Non-Intrusive Corrosion and Erosion Monitoring Solutions and Case Studies

Dr. Jake Davies,

ICorr Aberdeen meeting, 28th Feb 2017

EMERSON

Presentation Contents

- Company History
- Drivers to monitor for corrosion and/or erosion
- Non-intrusive monitoring systems
- Permasense system outputs
- Oil & Gas production: common applications and case studies
- Refining: common applications and case studies
- Conclusions

Permasense History - Established track record

permasense

EMERSON

- **2016** — Acquisition into Emerson
- **2013** — Reference applications across the oil and gas sector
- **2012** — Reference installations with all major oil companies
- **2011** — Exclusive agreement with BP finishes
- **2006-08** — Proving out of monitoring technology in BP Refineries
- **2005** — High temperature – waveguide / sensor technology prototype

Imperial College of Science, Technology and

Why Monitor for Corrosion or Erosion

- Corrosion and erosion happens
  - Well understood/measured: corrosion/erosion causes and mitigation
    - Process conditions
    - Fluid constituents
    - Abrasive solids
    - Corrosion inhibitors
    - Metallurgy
  - Not well understood: impact on the asset integrity
    - Rate of damage to asset
    - Variability of rate of damage from above factors
  - Leading to
    - **Conservative operations – poor profitability**
    - **Unplanned outages, and/or loss of containment**

Industry Drivers for Corrosion and Erosion Monitoring to Drive Profitability

- Higher crude quality variability “opportunity crudes”
- Higher plant availability requirements
- Longer runs between maintenance shutdowns
- Tighter HSE regulations
- Tighter CAPEX budgets
- Shortage of experienced inspectors
- More remote/unmanned or ageing assets

Permasense Monitoring: Data-driven decision making

Increased margin $

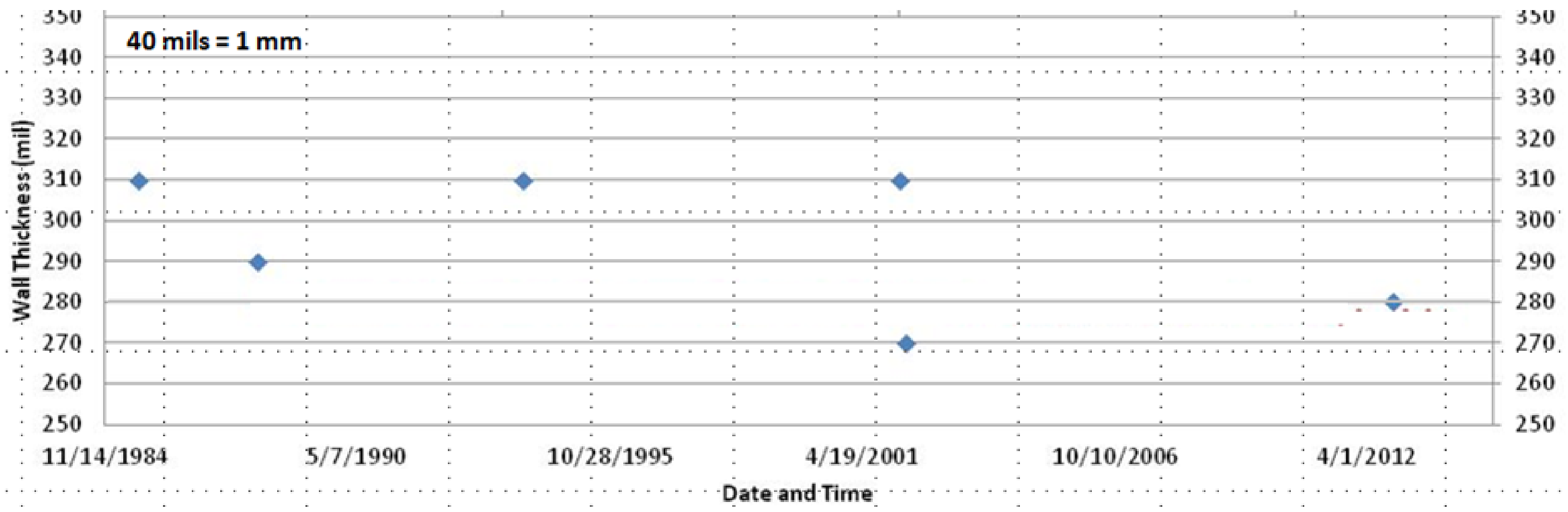
Leaks/ loss of containment

Overly conservative operations

Reduced margin

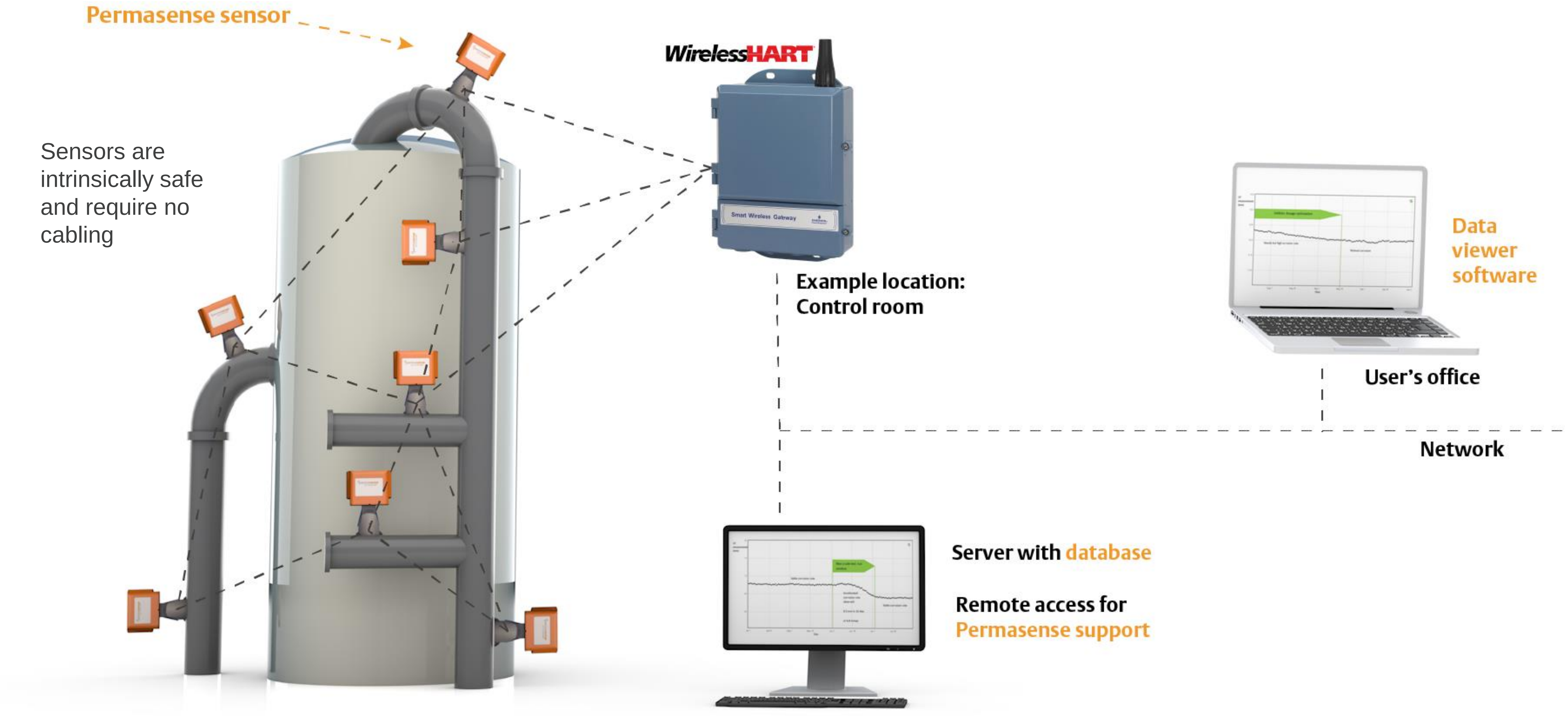
Traditional Corrosion Monitoring Approaches

- Intrusive (ER probes)
  - Fast response to changes in corrosion risk (if real time data delivery)
  - Maintenance headaches
  - Indirect measurement
- Manual UT inspection
  - Good snapshot of current equipment integrity
  - Very infrequent and poor repeatability, safety issues at high-temperatures
  - Normal UT measurements get confused by internal roughness



Fixed Non-Intrusive Sensors Deliver Continuous Wall Thickness Measurements of the Highest Quality Directly to Desk

Sensors are intrinsically safe and require no cabling



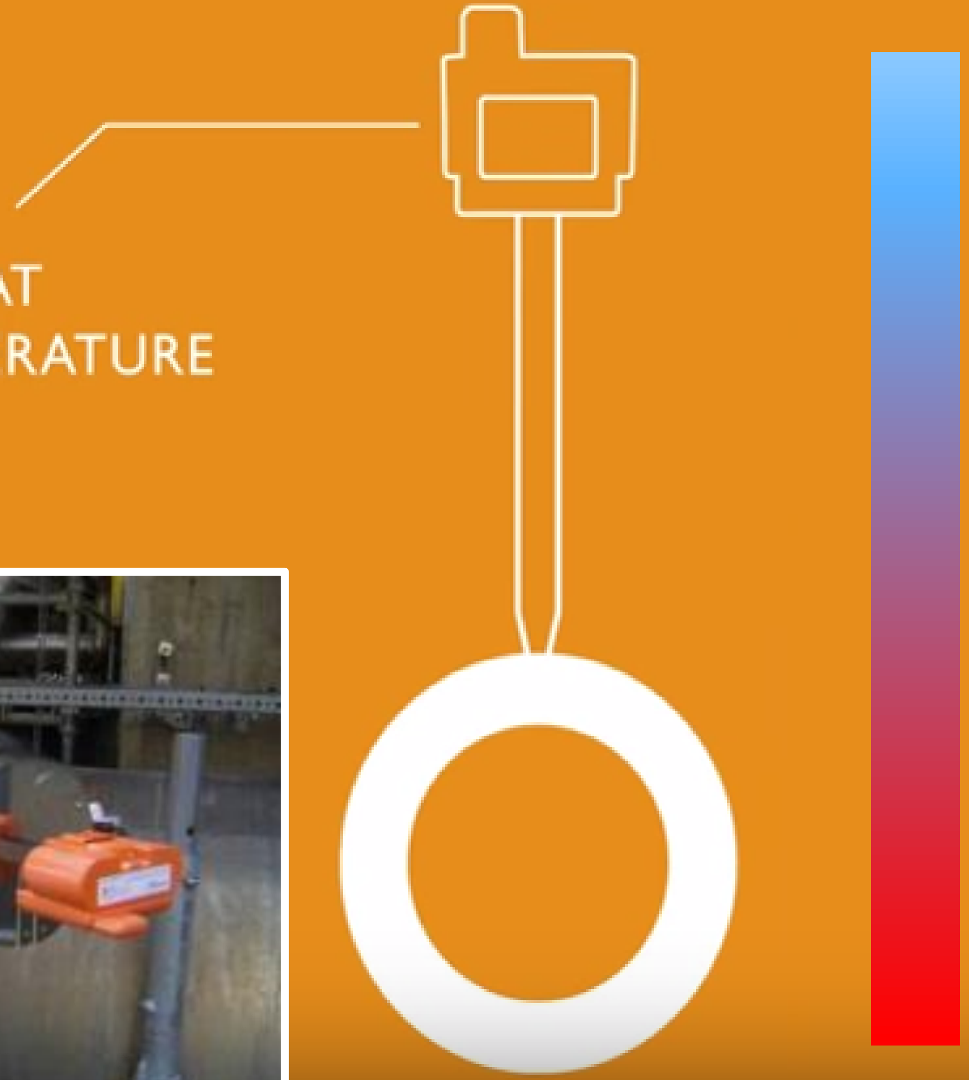
Non-intrusive ET210 Sensors Measure Through Coating – No Need to Remove External Protective Coatings

Ideal for oil & gas production assets

Magnetic mount, with plastic securing strap

Pipe operating up to 120 °C

Non-intrusive WT210 sensor design enables permanent installation on the hottest of equipment (up to 600 deg. C)



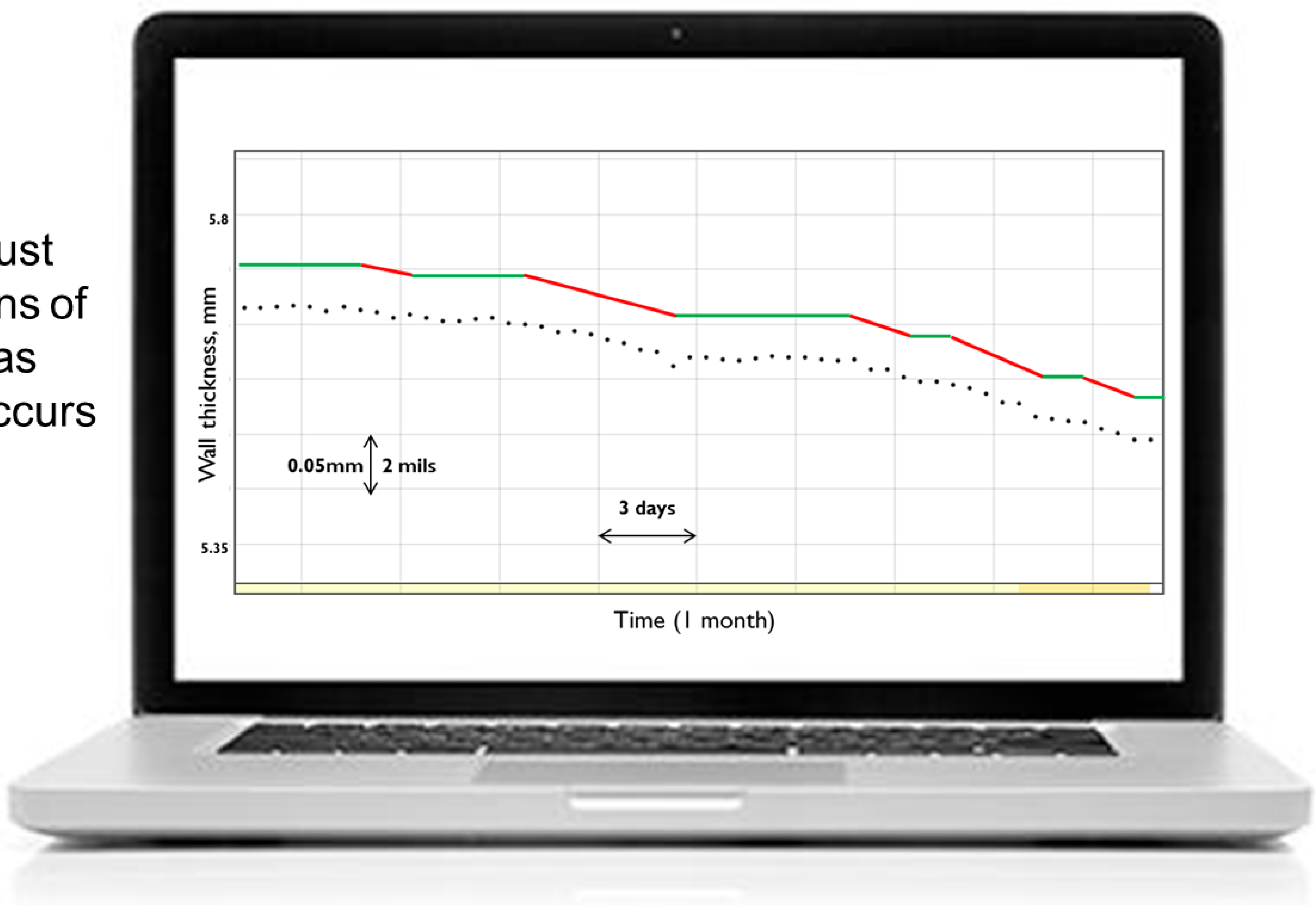
The WT210 sensor can measure from -180 to 600 deg. C

Ideal for refineries / steam applications

Insulation replaced after sensor mounting

Providing an unparalleled *Quality* and *Frequency* of data: Real Time Insight Into Asset Integrity, at Desk

Measure just 10s microns of wall loss, as the loss occurs

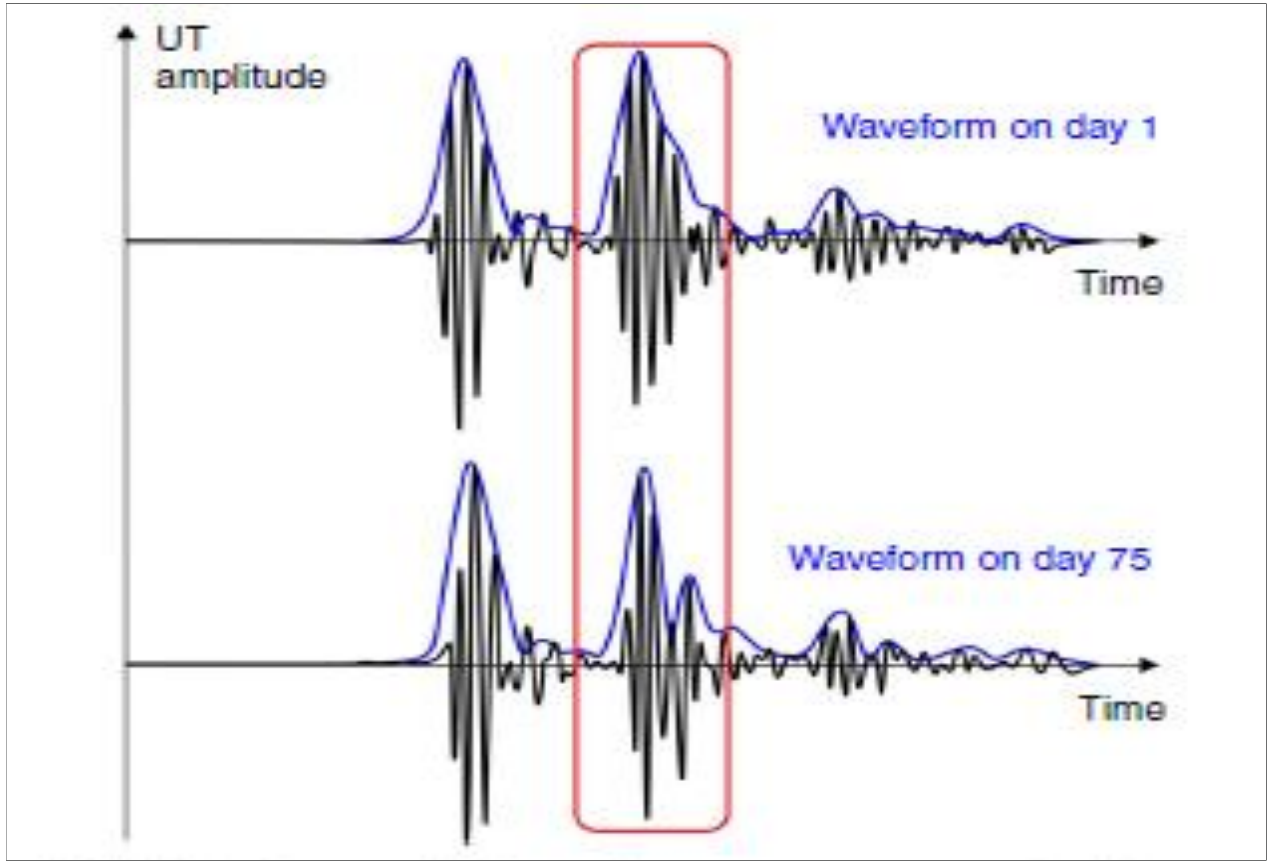


0.12mm/month overall, but periods of very high corrosion rates

System Outputs, From Each Sensor, Twice Per Day

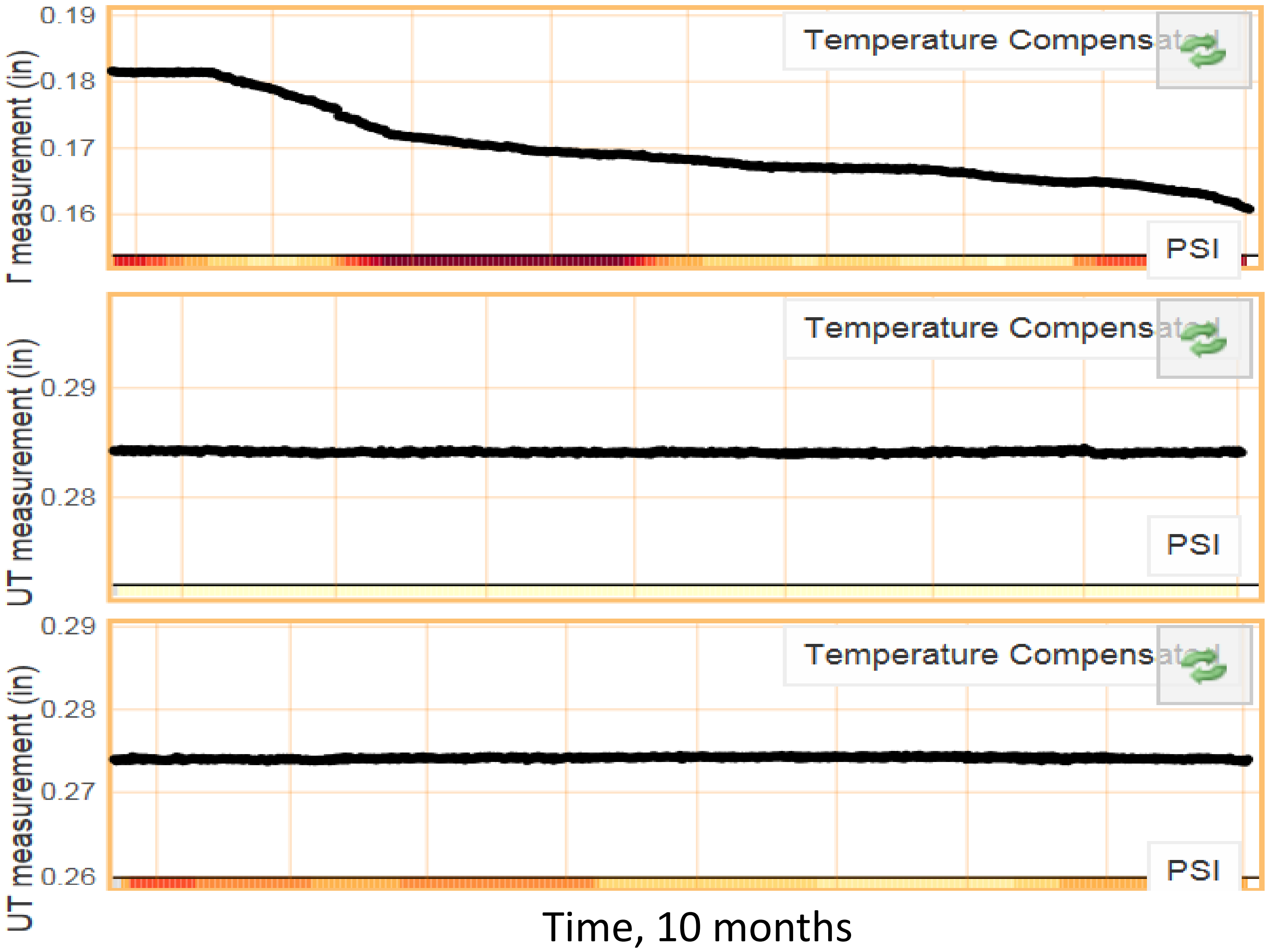
1. Wall thickness (temperature and material compensated)
   - Calculated by time-of-flight between two consecutive reflections (peaks detected using patented AXC processing)

2. PSI
   - detects change in shape of internal reflection signal



Change of UT waveform appearance over time (for one sensor) due to changing internal roughness

Example System Outputs Over Time



Very high intermittent wall loss & roughness changes

No wall loss, no roughness change

No wall loss, but intermittent roughness change

System Drives Improvements in Risk Management, Profitability and Safety

Operational Risk Management

- Availability Improvement
- Integrity Assurance
- Personnel Effectiveness

Enhanced Decision Making

- Production Maximisation
- Material Selection
- Equipment Life Management
- Process Optimisation
- Shutdown Planning
- Treatment Optimisation

Improved Profitability

Safety

- Personal
- Process

Global Leader in Non-Intrusive Corrosion Monitoring

>13,000 sensors in >130 facilities in >25 countries,

13 million wall thickness measurements delivered to desk

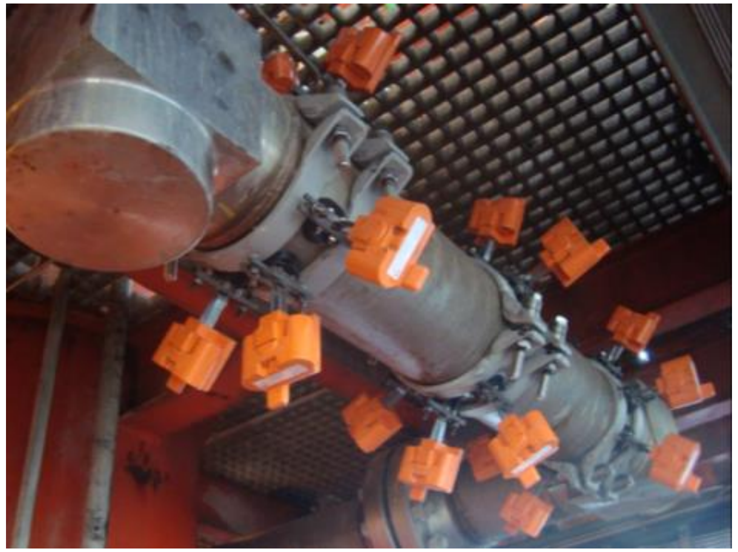
70% refineries, 20% upstream, 10% other industries

Top Oil & Gas Applications and Solutions

- **Sand erosion** – maximise production rates - 25-50 sensors per well, payback in days
- **Ageing Assets** – maximise profitable life – ~50 sensors per platform, payback in months
- **Assets with High-impact of failure**: eg, H2S processing – minimise risk of failure – potentially 1000s of sensors.

Offshore Production Case Study 1: Maximising Production Rate

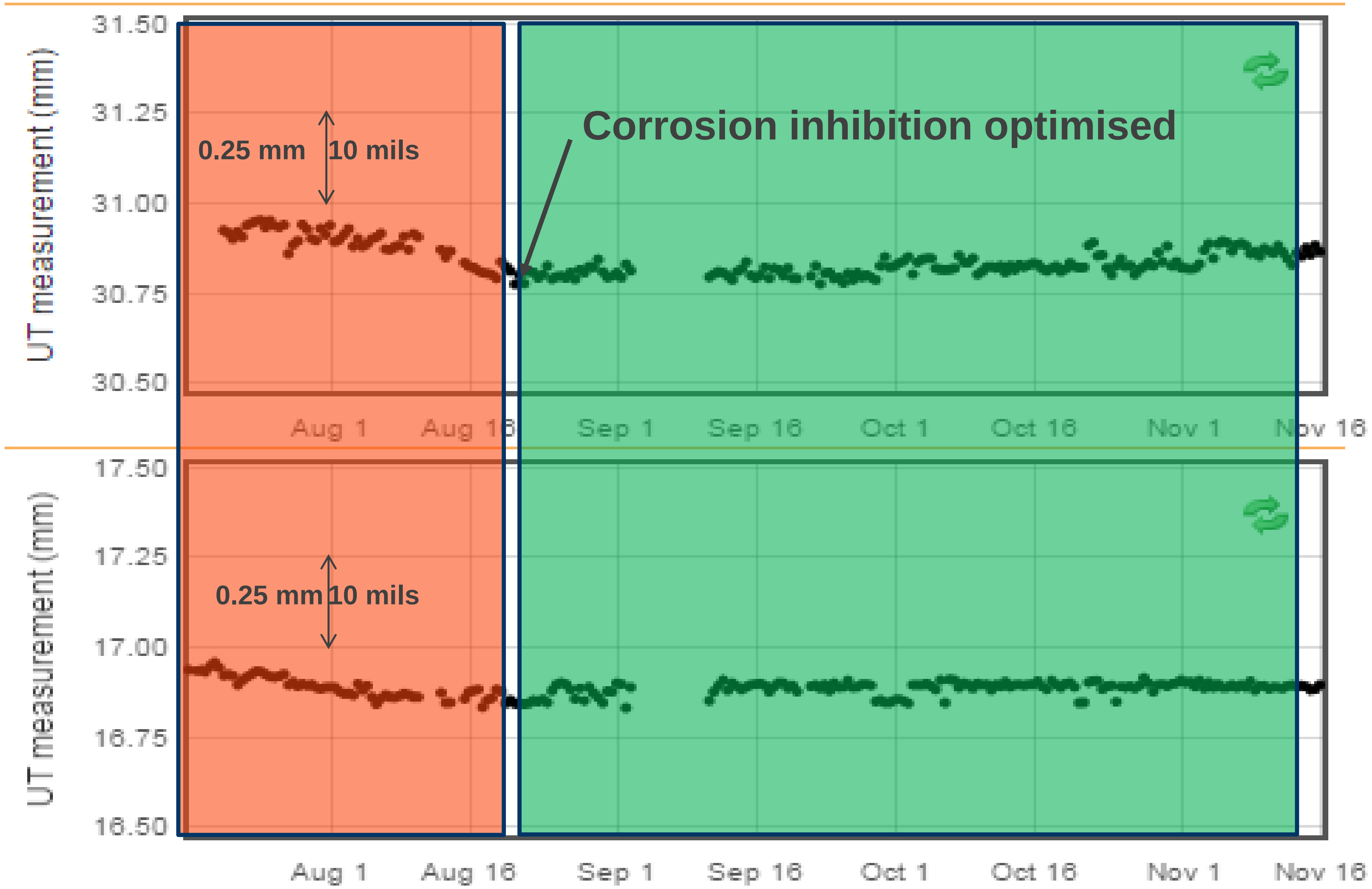
- Constrain on production rate: fear of sand erosion
- Acoustic sand detectors being used and detecting *presence* of produced sand
- Inline probe measurements were showing *high risk* of erosion
- Now monitoring with permasense system downstream of choke and after first bend (~25 sensors per riser) to measure *impact* of the produced sand on the asset integrity
- Production rate increased 12% to 2.8×10^{5} MBTU/day
- Permasense data *verified erosion rates not increased*
- At $4 / MBTU, payback on Permasense system in just days



Downstream of Cushioned Tee

Downstream of choke

Offshore Production Case Study 2: Maximising Availability of Ageing Asset



Sensor offshore – part of 30 sensor system

Corrosion *detected, measured, actioned, controlled*, control *validated* in service

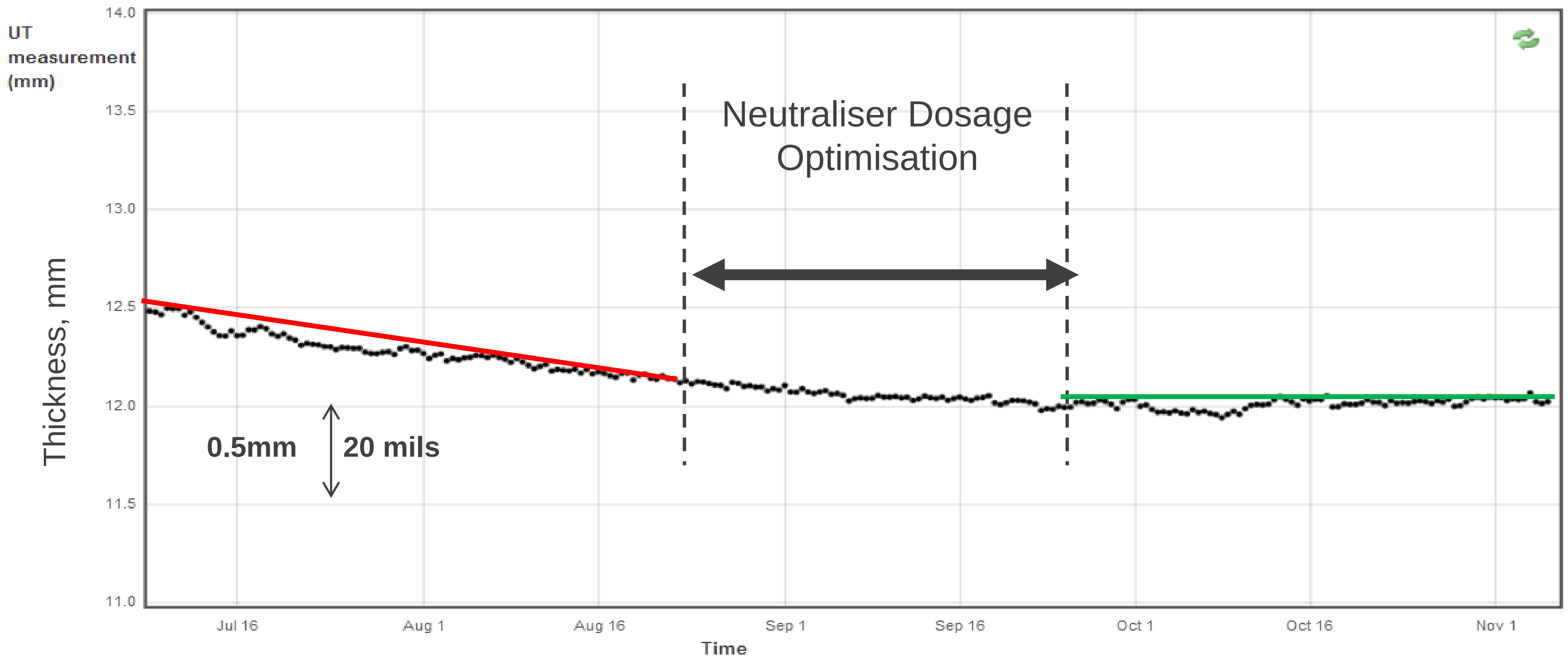
Top Refining Applications and Solutions

- **Opportunity Crudes** – have confidence to buy cheaper feedstocks – 150-200 sensors, 1-2 month payback

- **Shutdown management** – better plan shutdowns, maximising availability when margins are good – 35-50 sensors per unit, 1-6 month payback

- **Customer-specified starter system** – monitor the locations that keep the integrity team up at night, 25-50 sensors, solve a corrosion/process problem, avoid major outage, <6 month payback

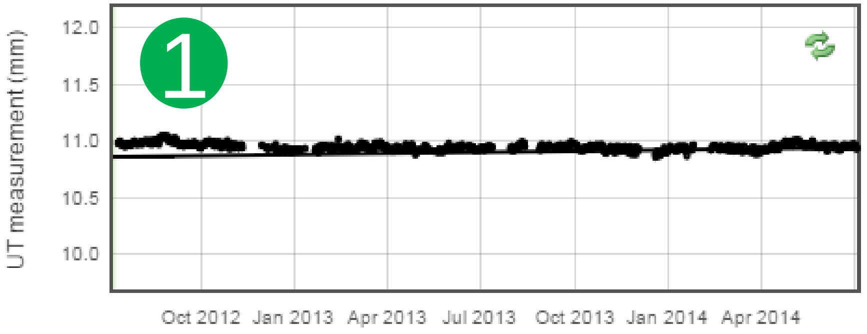
Refining Case Study 3: Hydrocracker Corrosion Inhibition Optimisation

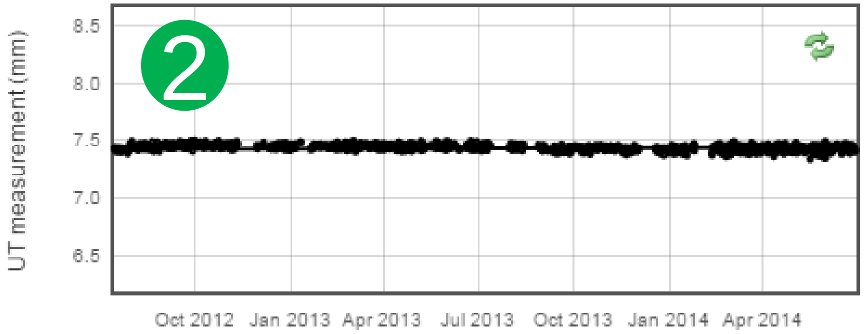


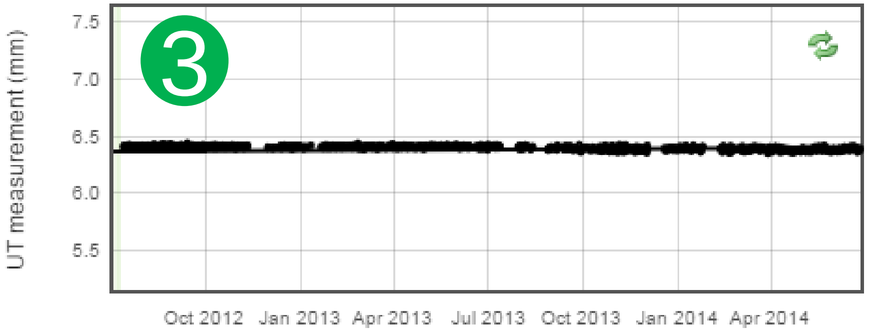
- High corrosion rate measured – 1.2 mm/year (48 mils/year)
- Neutraliser dosage adjusted using feedback from Permasense sensors over 1 month
- Corrosion rate *stabilised*

Refining Case Study 4: Preventing Unplanned Outages in Amine Unit

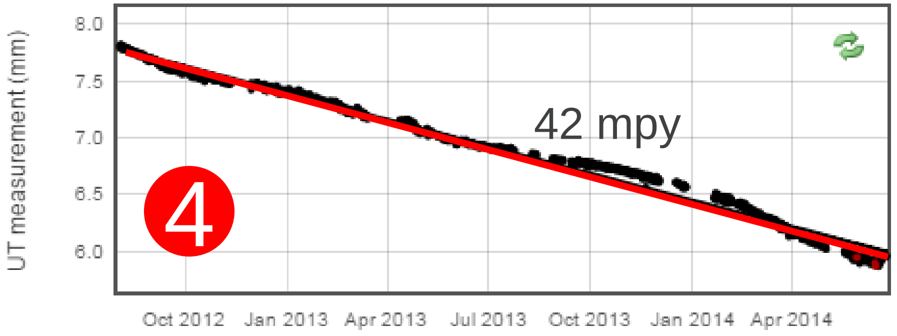
- Refinery with four amine absorber / regeneration trains
- All similarly configured, all stainless steel – corrosion <u>NOT</u> expected







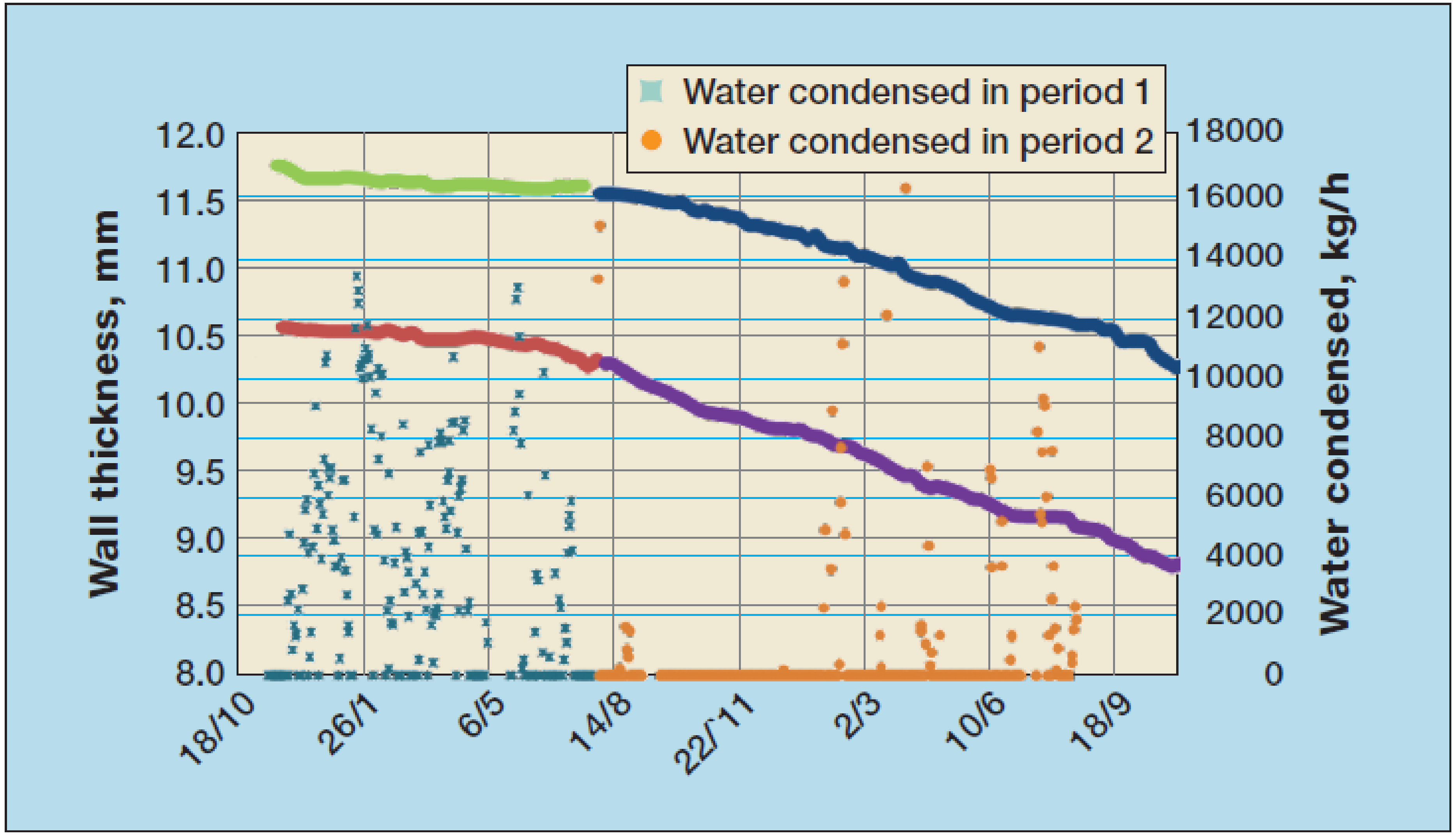
- Much faster and **unexpected** corrosion in train 4
  - 1 year to retirement even in stainless !
- High CO_2 content feed due to preferential routing of FCC off-gas to this train
- Carbonic acid attack mechanism
- Feeds redistributed to dilute effect of CO_2 corrosion across trains and extend run length



Permasense Technology Caught an Unexpected Failure

Refining Case study 5: Crude Unit Overheads – Root Cause Analysis

European refinery – monitoring shell of overhead shell and tube condensers



Conclusion: Better Asset Integrity Data Drives More Profitable Operations

- Permasense System delivers wall thickness measurements continuously from locations where access is costly, dangerous or physically restricted
- WirelessHART data transmission facilitates cost effective, rapid installation in difficult working environments
- Operators get more accurate and timely understanding of the asset integrity and corrosion or erosion rates
- Data provides insight into the impact of changing operations on corrosion/erosion rates, especially when correlated with other recorded process variables
- Data supports more effective risk-based decision making about
  - Opportunity crude processing
  - Increasing production rates
  - Optimising chemical inhibition strategy
  - Improving shutdown/maintenance timing and planning

Where To Get More Information

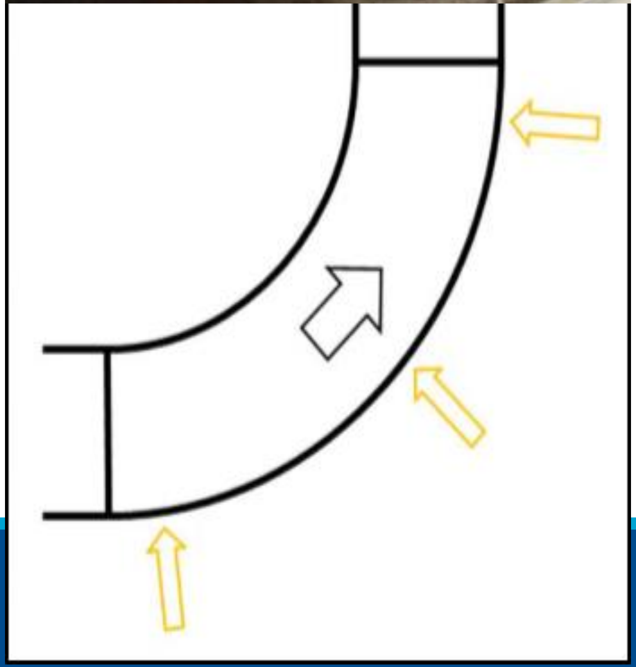
Email: sales@permasense.com

Web: www.permasense.com

Aberdeen Contact: Gary Wallace (Upstream Technical Manager)
Email: gary.wallace@permasense.com
Telephone: +44 1224 776200 / +44 7720 839677

Deep Dive Case Study: European Refinery, on-the-Run Installation of Monitoring System to track Sulfidation Corrosion

- 183 sensors across CDU and VDU
- Majority of locations selected for high-temperature corrosion mechanism monitoring
- Sensor locations chosen based on:
  - previous inspection history
  - predicted corrosion rates
    - Using geometry, fluid, process conditions
- Sensors installed on range of materials

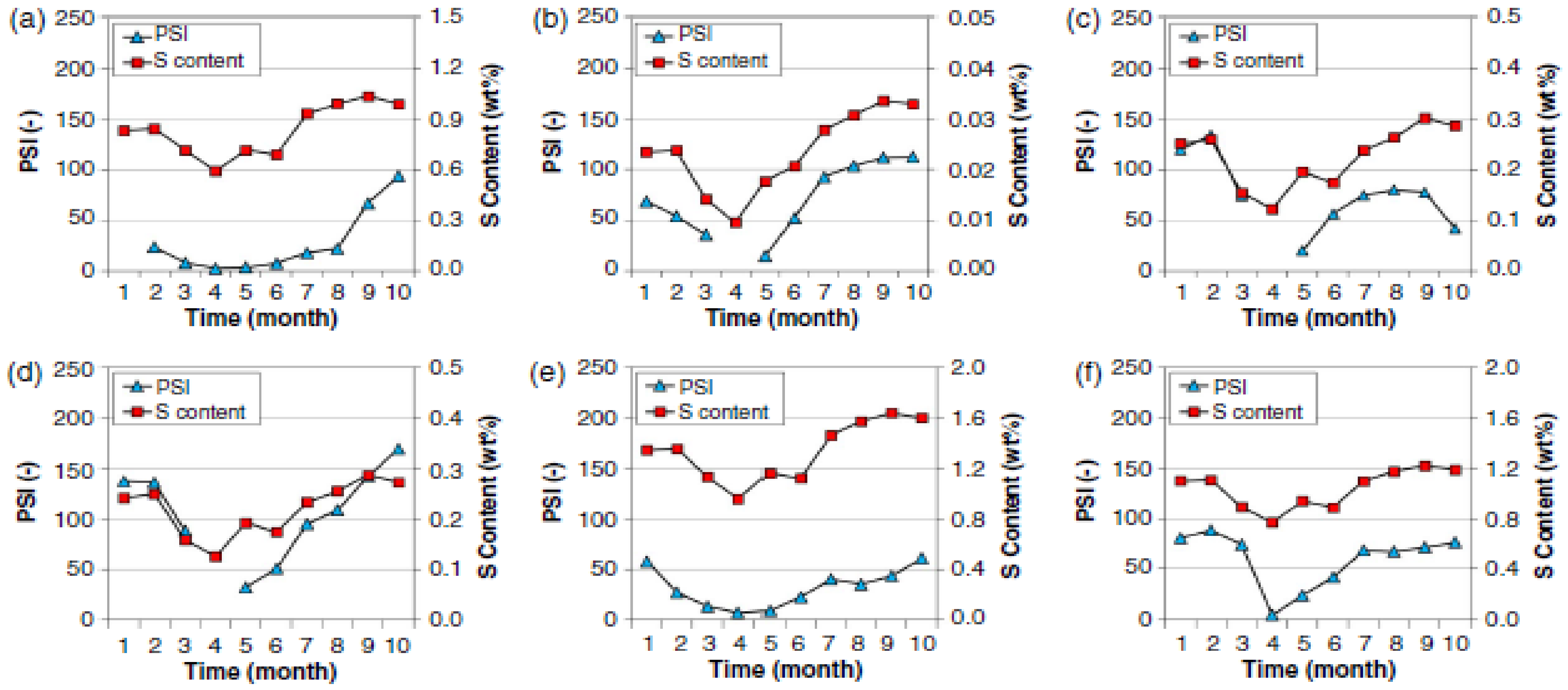


Sulfidation Corrosion in Refineries

- Reaction of steel with reactive sulphur compounds such as H_2S in high-temperature environments
  - Occurs above ~260°C (500ºF), sulfidation corrosion rates increase with temperature, peaking at ~450°C (850 ºF).
  - Affects carbon steel/low-alloyed steel and stainless steel
  - usually results in general wall thickness reduction, but can also create rough internal surfaces as the iron sulphide layer is created or destroyed

- Presence of mercaptans in crude oil can accelerate corrosion, most reactive 235°C (455 ºF) - 300°C (572 ºF)
  - Mostly Affecting Middle Distillate loops

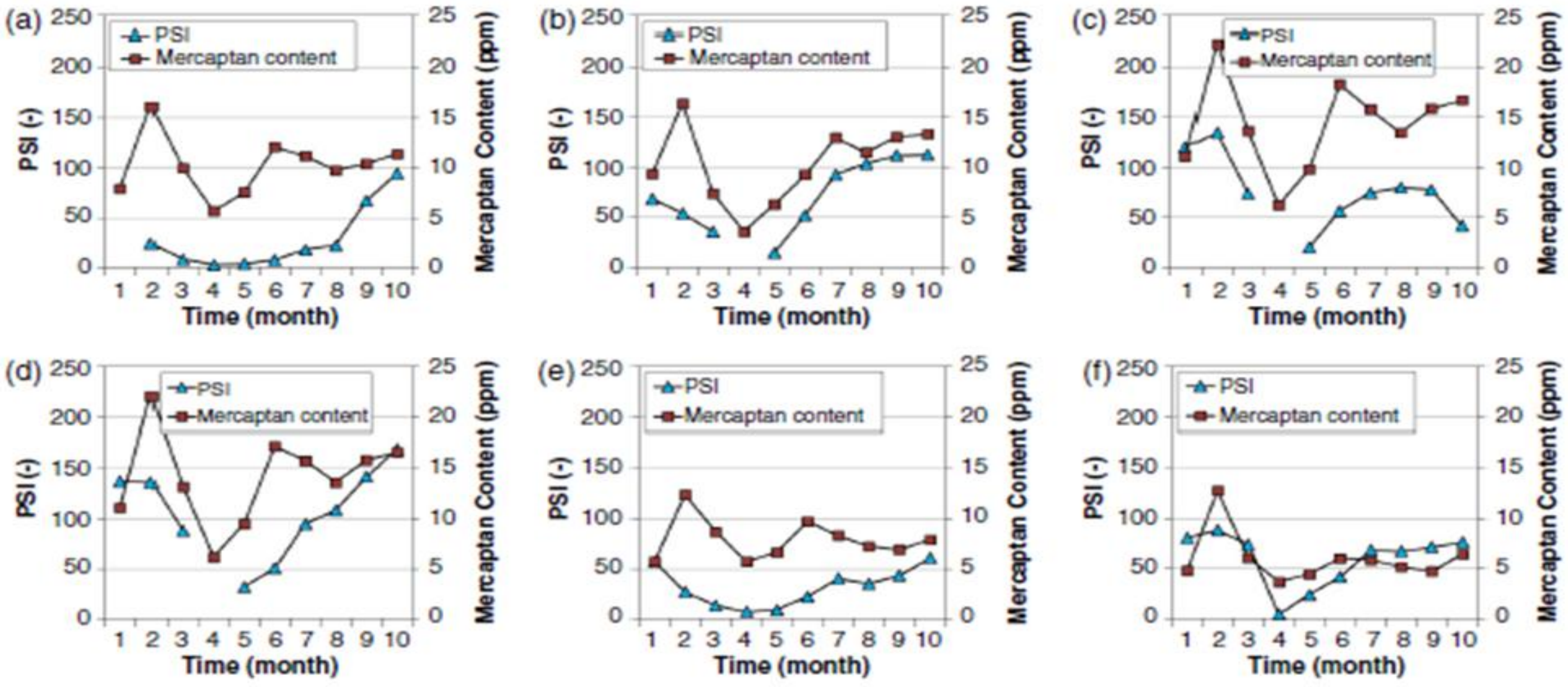
Excellent Correlation Between PSI Measurements and Total Sulphur Content



(a) crude oil, (b) kerosene, (c) gas oil reflux,
(d) gas oil, (e) long residue, (f) heavy vacuum gas oil

For more detail, see Dr Philipp Schemp's NACE paper

PSI Measurement Correlated Very Well With Mercaptan Content



(a) crude oil, (b) kerosene, (c) gas oil reflux,
(d) gas oil, (e) long residue, (f) heavy vacuum gas oil

Summary of Results

- ~180 wireless UT sensors monitoring six different high-temperature corrosion loops of a European refinery's CDU and VDU

- Recent breakthrough in UT signal processing: PSI.
  - Detects change in internal roughness through change in recorded ultrasound signal shape

- Correlation between measured data from online UT monitoring (PSI) and crude parameters - that represent the crude oil diet's potential for high-temperature corrosion in CDU/HVU.
  - Excellent correlation between measured PSI and total sulphur content across all 6 circuits
  - Very good correlation between measured PSI and Mercaptan content across all 6 circuits

- Correlation allows for improved corrosion prediction based on measured crude parameters and demonstrates the sensitivity and relevance of online ultrasonic wall thickness monitoring coupled with powerful signal processing methods in the safe and profitable processing of opportunity crudes.

Where To Get More Information

Email: sales@permasense.com

Web: www.permasense.com

Aberdeen Contact: Gary Wallace (Upstream Technical Manager)
Email: gary.wallace@permasense.com
Telephone: +44 1224 776200 / +44 7720 839677