTU
-Data delivered
  -Wall thickness
  -Temperature on pipe
  -CSV format
-Power options
  -Battery operated
  -24 VDC/110-240VAC

-Ex rating
  -Ex II 2G Ex ib IIB T4 Gb

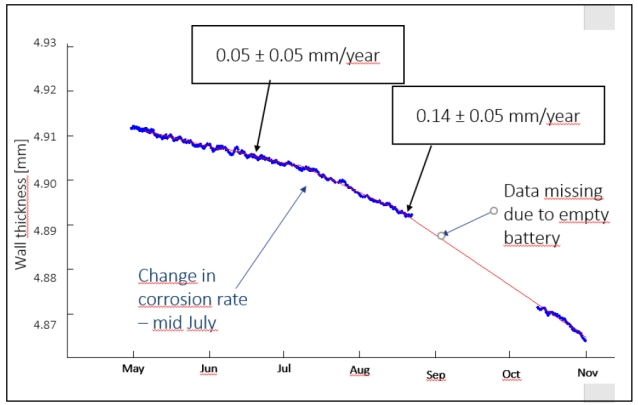
Swarm SDL datalogger

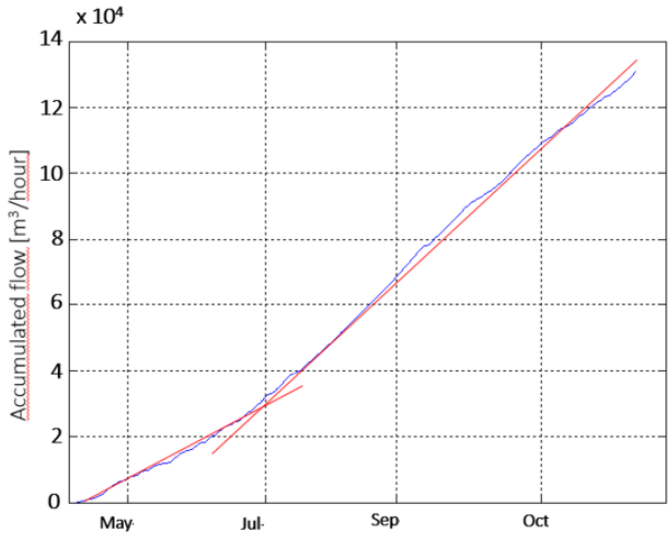
-Ambient temp -20°C to 50°C
-Data output options:
  -USB
  -Modbus TCP/RTU
-Data delivered
  -Wall thickness
  -Temperature on pipe
  -CSV format
-Power options
  -24 VDC/110-240VAC

-Ex rating
  -None, need ExD housing for ATEX zone

Operational optimization = reduced OPEX

- In a monitoring period, a significant increase in the corrosion rate was observed. Increase was correlated to an increase in the flow rate
  - The change in corrosion rate was seen within 2 days of the operational change and the new stable corrosion rate was defined within (3 weeks) [1]
- Further, comparison of the results showed that the manual UT measurements overestimated the corrosion rates up to 400% compared to ultrasonic monitoring[1]





Reading Positions	Corrosion rates based on Manual UT Reading (mm/year)	Corrosion rates based on continous readings (mm/year)	Difference (mm/year)
1 (0°)	0.51	0.18	0.33 +/- 0.38
2 (45°)	0.4	0.10	0.3 +/- 0.38
3 (90°)	0.39	0.08	0.31 +/- 0.38
4 (135°)	0.27	0.05	0.22 +/- 0.38
5 (180°)	0.48	0.11	0.37 +/- 0.38
6 (225°)	0.28	0.07	0.21 +/- 0.38
7 (270°)	0.23	0.10	0.13 +/- 0.38
8 (315°)	0.55	0.10	0.45 +/- 0.38

1) Martinusssen, Hanne "Observation of Flow Dependent Corrosion Rate by Ultrasound Corrosion Monitoring on a Gas Pipeline" NACE paper 51317--9336-SG, 2017

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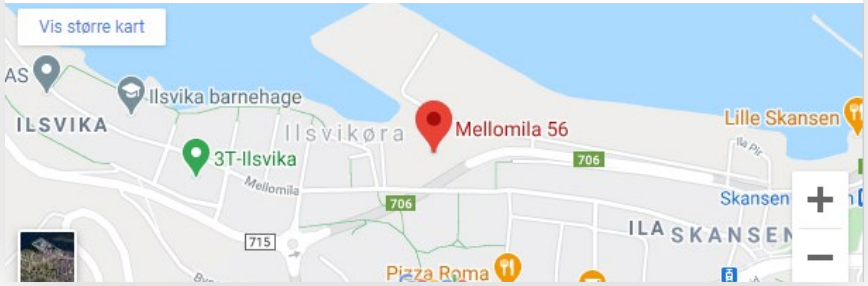

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THANK YOU FOR YOUR TIME

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