YEP ICorr

Integrity Management Lecture 14th October 2020.

Presented by Stephen Tate – Technical Services and Projects – TOTAL E&P UK Limited, Total House, Tarland Road, Westhill, AB32 6JZ

About Presenter

Stephen Tate MICorr

First Joined the Oil Industry in April 1980 (from Construction Industry)
OND Construction and Surveying, Guildford College.1974
PG.Dip.Eng. (Offshore Corrosion and Materials), RGIT, Aberdeen.1983
MBA (Integrity Management) Aberdeen University. 1999
35yrs Aberdeen / 5 Yrs Overseas based Assignments – Europe/UAE/Africa.
Last 10 Yrs with ICorr Aberdeen Branch, 2 x Chair, 2x Vice Chair.
Worked with Major Operators and Inspection Providers.
Last 5 Yrs with TOTAL E&P.

Programme for Tonight – Part 1

Definition of integrity in process plant and structures.

Examples of failures of integrity process plant and structures with the consequences.

Frequent causes of loss of integrity due to corrosion in:

Oil and gas process systems.

Pipelines.

Land based structures.

Offshore structures (fixed and floating).

Corrosion management documentation systems (and recent updates).

Principles

Guidance documents

Q&A Part 1 (questions entered into CHAT). Coffee Break.

Integrity

(to be complete)

Ensure Facilities remain safe, productive and legally compliant.

Wars can cause instant loss of Structural Integrity – Many South Pars Structures were Badly damaged in 1980-1988 Iran Iraq War.

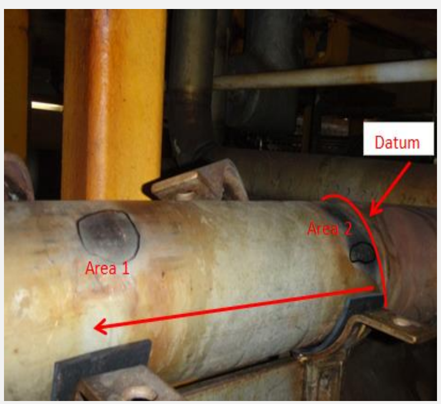
Integrity Failures and Risks

Frequent Causes of Loss of Integrity – Oil and Gas Production

Flow Erosion

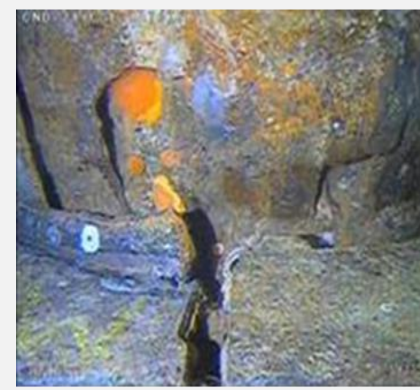
Choke Failure

Salt Deposits / Dis-bonded Coatings CSCC



Pipe Supports

CUI



Conductors and Guides

Other Causes of Loss of Integrity – Oil and Gas Production

Poor Fabrication / Material Selection Practices – Uncoated 316L in Marine Environment

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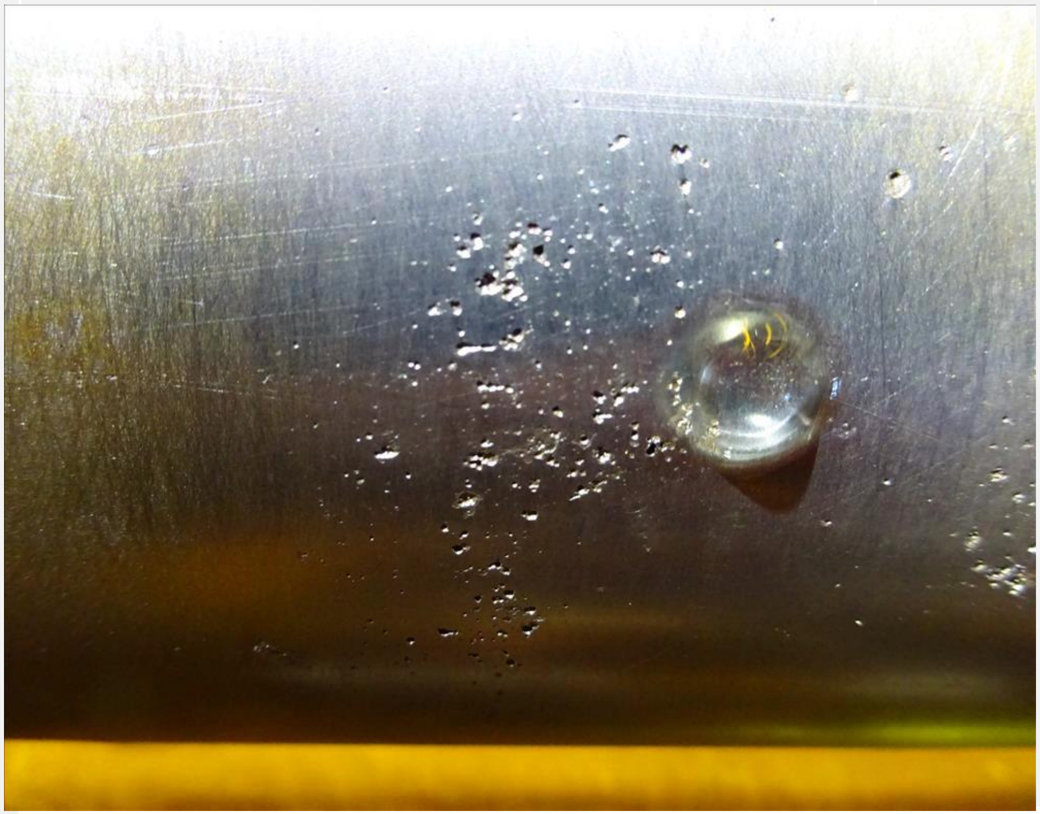
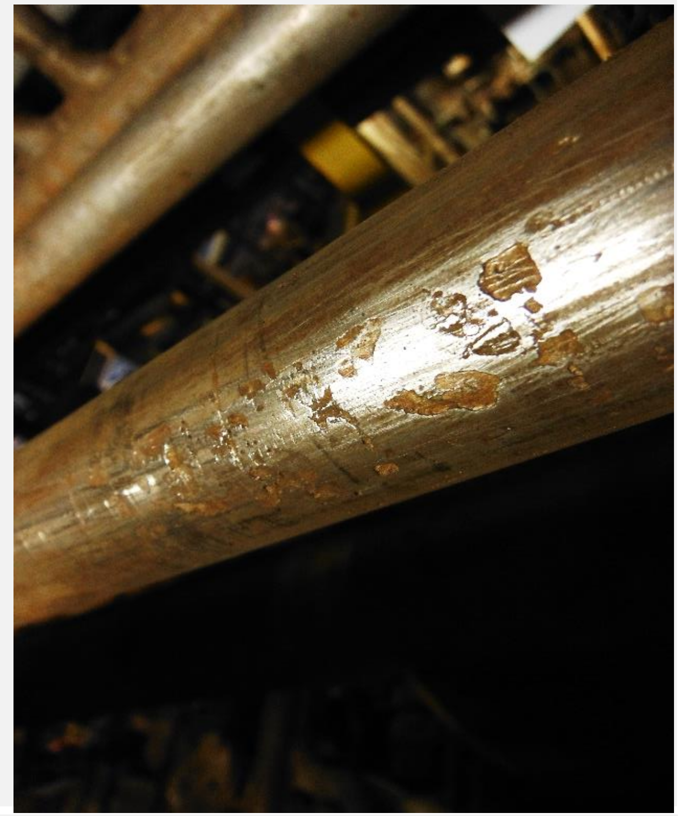
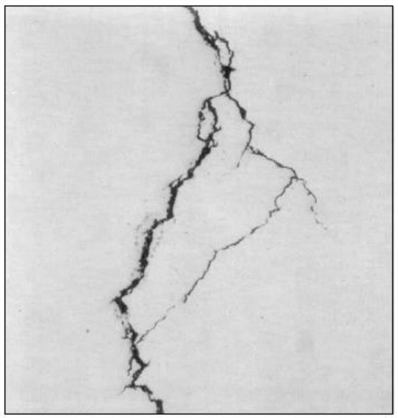
Other Causes of Loss of Integrity – Oil and Gas Production

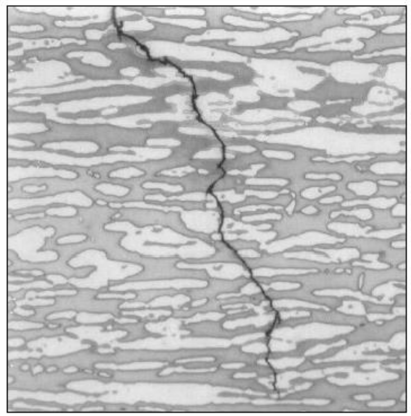


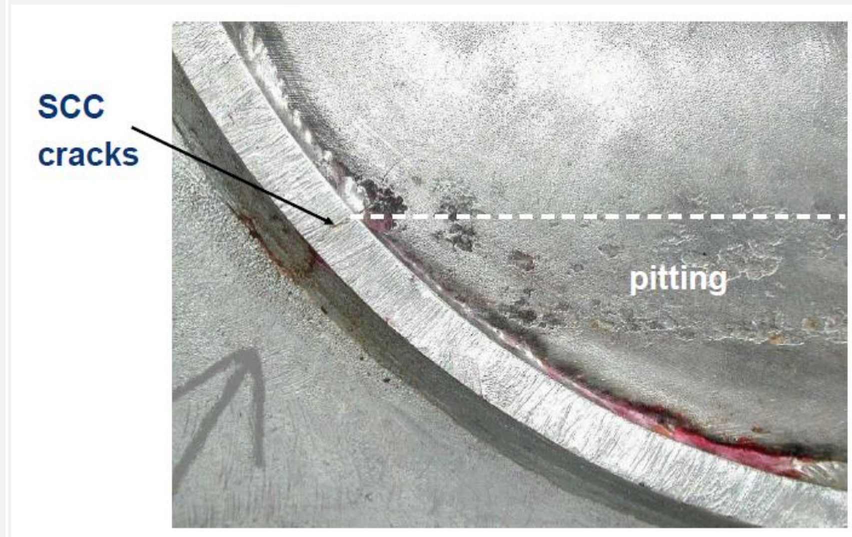


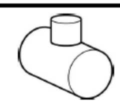
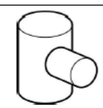
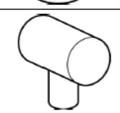
Poor Fabrication / Material Selection Practices – 316L Weeps + Pitting under ID Labels

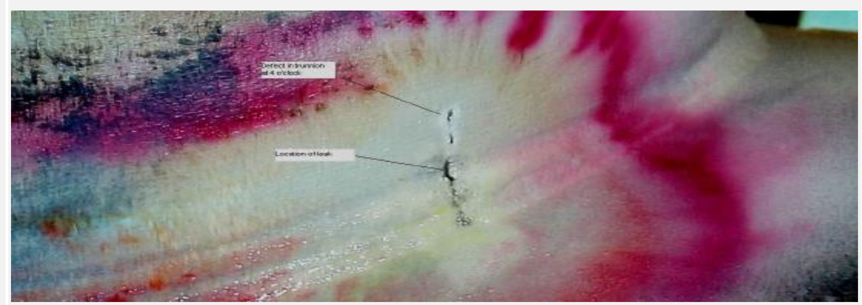
Other Causes of Loss of Integrity – Oil and Gas Production







Category 1	Vertical trunnions were either cut open for access and subject to MPI surface defect assessment and ACFM (Alternating Field Current Measurement) defect assessment, or replaced completely.	
Category 2	These horizontal trunnions were subject to visual boroscope inspection for initial evaluation. If there were any significant findings these could be re-classified as Category 1.	
Category 3	These trunnions were all positioned on the vertical below position and were classified as requiring sample boroscope inspection only. Priority was given to any trunnion where there was evidence of Salt Deposits.	
Category 4	These trunnions were previously sealed during construction prior to phase 1 CSCC inspection. They can be any orientation.	



Pipe Trunnion Salt Water Ingress / Corrosion / Cracking Risks to HT Duplex Lines

Frequent Causes of Loss of Integrity – Oil and Gas Production

Examination after Intermittent Use

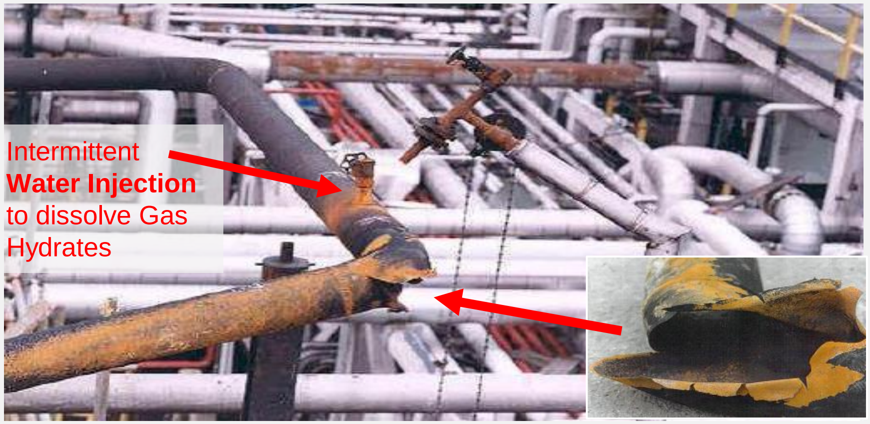
Post-Cleaning BOL – UDC / MIC

The Pipework from both First Stage Separators to the Second Stage and from Second to third was subject to severe internal pitting partly due to being shut in and not drained for quite long spells 6-12M. The failed spool had **many pits which were not reported from previous manual UT** Inspections. **Phased Array** scanning of the 3-9 o'clock parts of the horizontal pipework gave a more definitive view of the status (where accessible).

Holes – Visible Externally after Scale Rem.

Close-Up of Pitting

Examples of Failures – Oil and Gas Process Leaks

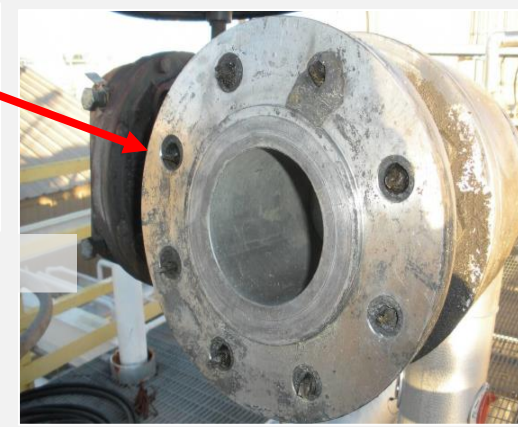


Humberside 2001 – Int. Erosion (New WI Pt)

Gas Explosion – Damage Adjacent Plant

Sour Gas Leak 2011

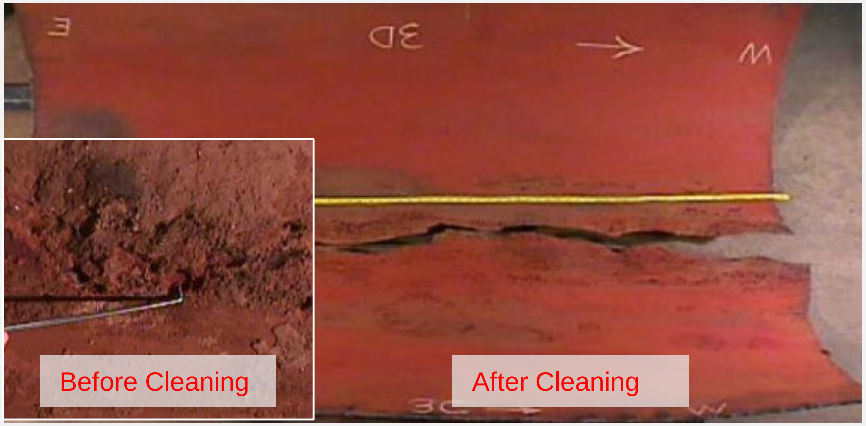
Uniform ~ 90% corrosion of 8x bolts allowed nor. working pressure to fracture the bolts. **Duct tape** around Flange allowed "micro-environment" of H2S, CO2, heat / humidity.



BV Bolting Failure

Examples of Failures – Pipelines

Gas Pipeline Failure – New Mexico 2000



Internal BOL Corrosion – Common Cause

Mississippi – Multiple Fatalities 2009

Resulting Hydrotest Failure

Examples of Failures – Pipelines

- 29th July 1995
- Failure on a 42 inch grade X60 natural gas pipeline approx 3 km southeast of Rapid City Manitoba. (Pup was X65)
- 19.6 m^3 gas consumed by fire
- The initial rupture occurred as a result of a pre-existing stress corrosion crack (SCC).
- This piece of pipe had been fabricated in the field and coated with polyethylene tape.

With thanks to Alan Denney

Examples of Failures – Pipelines

With thanks to Alan Denney

- 21st March 2006
- Leak from Trans-Alaska pipeline
- At least 190000 litres of oil released onto tundra
- Corrosion at a point where line dips for Caribou to cross,
- corrosion rate had unexpectedly accelerated

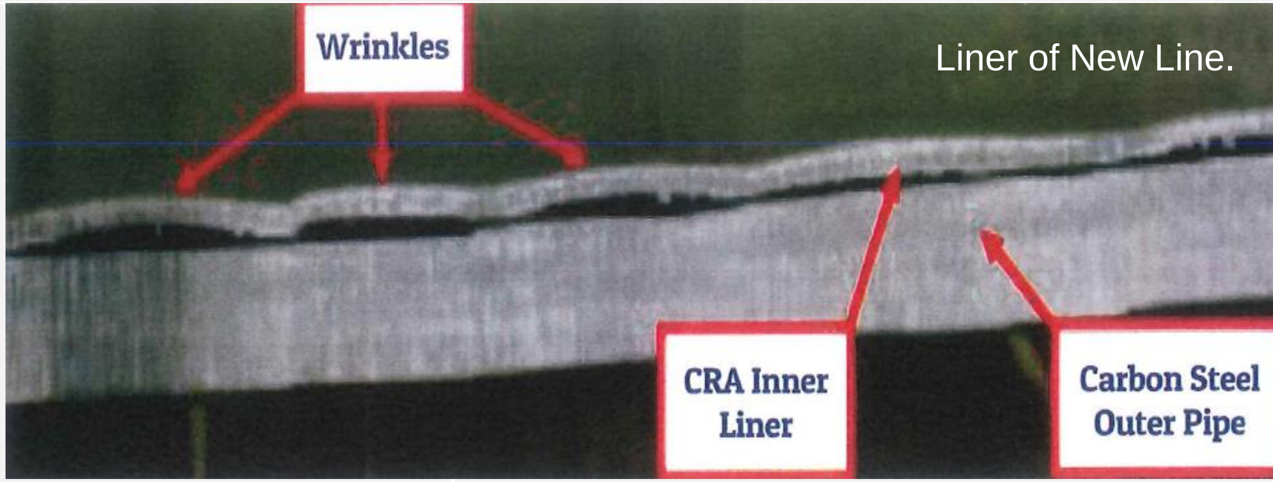
- Prudhoe Bay oilfield closed down on 9th August 2006 losing 400000 barrels of oil/day production
- US$12 million federal criminal fine,
- US$4 million in criminal restitution to the state
- US$4 million for Arctic research.
- BP Exploration (Alaska) Inc. on probation for three years.

Examples of Failures – Pipelines

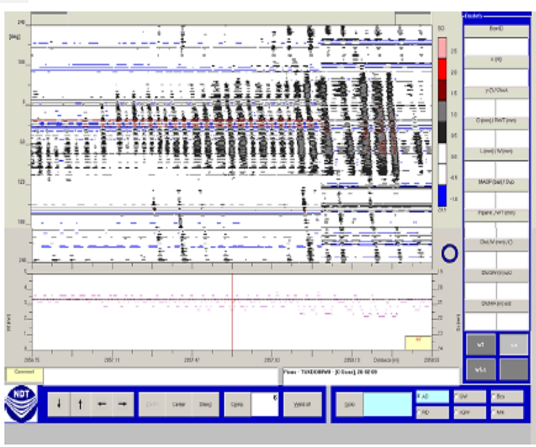
CASE - ILI (in Line Inspection) **of North Sea Multiphase Export Line found line beyond continued service after only 10 yrs operations.**

- **Corrosion wall thickness Losses were so great 60-70%, that replacement was required.**
- These corrosion defects were deduced to be related to CO^2 in the water.
- It was observed that despite of corrosion inhibitor (CI) injection; the areas within the pipe with $BaSO^4$ scale acted as a filter and **restricted inhibitor access** to the inner wall of the pipe.
- The $BaSO^4$ scale was of different thicknesses and in some areas permeable.
- A secondary corrosion mechanism was noted to be in operation where the scale was impermeable.
- The **sections under scale became anodic with respect to the neighbouring un-scaled areas** and the difference in galvanic potential lead to localized corrosion under the scale.

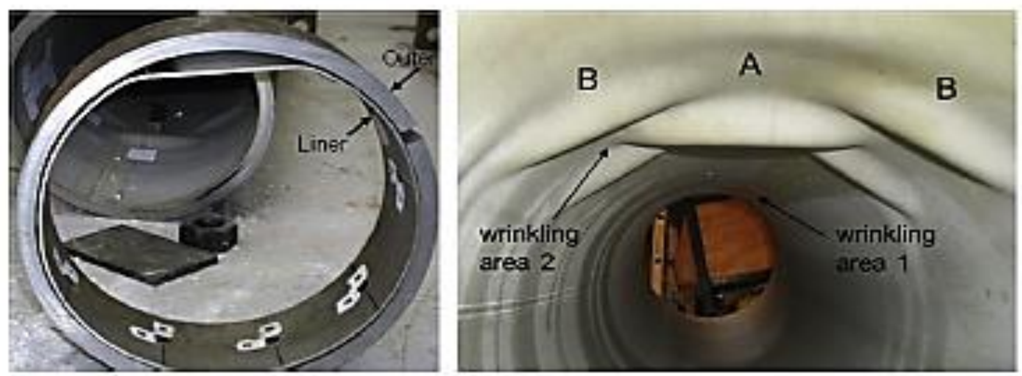
Examples of Failures – Pipelines



Pipe Lay Buckling Effects



NDT Wave Form (ILI)

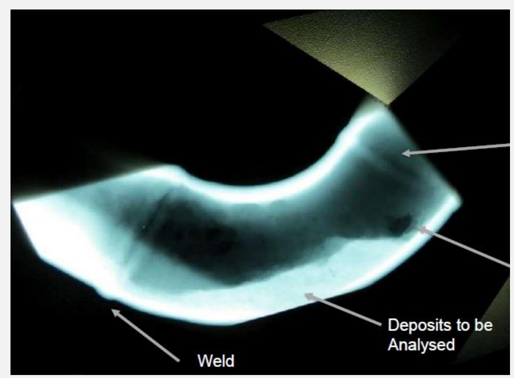


Lined pipe, (a) photo after experimental testing (Focke, 2007) and (b) wrinkled liner pipe (Hilberink, 2011).

Replacement Line has not leaked but requires careful Cleaning / Monitoring.

Critical Dead Leg Management

Failure Site and Sludge Below.



Drain Located Upstream of Export Biocide Injection – Loss of 2 Wk's Export

Dead Leg Management

DL1 - Coating in good condition.

DL2 - Coating in good condition.

DL3 - Coating in good condition.

DL4 - Coating in good condition.

DL5 - Minor isolated CD/CR throughout.

DL6 - Coating in good condition.

10-12 Piping Deadlegs per P&ID can be expected with Internal / External Corrosion Risks

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Dead Leg Management + CUI

DL1 - Coating in good condition.

DL2 - Under insulated jackets.

DL3 - Partially under insulated jackets.

DL4 - Partially under insulated jacket.

DL5 - Under insulated jackets.

DL6 - Under insulated jackets.

10-12 Piping Deadlegs per P&ID can be expected with Internal / External Corrosion Risks

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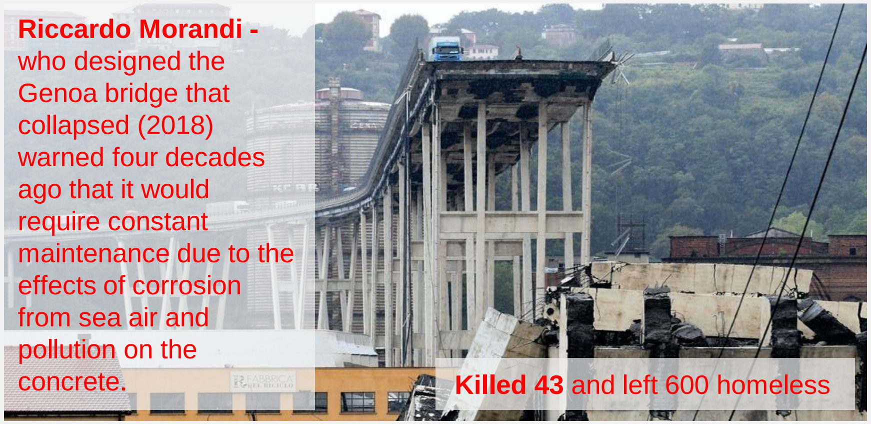
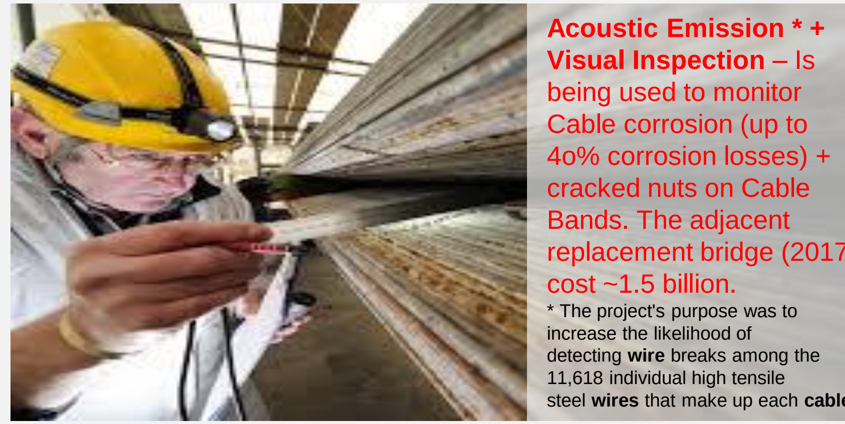
Examples of Failures – Land Based Structures



Riccardo Morandi - who designed the Genoa bridge that collapsed (2018) warned four decades ago that it would require constant maintenance due to the effects of corrosion from sea air and pollution on the concrete.

Killed 43 and left 600 homeless

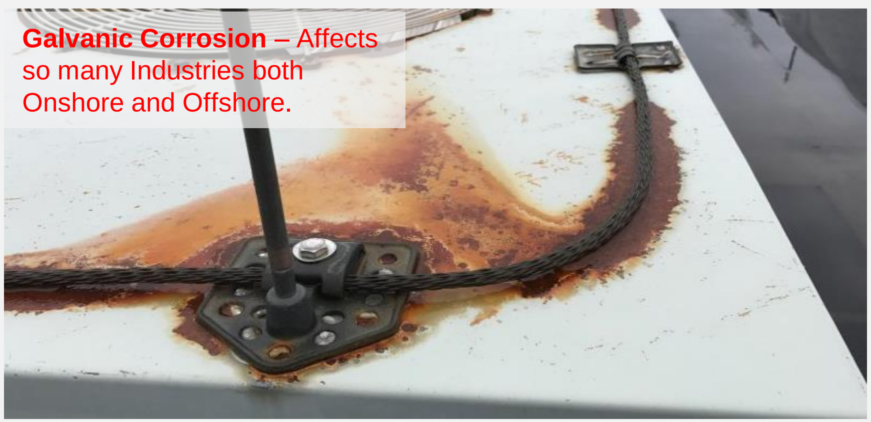
The Broken Bridge of Italy – RC Failure



Acoustic Emission * + Visual Inspection – Is being used to monitor Cable corrosion (up to 4o% corrosion losses) + cracked nuts on Cable Bands. The adjacent replacement bridge (2017) cost ~1.5 billion.

* The project's purpose was to increase the likelihood of detecting **wire** breaks among the 11,618 individual high tensile steel **wires** that make up each **cable**.

Forth Road Bridge Cable Corrosion



Galvanic Corrosion – Affects so many Industries both Onshore and Offshore.

Safety Earthing – Typ. Galvanic Corrosion

Near Miss (2014) ! - Train travelling at 110 mph (177 km/h) struck the top of a signal which had col fallen lapsed and across the adjacent railway line near Newbury. Very luckily there were no injuries and the train did not derail.

Newbury Railway – Corroded Signal Base

Examples of Failures – Offshore Structures

Caisson Failures – Pump and Drains

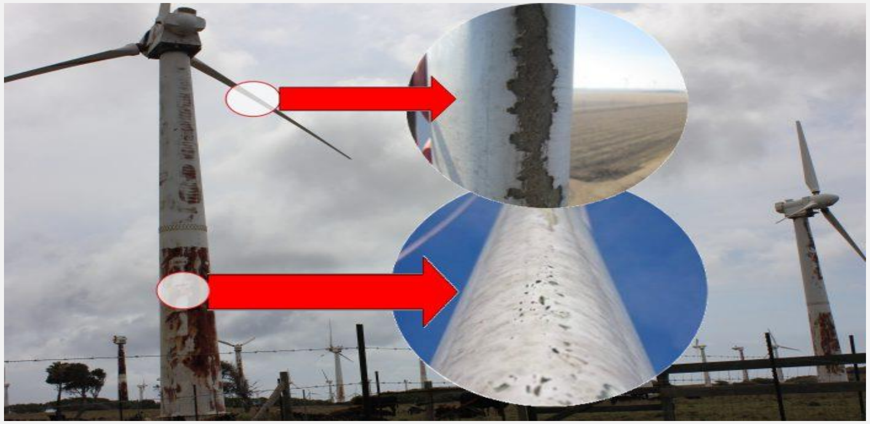
Walkway and Staircase Failures

Boat Landings

Subsea Structural Failure

Examples of Failures – Renewables (Hydrogen / Wind / Solar)

Coatings Failure



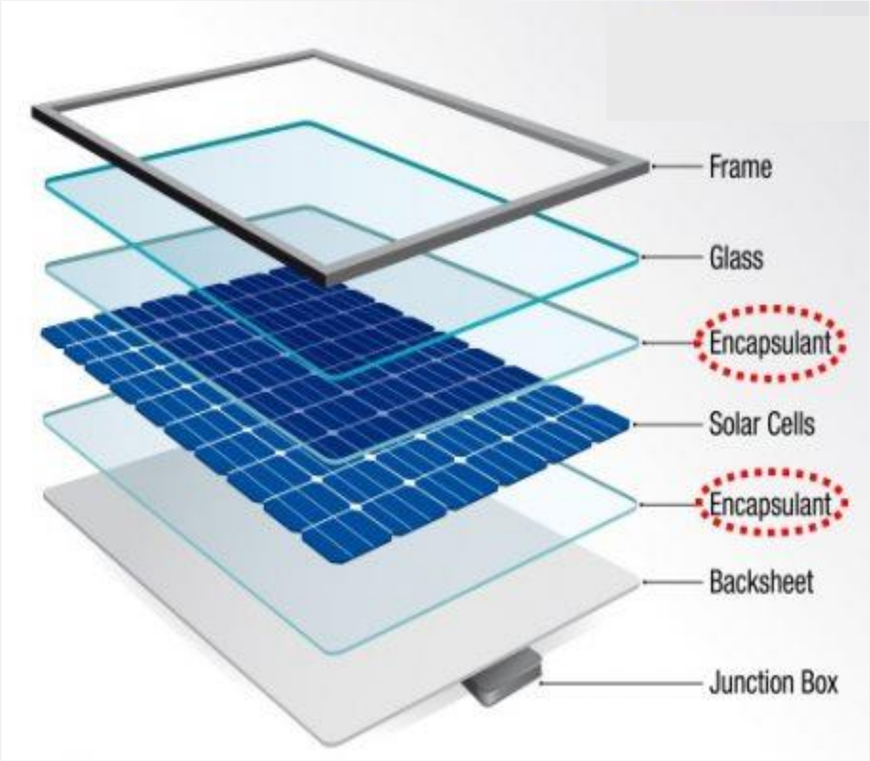
Blade Erosion

Corrosion is a continuing and major issue in all fields of energy, **not excepting renewable energy.** Newly engineered systems are designed for up to 30 years of service but exposure to environmental corrosion, UV, extreme temperatures and salt corrosion can challenge component durability. Excessive component failures can lead to high maintenance cost and overall under performance of energy output.

Load-out Integrity can be Short-lived

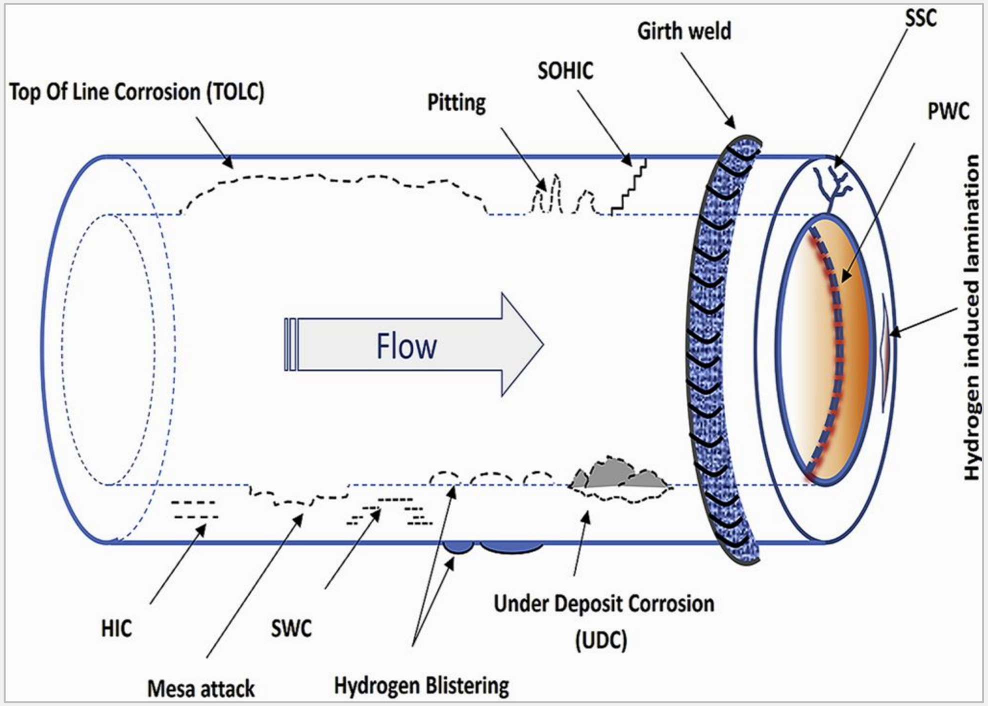
Atmospheric Corrosion

Examples of Failures – Renewables (Solar)



Browning is a change in color of the EVA film and occurs when certain additives used to prevent browning and enhance UV resistance, start to disappear. This can cause bleaching and blistering at the EVA film and the solar back-sheet, resulting in **Solar Cell Corrosion.**

Potential Failures – Renewables (Hydrogen Transportation)



Lower Risk – Blending with Natural Gas (up to 15%) but this does not move much product !

Higher Risk – Single Product / Hydrogen use. Essential to under take full threats analysis and ILI run (ideally including some material sampling) if re-using a line. Historical records are often poor !

Pipelines used (or Re-used) for Hydrogen Transportation have many potential failure modes – both Internal and External. Worldwide there are more than 5000 km of hydrogen pipelines in total, the vast majority of which are operated by Hydrogen producers. **The longest pipelines are operated in the USA**, in the states of Louisiana and Texas, followed by Belgium and Germany. https://hydrogeneurope.eu/hydrogen-transport-distribution The most common causes of hydrogen-related hazardous failures are: **mechanical damage or damage due to material defects (from original manufacture), corrosion, enhanced embrittlement of storage tanks in low temperatures and human error (in operations).**

CM Documentation

Corr. Management – Key Elements

ROLE of CMS

It is the responsibility of the Operator to ensure that the required corrosion assessments, corrosion control strategies and corrosion monitoring processes are in place **so that the risk of loss of containment and equipment/structural failure is minimized. Many are SECE's (Safety Critical Elements)**

The **CMS - Corrosion Management Strategy** is a key document that defines the overall management approach but is supported by many other documents such as:

- Facility Specific Corrosion Control Schemes (with Monthly KPIs),
- Inspection Manuals,
- Chemical Treatment Manuals,
- Site Operating Instructions.

- **CMMS** (SAP or other) – Computerized Maintenance Management System records all required Mitigations / Monitors / Inspections and their Frequency.
- **Ea. routine will be prioritized according to assessed risk.**

Corr. Management – Key Elements

Level 1 – Company Policies

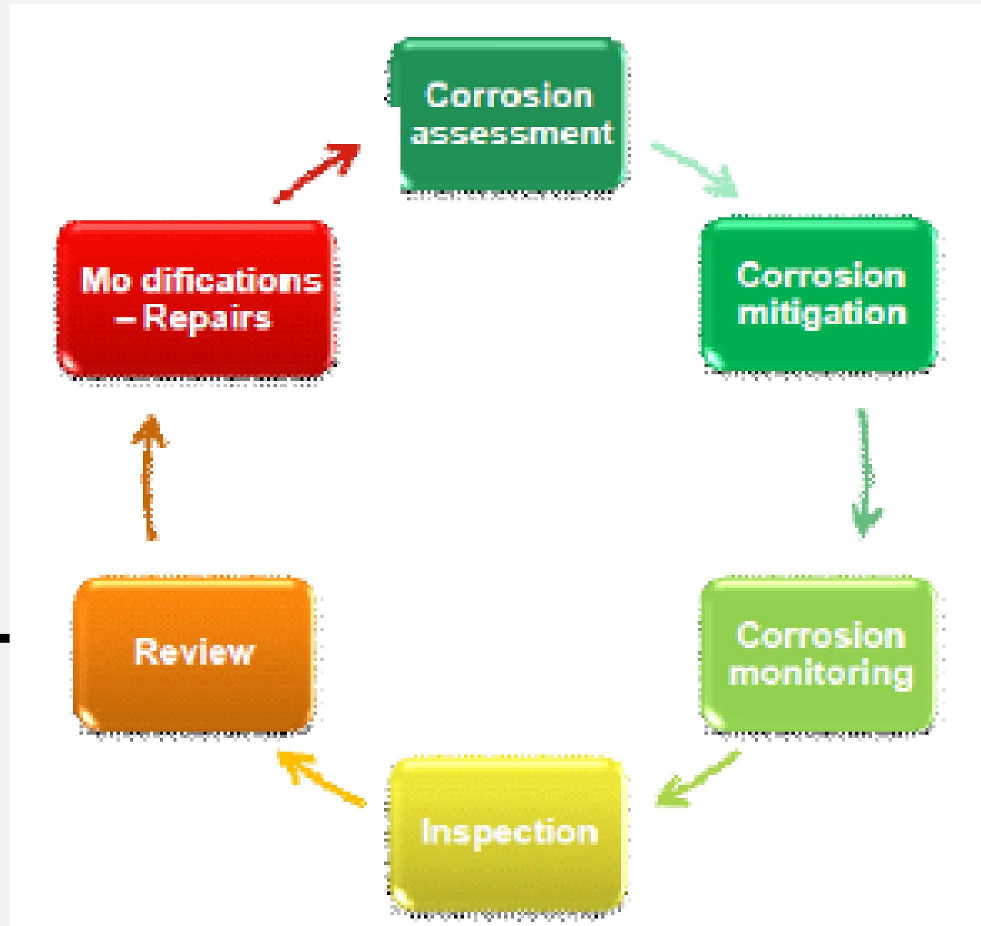
Level 2 CMS - Key Elements:

- Defining Roles and Responsibilities.
- Defining Corrosion Control Strategy for ea. Facility operated.
- Defining Degradation Mechanisms.
- Defining Mitigations.
- Defining Performance Monitoring and Techniques.
- Defining Devices to be Deployed.
- Defining how Collected Data will be Measured / Stored / Interpreted.

Level 3 – Site Specific Corrosion Management Documentation.

Level 4 - Site Specific Work Instructions.

Simplified Cycle



KPI Reviews
X-Discipline
Mtgs

Review Meetings

Every Operating Asset will maintain Pipelines and Topsides KPI's and hold Regular Meetings involving:

- Production Chemist.
- Process Engineer.
- SMART Rm Operator.
- Corrosion Engineers.
- RBI Engineers.
- Inspection Leads.
- Materials and Welding TA.
- Pipelines TA.
- Pipelines Engineers.
- HSE representatives.
- Other Disciplines (as req.) E.g. SECE Owners.

These meetings are a key part of the CMS Implementation.

Corr. Management – Reading

Recommended Further Reading:

- **EI's Guidance on corrosion management in oil and gas production and processing, Mar.2019,** provides general principles and essential engineering guidance and requirements for improving corrosion management practices in oil and gas production and processing. It has been produced by an experienced oil and gas industry work group with the objectives of:

    - Reducing the number of corrosion related hydrocarbon releases and other safety related and environmentally damaging outcomes.
    - Identifying good practices for setting up an optimal corrosion management scheme.
    - Providing an overview of the top corrosion threats to production and processing facilities downstream of wellheads.
    - Improving the safety profile of hydrocarbon installations.
    - Improving equipment reliability.
    - Improving equipment availability.
    - Improving profitability.

Building on the previous edition, which was recognized in the HSE KP4: Ageing and Life Extension Programme as a major contribution to the industry's successes in addressing corrosion issues

- **Guidelines for the Management of Access Fittings for Pressurised Systems. Energy Institute, Aug.2020.**

Risk Assessment

RBI Documentation / Corr. Management

Risk is a function of **combining**:

- **Probability** of an event
- **Consequence** of the event

For low risk we control: the probability of failure ***or*** the consequences

- Many aspects of risk are controlled at design stage
- Limiting risk by limiting stresses, strength and toughness of line pipe
- Limiting consequences by classification of location, and proximity controls.
- Assessing consequences, according to pipeline type and situation.
- **Qualitative, Quantitative and Semi-Quantitative Tools + PIMS + Plans**

RBI Documentation / Corr. Management

- Database development to cover risk and inspection planning
- Analysis to establish the major threats to the pipeline
- Preliminary risk analysis
  - Probability estimation
  - Consequence estimation
- Detailed investigations to confirm risk estimates for critical sites
- Failure modes and Effect Assessment – to define appropriate inspection methods
- Development of the RBI plan and database
- Implementation of RBI
- From outcome of inspection - plan and organise remedial activities (maintenance etc)
- Re-assessment of risks and updating the database accordingly

Specialised RBI Software – Last 20yrs

In most systems, a large portion of risk is concentrated on relatively few items or areas. RBI assigns correspondingly high levels of inspection and monitoring.

Implementation is the hardest part of any RBI exercise – Many Internal Inspections now replaced by NII.

COFFEE Break / 15 mins

Programme for Tonight – Part 2

Tools for monitoring corrosion (and erosion).
Corrosion monitoring methods for process systems.
Ultrasonic and other NDT based methods (prev. covered by Alan Denney).
Acoustic methods and Advanced WT Monitors.
Over the line surveys of pipelines.
Internal inspection methods - pipelines and floating units.
Future Inspection / Post COVID Trends,

Q&A Part 2 (questions entered into CHAT). Closing Remarks.

Corrosion Monitoring Methods for Process Systems.

Tools for Monitoring Corrosion / Erosion

- **Corrosion Coupons** – Pitting + Microbial + Corrosion Product Analysis.
- **Corrosion Probes** – Alarms For Process Trends / Corrosion Trends / Upsets / Loss of Inhibition.
- **UT Parent Metal Scan at Probe / Coupon Sites** – More Accurate Determination of WT Losses / Regular WT Trending, (Monthly Preferred at Main Complexes).
- **TOFD** – Additional Weld Monitoring (where Appropriate), e.g. Manifold Tees.

Types of Monitoring…..

1. Intrusive
2. Non-Intrusive

Intrusive…..

- Test Coupons (of Same Material as Pipe.
- Corrosion Probes – Electrical Resistance, Galvanic, Weld etc.
- Erosion (Sand Monitoring) Probes.

Non-Intrusive…..(NDT)

Prev. Covered under Alan Denney lecture on Welding/NDT

- Electro-magnetic
- Radiographic
- Ultrasonic

Corrosion Coupons

1. A Coupon is not a direct measurement of wall loss but remains a useful guide to process trends and process ‘corrosivity.

2. An insulating washer separates the test coupon from the coupon holder and the pipe wall itself.

3. Coupons should be pulled at least annually for Examination / Weight Loss Measurement / Micro Swabbing.

Corrosion Probes

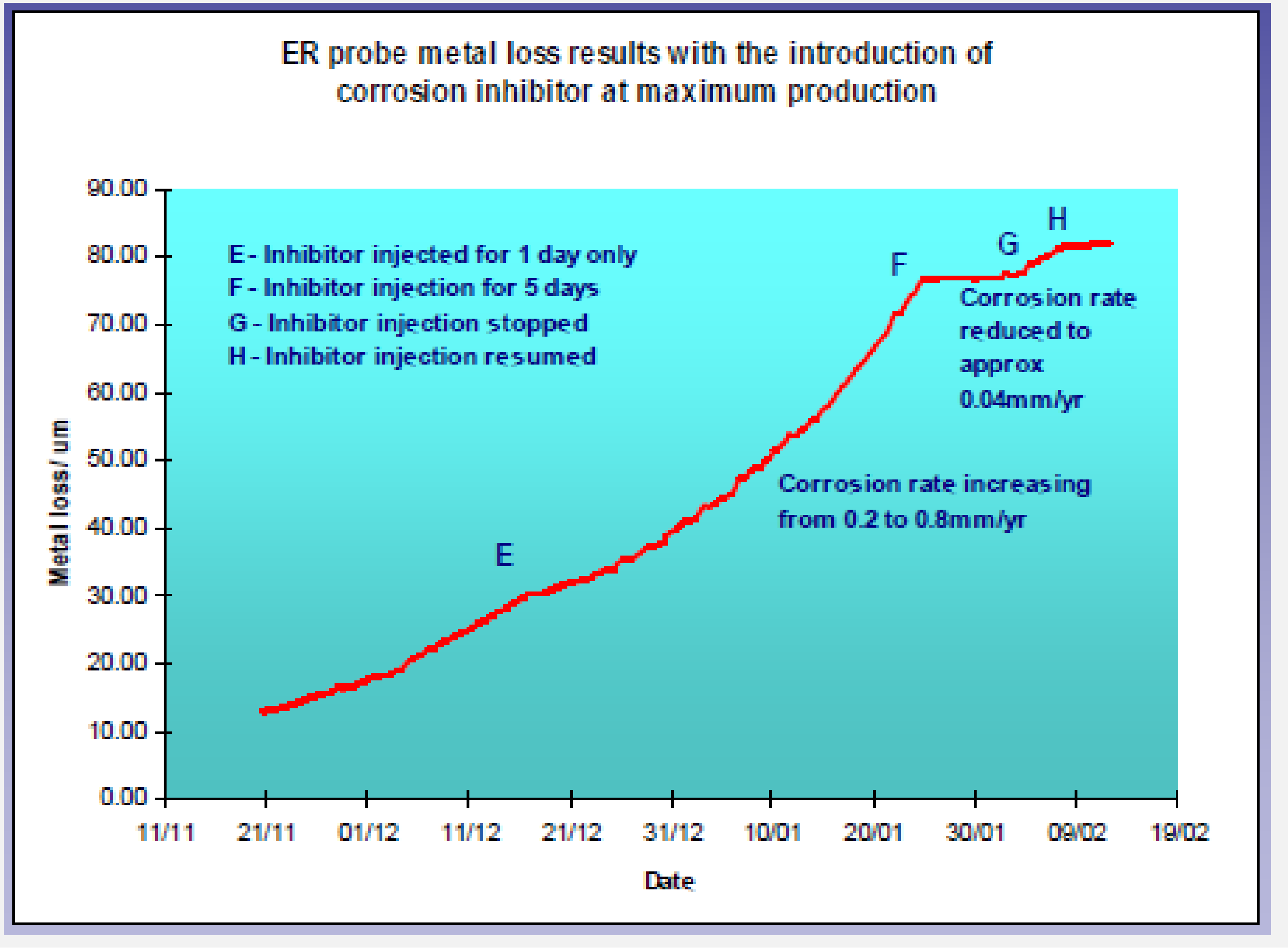
1. Electrical Resistance probes (when used for Corrosion Monitoring), monitor material loss directly* and do not require a continuous conductive path. Therefore the ER technique can be used to monitor corrosion in areas where water wetting is not continuous or under deposits where conductive may be limited.

1. The replacement interval for electrical resistance probes is dependant on probe sensitivity and the corrosion rate. Readings from ER probes will be obtained manually or automatically via an offline or online logging system (PI).

Electrical resistance probes can be used in conductive systems, as well as non-conductive environments such as oil, gas, and atmosphere.

ER Electrical Resistance Probe – is used to track rates of metal loss. The probe directly measures the increase in resistance of a metal as its cross-sectional area is reduced by corrosion. At suitable times, after probe bedded-in readings can be converted into corrosion rates

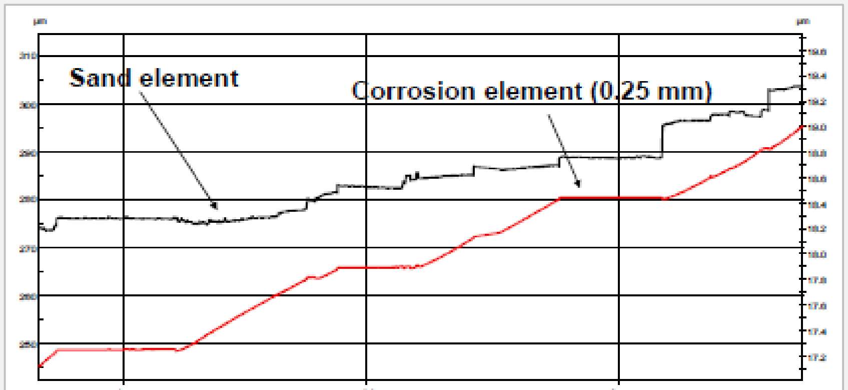
ER Probes used for CI Dosing Op.



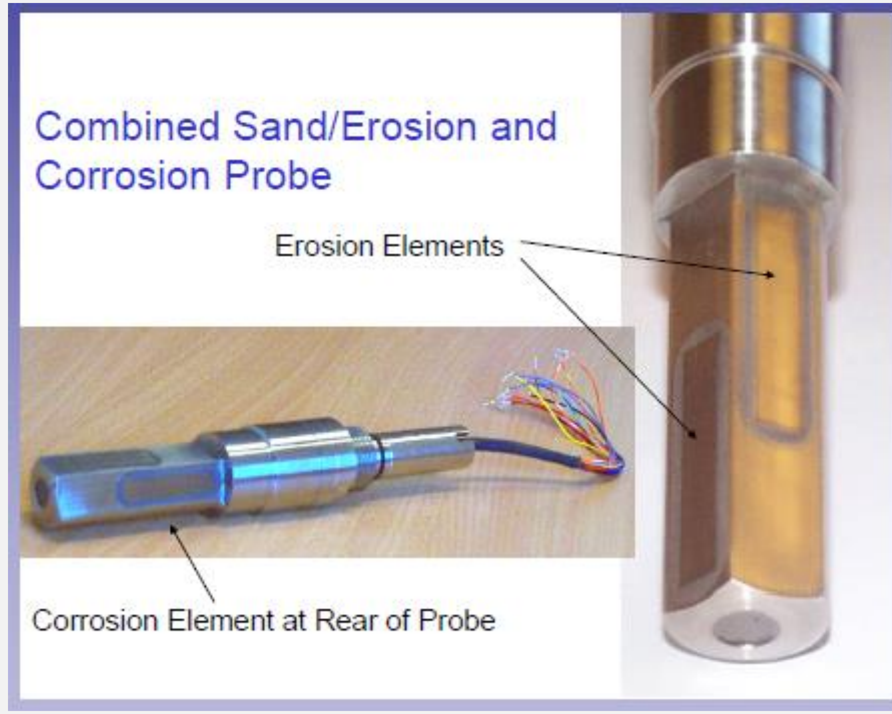
Erosion Probes

1. ER probes of stainless steel, with similar mechanical properties as for the pipe that is the subject for monitoring. Hence the erosion sensors will not corrode and all material loss and can then be attributed to erosion.

1. Often there is little general evidence of solids posing a serious problem, **other than very locally at Choke Valves / Sudden Geometry Changes.**



Data from Combined Sand/ER Probe

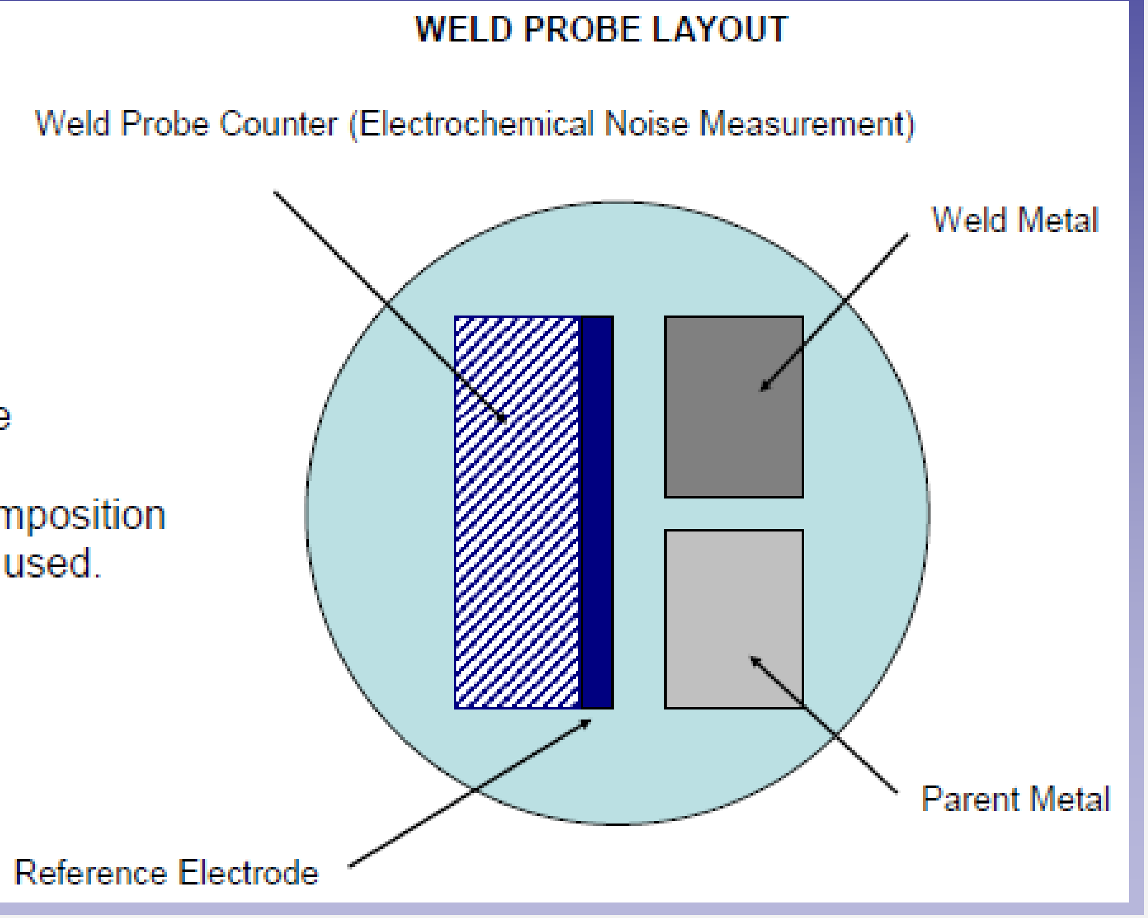


Galvanic Probe

Galvanic Probe - operates by measuring the galvanic current in the circuit between a steel and a brass electrode and is particularly sensitive to the amount of oxygen in the water. Although the galvanic current, within certain restrictions, is proportional to the oxygen concentration in a system.
It is not intended to replace an oxygen sensor (Orbisphere).

Less Commonly Used – Mainly in WI Systems

Weld Probe



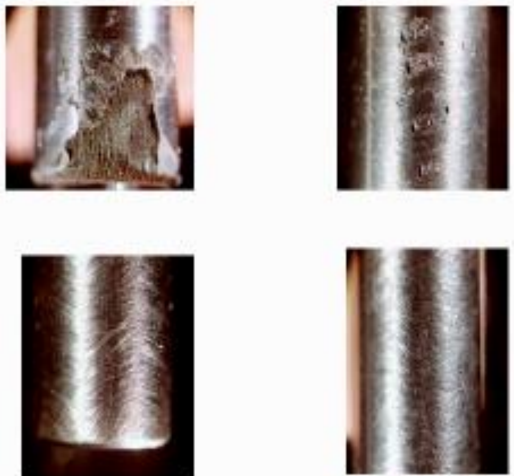
Weld probes - are fabricated to simulate Weld Composition but are not widely used.

Linear Polarization Resistance (**LPR**) **Probes**

Crevice Attack | **Pitting**

No Inhibitor 28 days

Inhibited 28 days

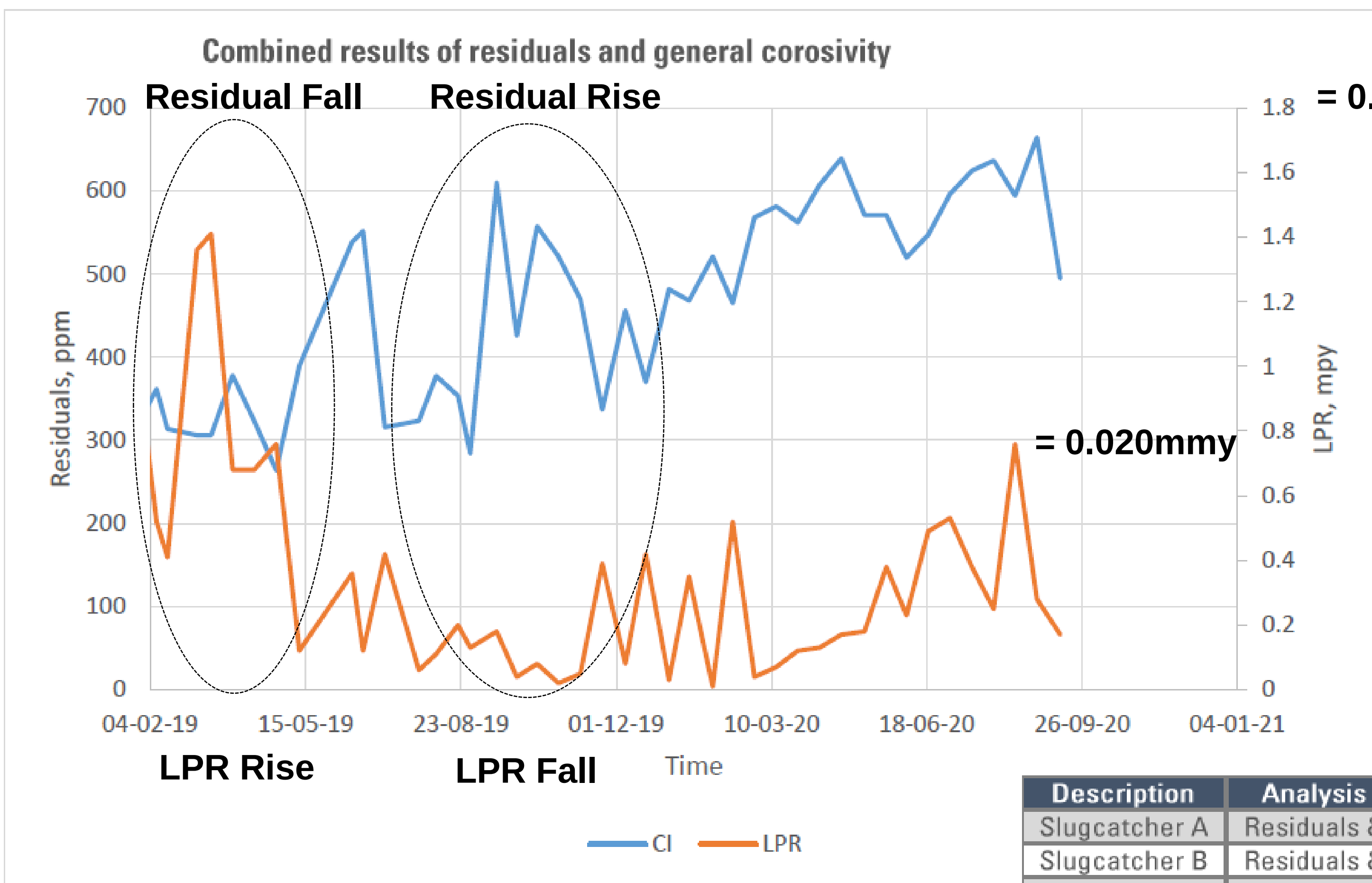


Clean LPR Electrodes in solution of 50ppm Oxygen Passivated Corrosion Inhibitor

LPR probes - are used in conductive environments such as water or **any electrolyte**. The operating principle is based on measuring the flow of current between multiple electrodes.

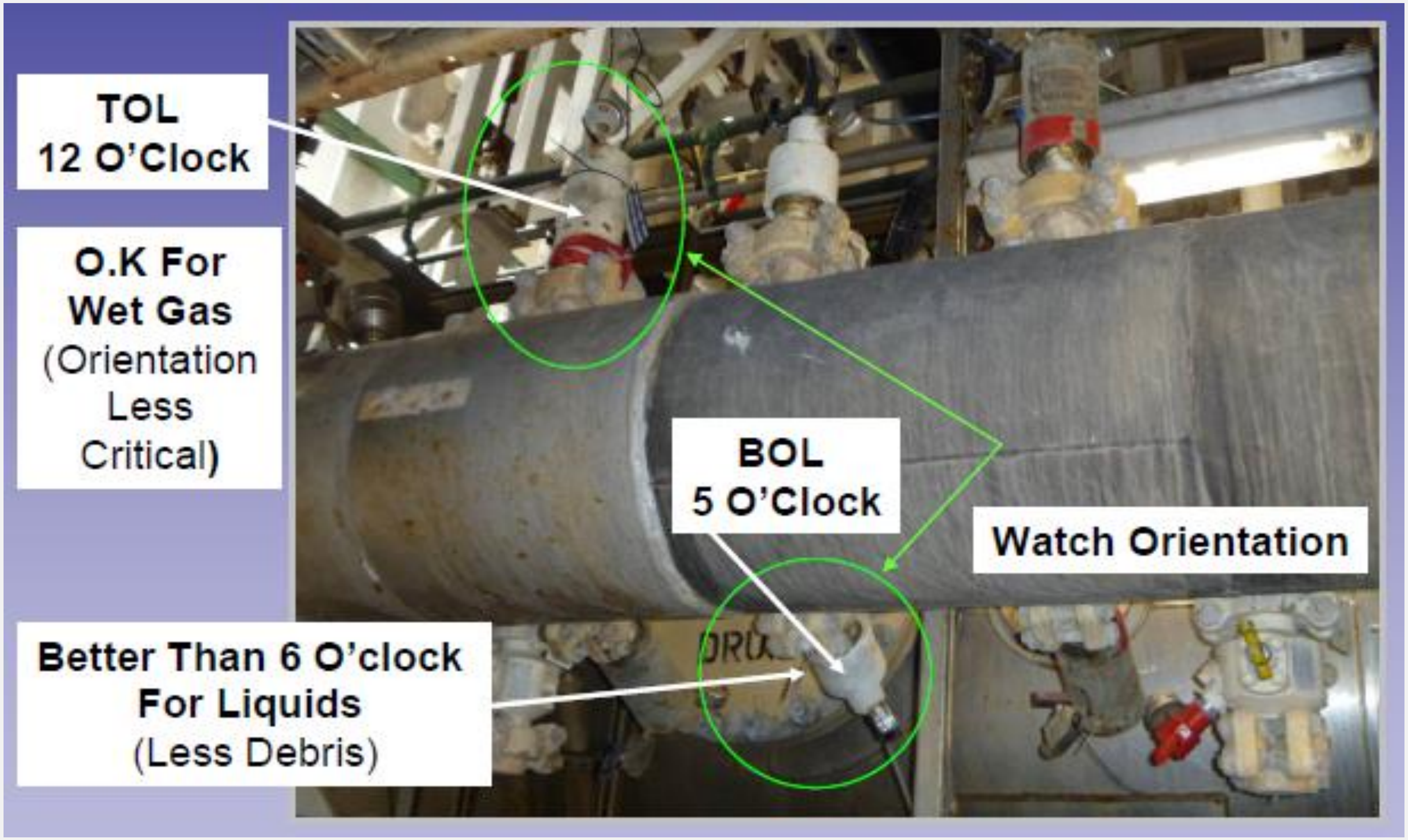
Less Commonly Used – More for Laboratory Use

Linear Polarization Resistance (**LPR**) **Probes**



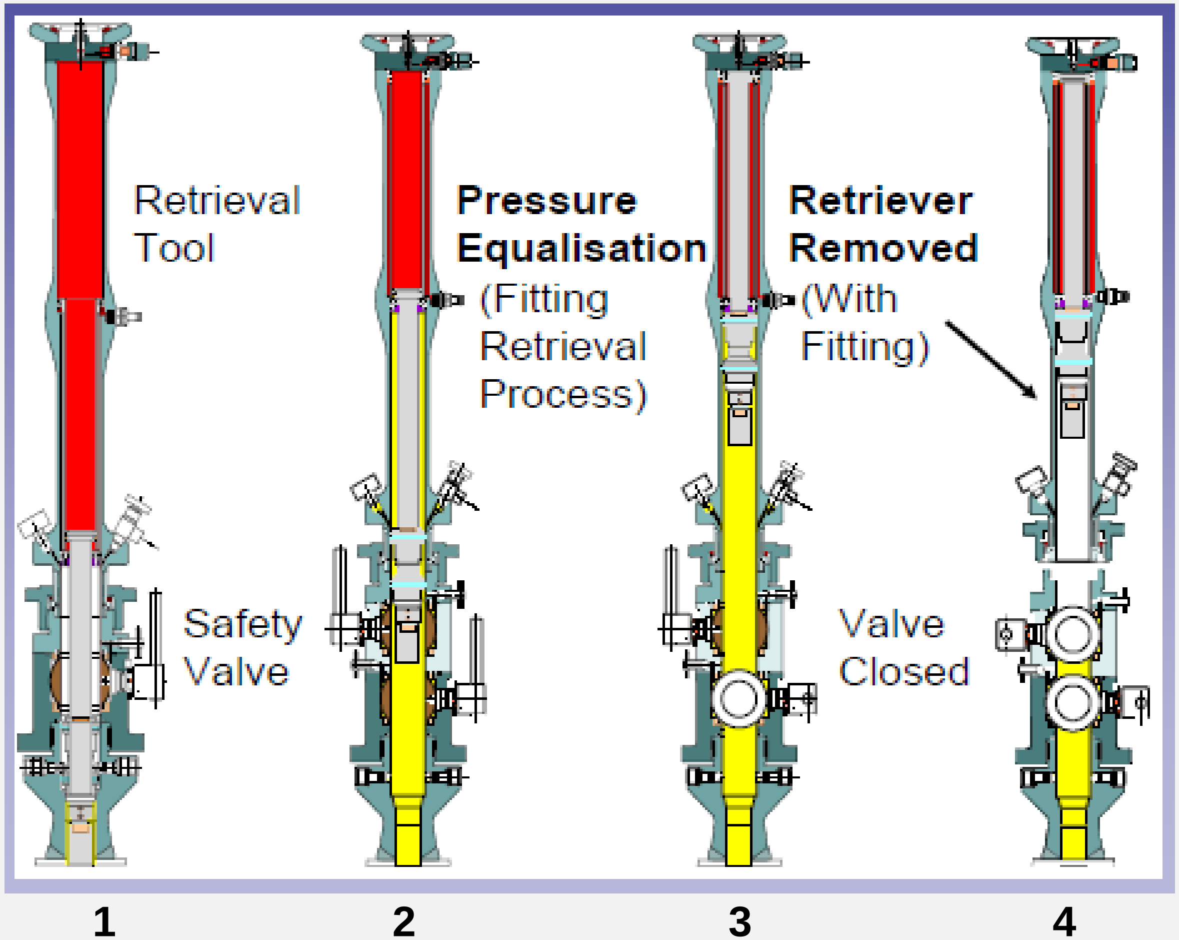
Description	Analysis performed
Slugcatcher A	Residuals & Corrosivity
Slugcatcher B	Residuals & Corrosivity
Lean MEG Inj	Residuals & Corrosivity

Positioning

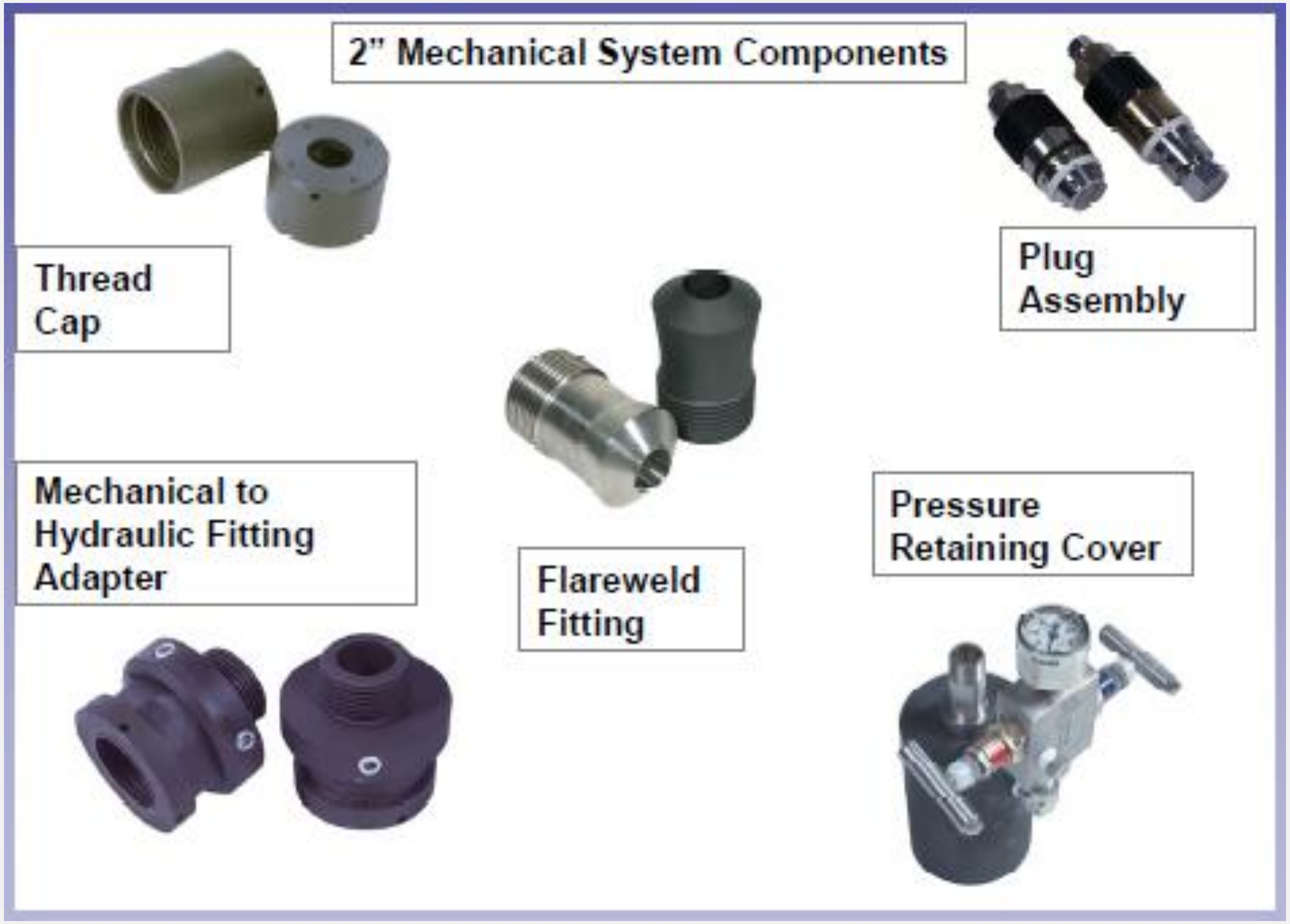


Positioning

Fitting Removal

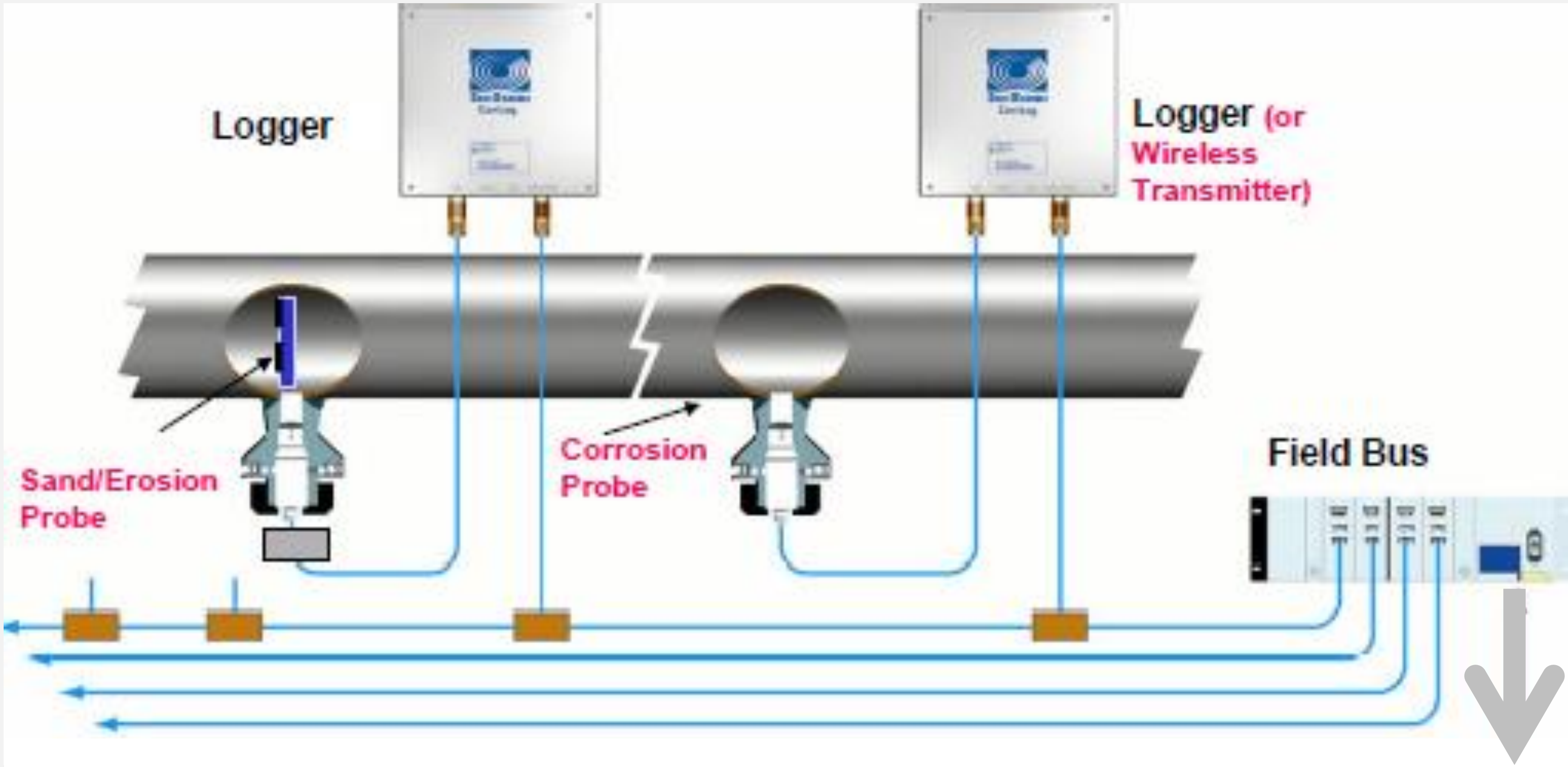


Wide Range of Access Fittings Available



Probe Fitting with Pressure Gauge (for checking Primary Seal) and Heavy Duty Cap (for Secondary Pressure Containment)

Probe Data Transfer



Data Transfer – Manual / Hard Wired or Wireless

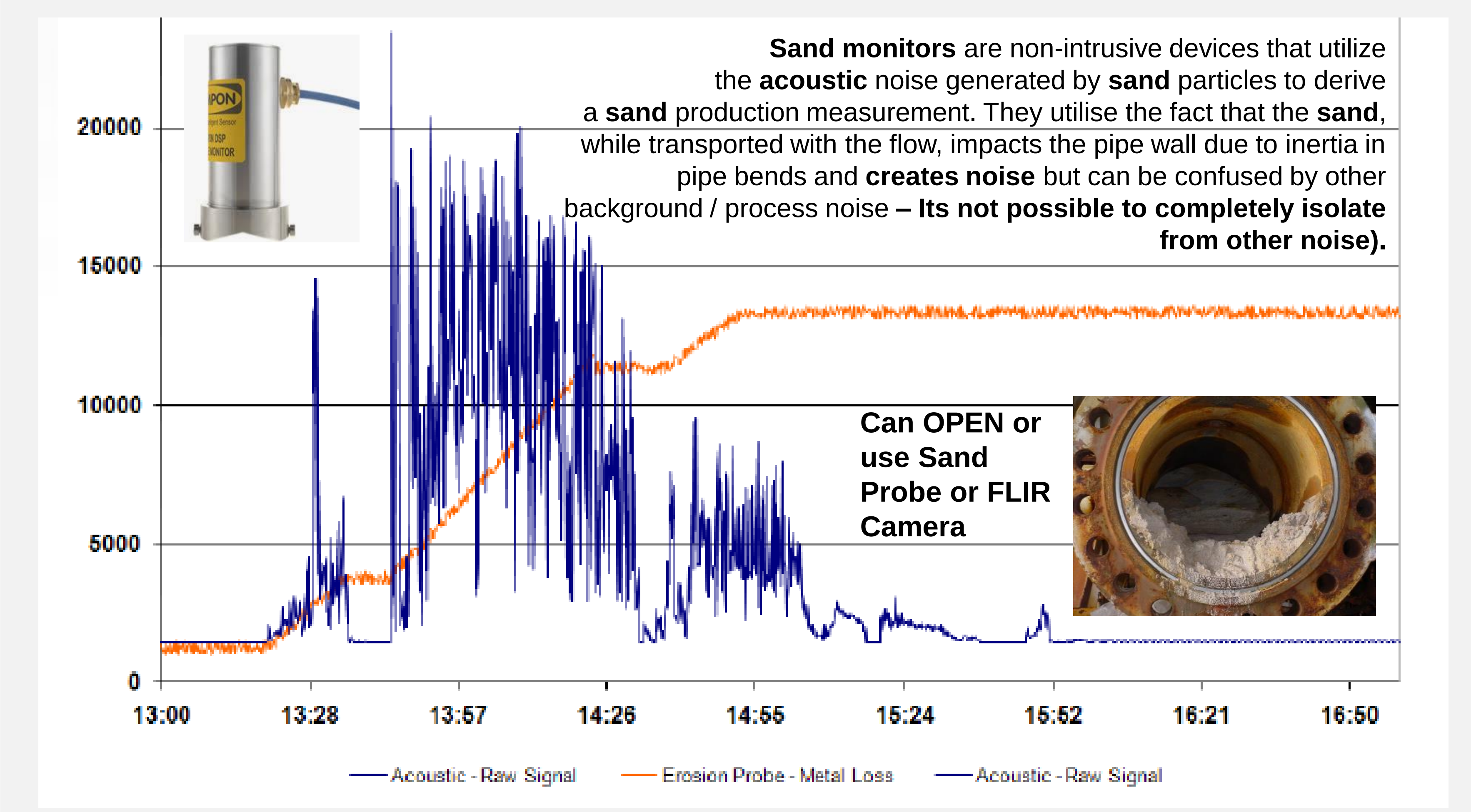
Data F.

Modern System

Gas Import – BOL Transmitter (White) / ER Probe and HD Cap (Blue)

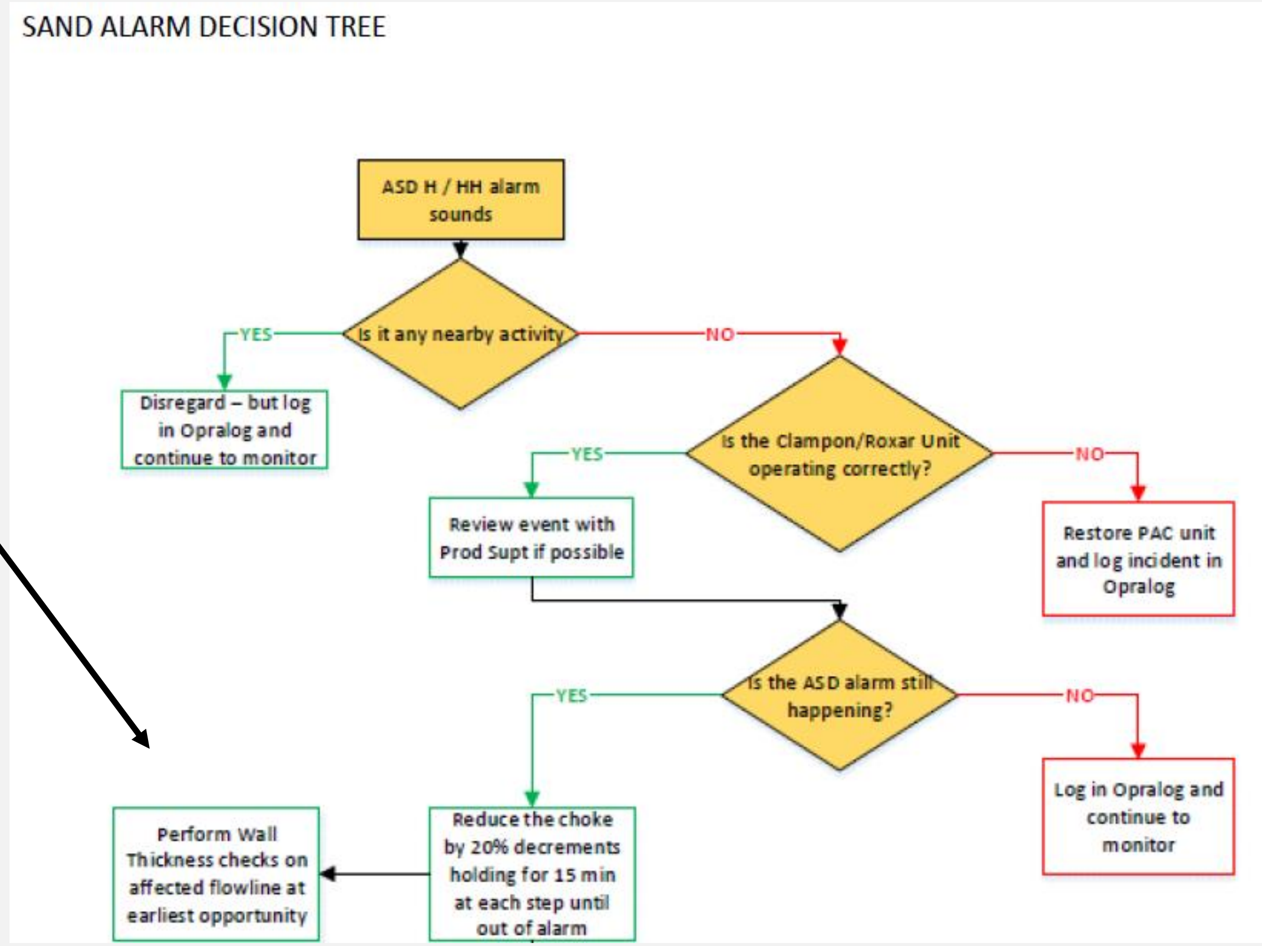
Acoustic Methods and Advanced WT Monitors

Acoustic – Other Means req. to Confirm



Acoustic / Manual Verification

SMS (Sand Management Strategy) requires that we perform Manual UT Checks if ASD Alarms (or out of service).



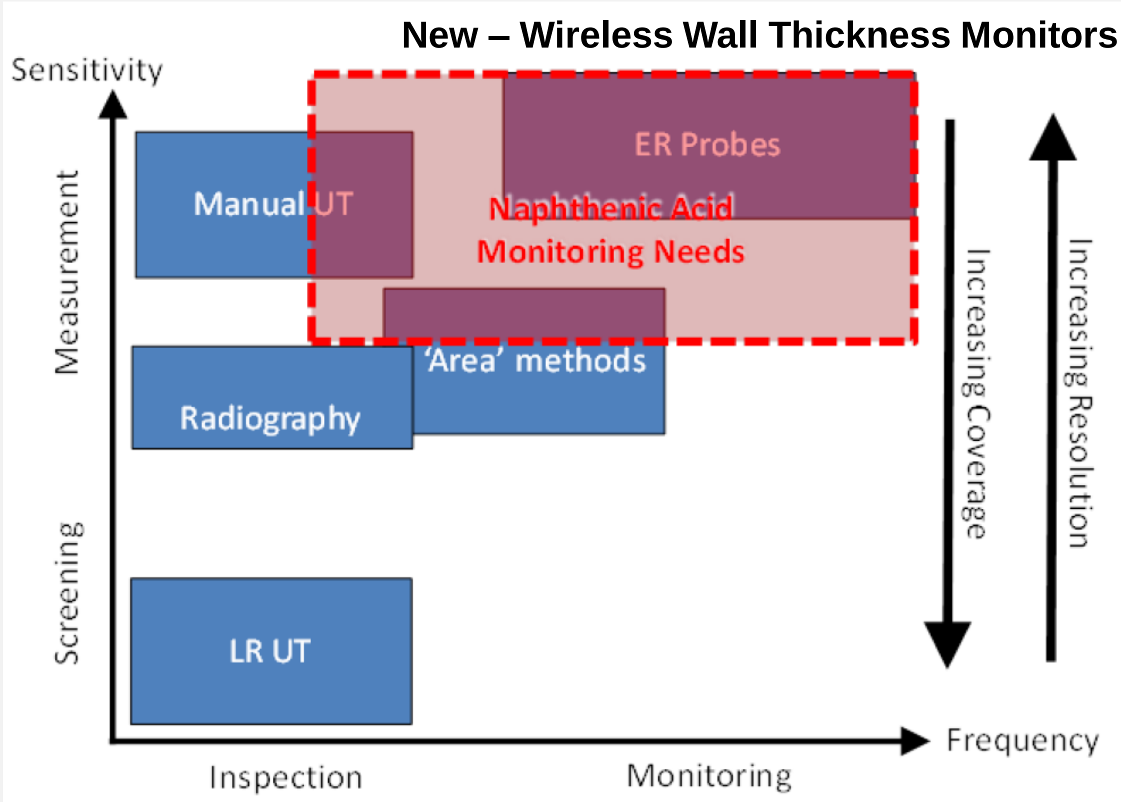
Wireless Acoustic Replacements

Corrosion Monitoring Update – CGA

- Permasense Trials – Probes (West Franklin)

Extremely useful on Flowlines of NUI's – Normally Unmanned Installations (where the Cost of sending UT Inspector is very High)

Novel NDT Wall Thickness Monitors



The diagram above shows this categorization of the various technologies, including intrusive (ER) corrosion probes and manual ultrasound (UT) described in the previous section, according to whether it is a screening or a measurement technique, and whether it can be used for inspection purposes or for monitoring purposes.

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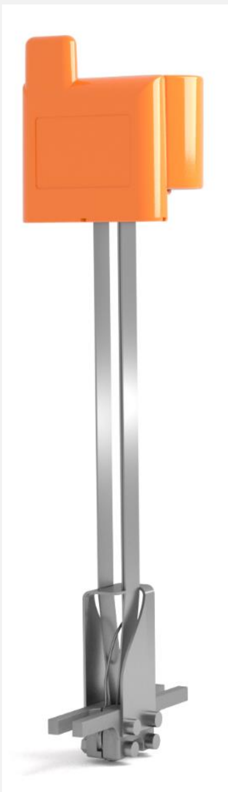
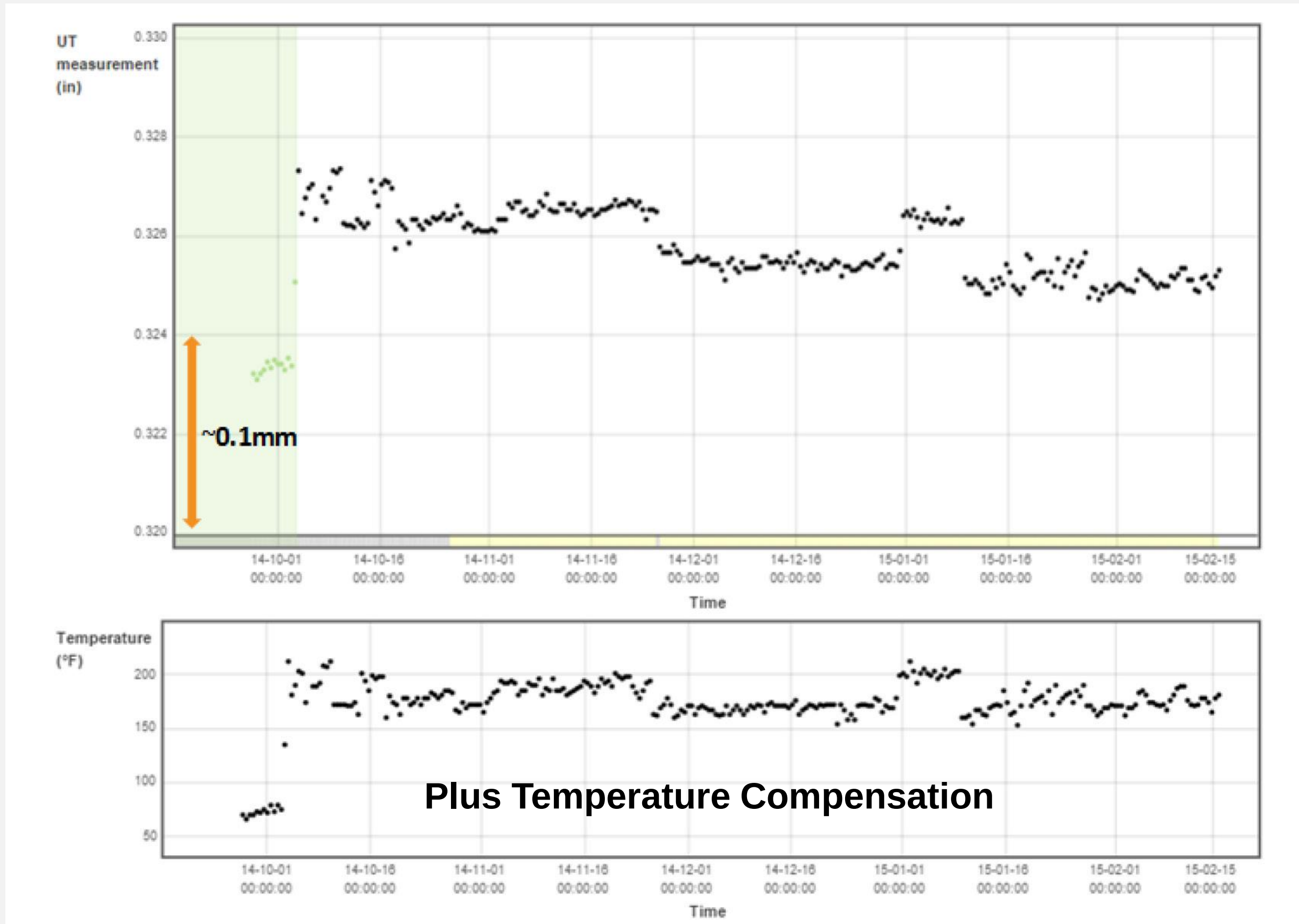
Increased Accuracy v. Manual UT



Up to 600 Deg. C



Inspection Methods – Pipelines

Pipeline Incidents are very rare and reported in:

European Oil and Product Pipelines
- CONCAWE (Conservation of clean air and water in Europe).
- Crude oil and petroleum products.
- European Gas Pipelines

EGIDG (European Gas Incident Data Group).
- Every 3 years
- British Oil and Gas Pipelines

UKOPA (UK Onshore Pipeline Operators' Association).
- Published annually.

USA – Office of Pipeline Safety(OPS)
- Part of U. S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration.
- Published annually

Normally, integrity faults are captured ahead of failure.

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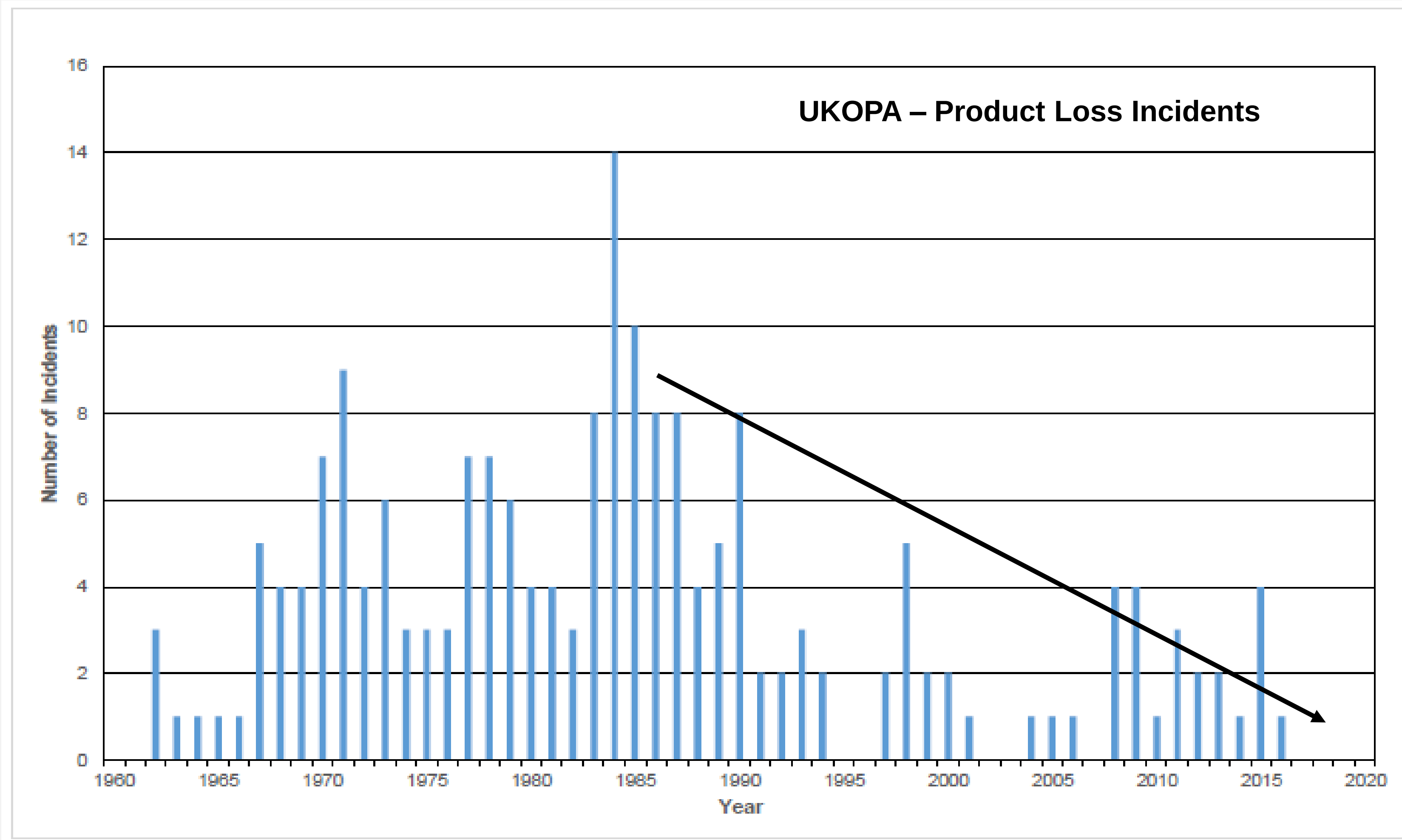
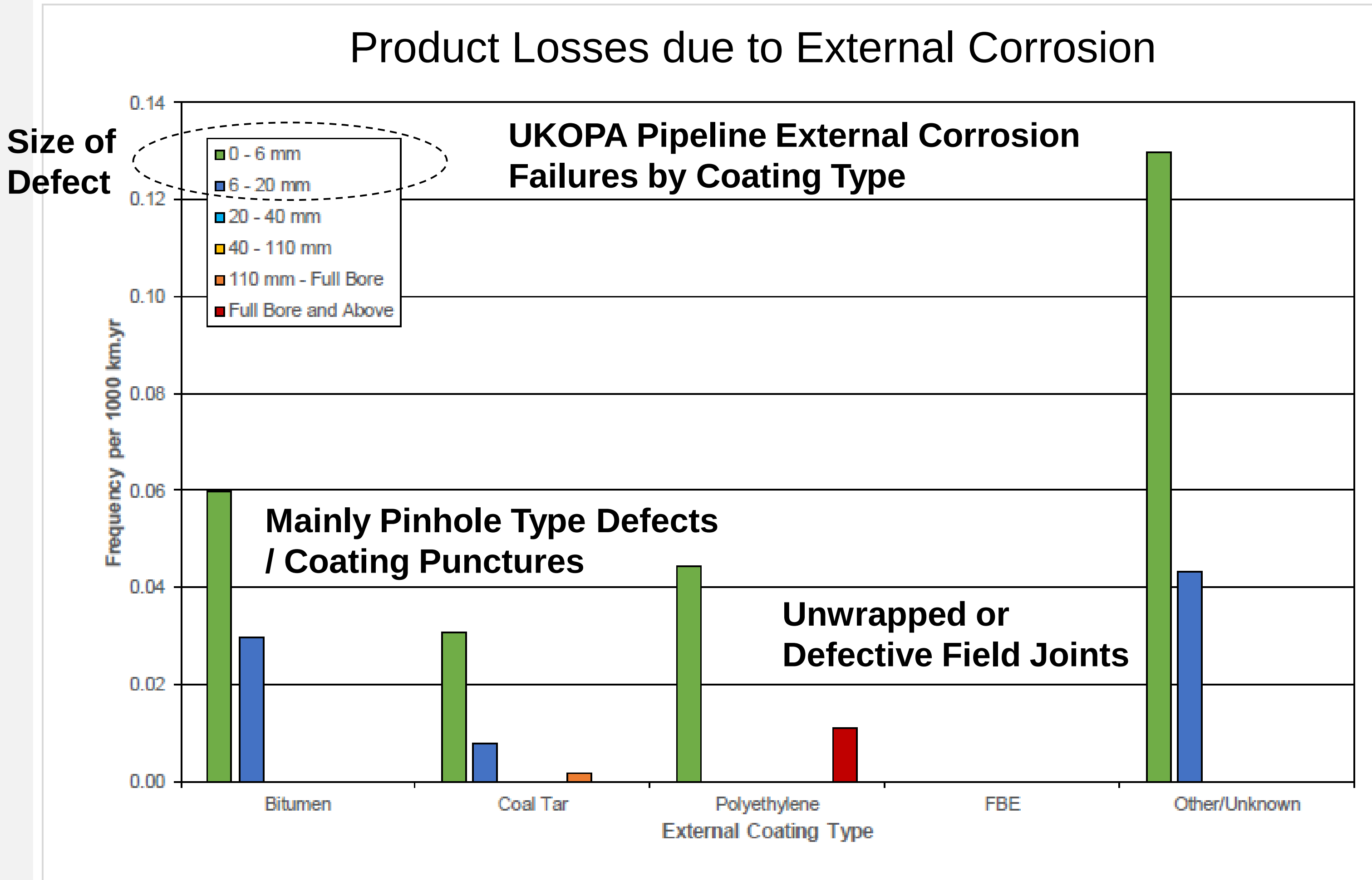
Pipeline Surveys / Fault Finding



Pipeline Surveys / Fault Finding



Pipeline Surveys / Fault Finding

P
E
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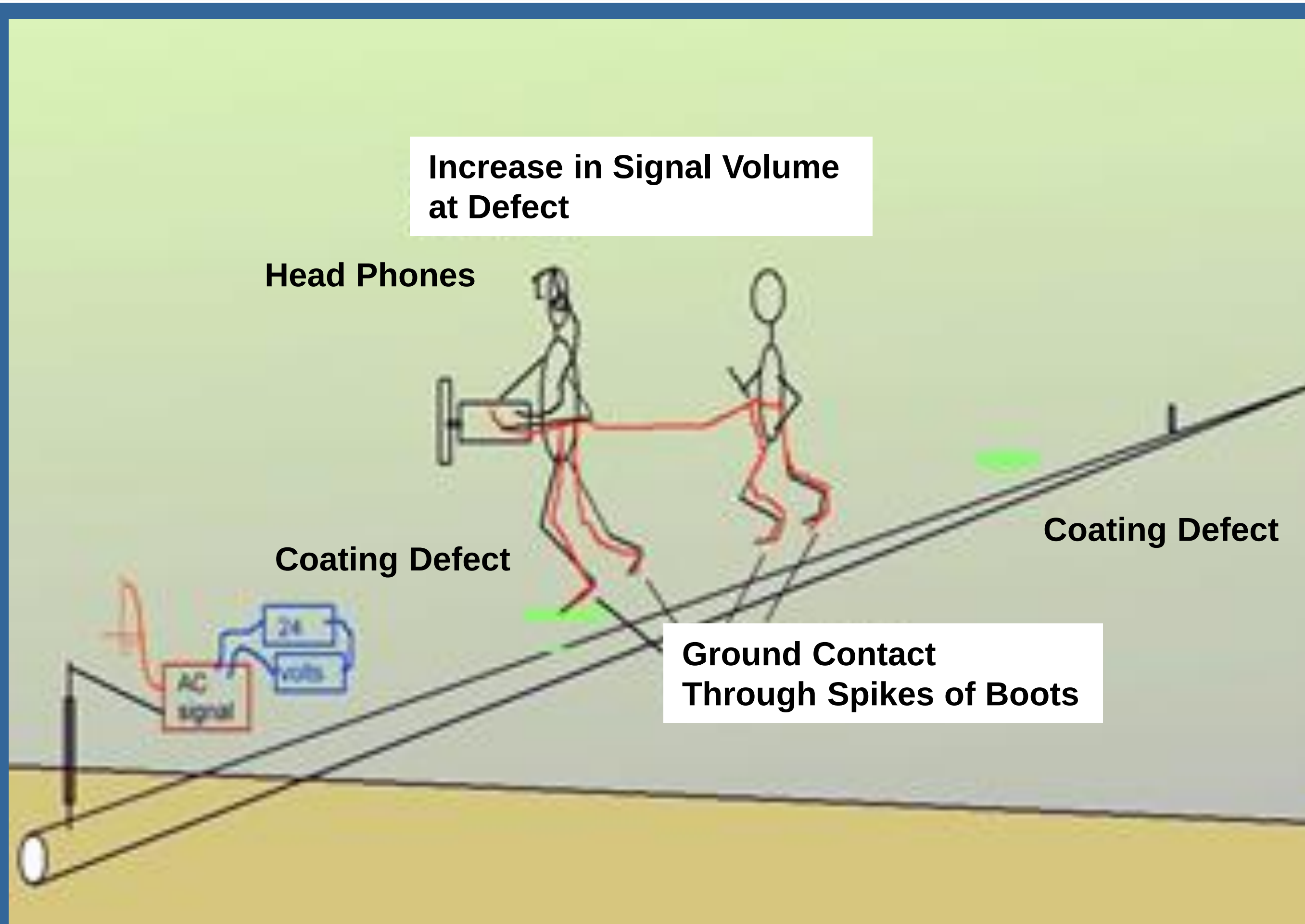
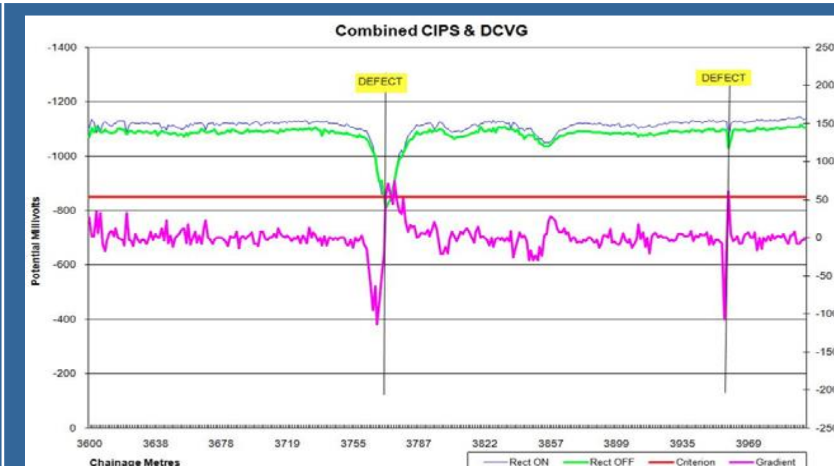


Pipeline Surveys / Fault Finding

C SCAN SURVEY

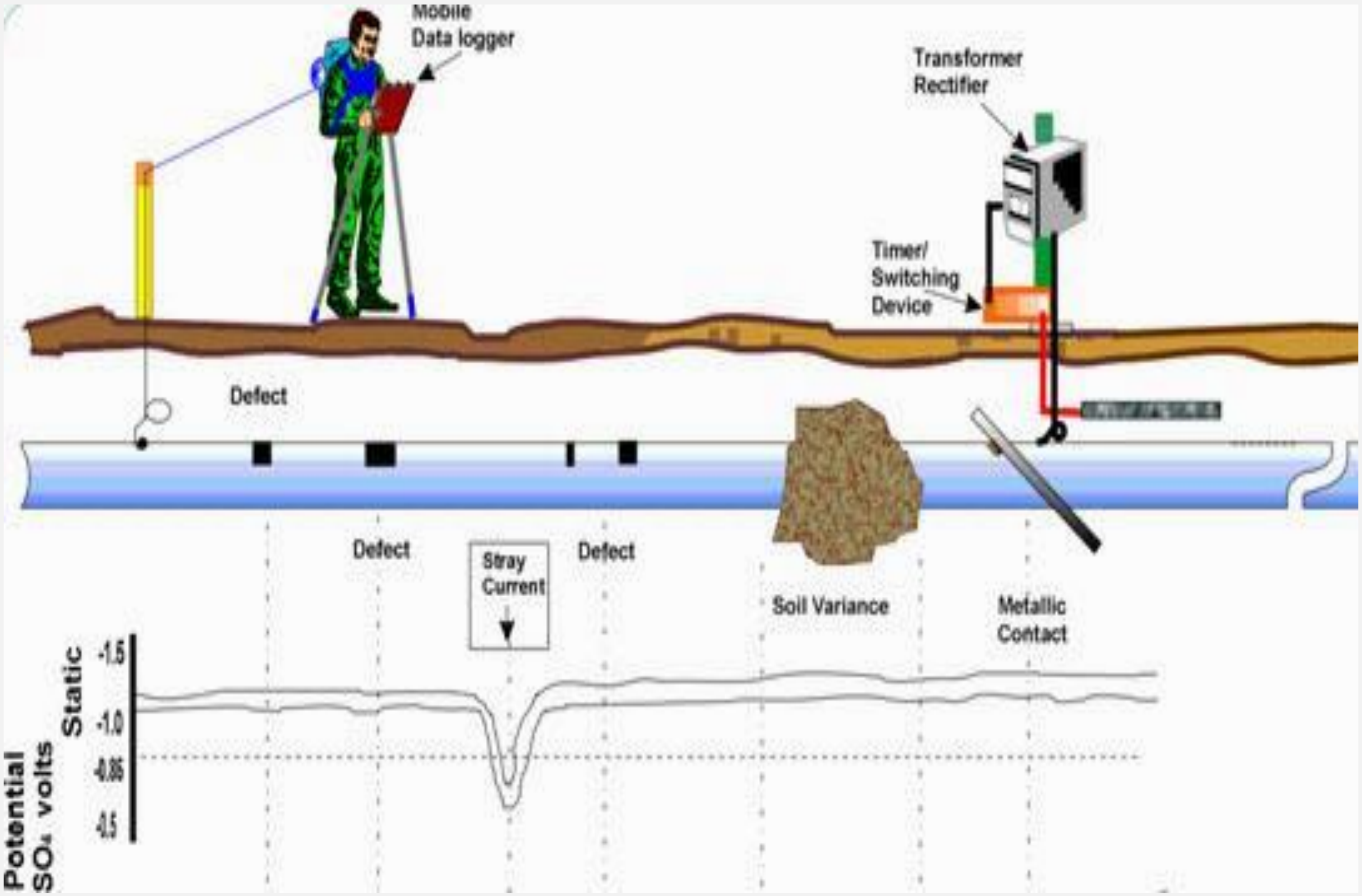
CIPS SURVEY

CIPS + DCVG



Pipeline Surveys / Fault Finding

CIPS SURVEY



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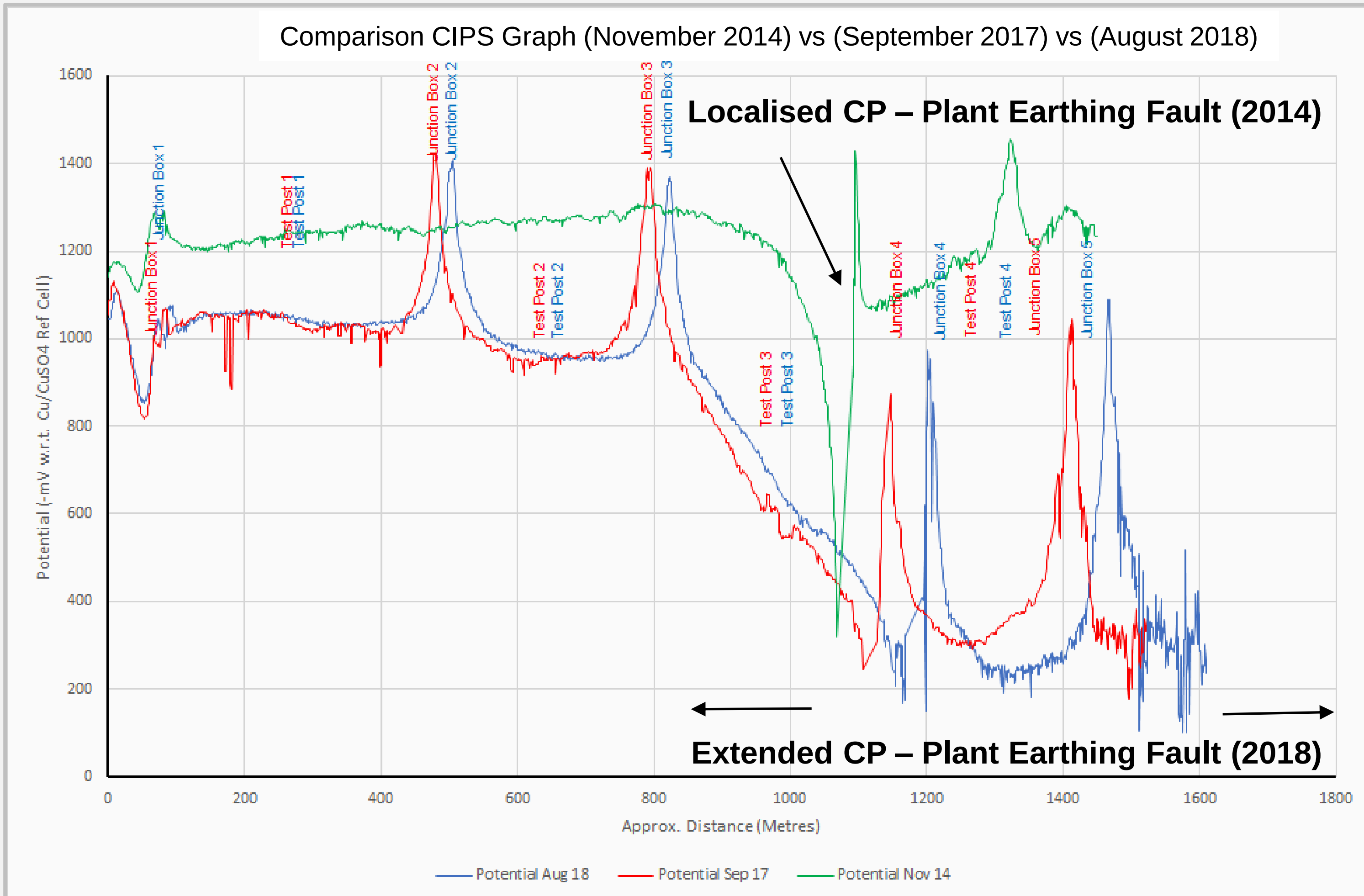
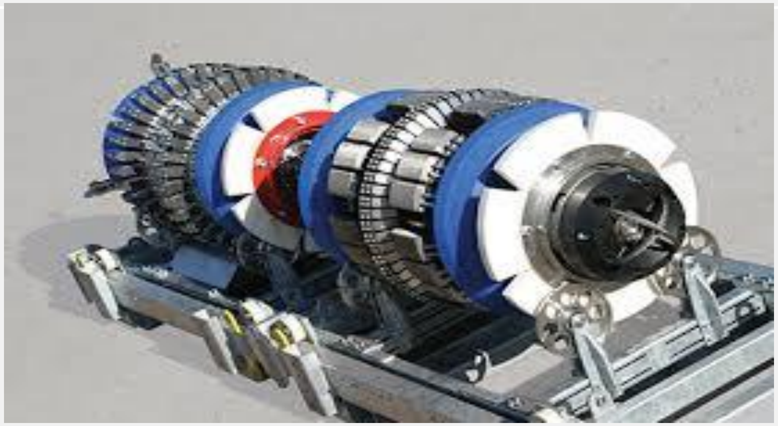
Pipeline Surveys / Fault Finding

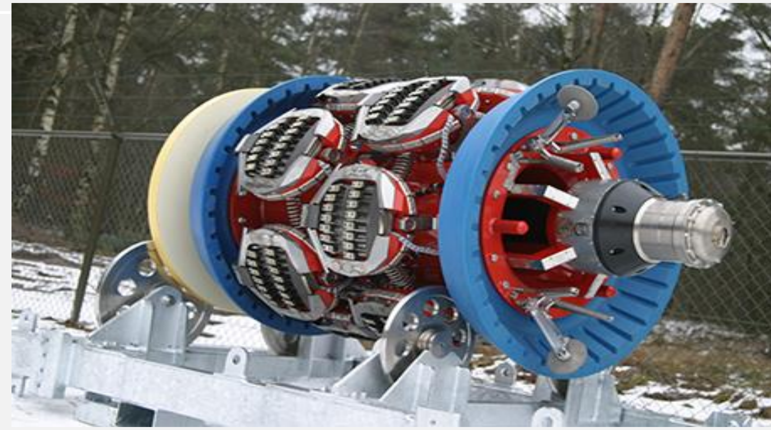
CIPS SURVEY



Pipeline Surveys / Fault Finding



Common MFL Pig



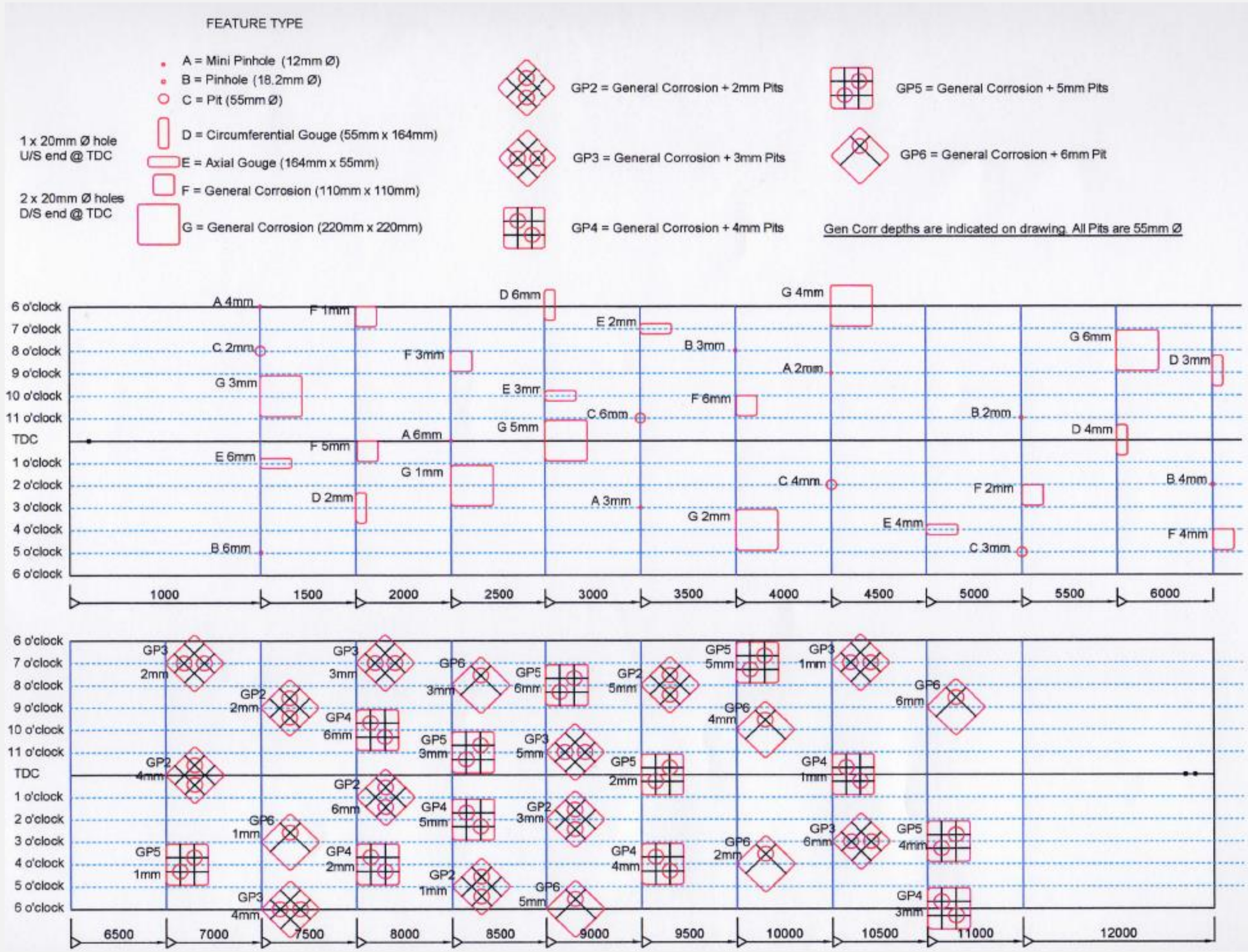
Specialised High Res MFL Pig

Pre ILI Geometry Pig

Pre Cleaning Pig

Pipeline Surveys / Fault Finding

ILI Runs are extremely expensive, typically >£0.5M + any associated loss of Production



A pull through run on a Test Piece with machined Defects is often used to assess an ILI Tool before use.

Pipeline Surveys / Fault Finding

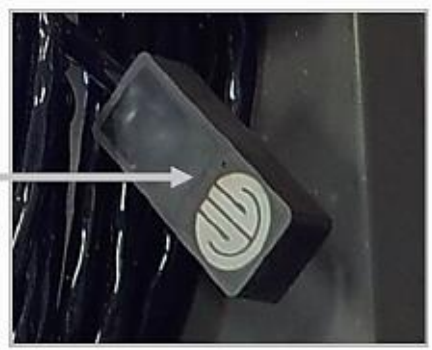
Assessing External Corrosion Risks

AFTER ~ 6M BURIAL

Heavily Corroded / Dissolved ER Probe Element

Heavily Corroded / Dissolved ER Probe Element

Brand New ER Probe Element



Pipeline Surveys / Fault Finding

Effects of Plant – Copper (Cu) Earthing Connections

Location Tag	Corrosion Rate	Extended Period Corrosion Rate	Metal Loss	Probe Span	% Life Left
JB5 Carbon Steel	203.9 µmpy	406.8 µmpy	382.26 µm	508 µm	24%
JB5 Duplex	Negligible	0.4123 µmpy	16.13 µm	508 µm	96%
JB4 Carbon Steel	1420 µmpy	448.2 µmpy	508 µm	508 µm	0%
JB4 Carbon Steel Period 1	-	583.2 µmpy			
JB4 Carbon Steel Period 2	-	754.5 µmpy			
JB3 Carbon Steel	2.818 µmpy	1.49 µmpy	14.47 µm	508 µm	97%
JB2 Carbon Steel	0.492 µmpy	0.7631 µmpy	23.8 µm	508 µm	95%
JB1 Carbon Steel	Negligible	2.105 µmpy	16.4 µm	508 µm	96%

Inspection Methods – Floating Units

Inspection of Floating Units

Pre – Service Condition

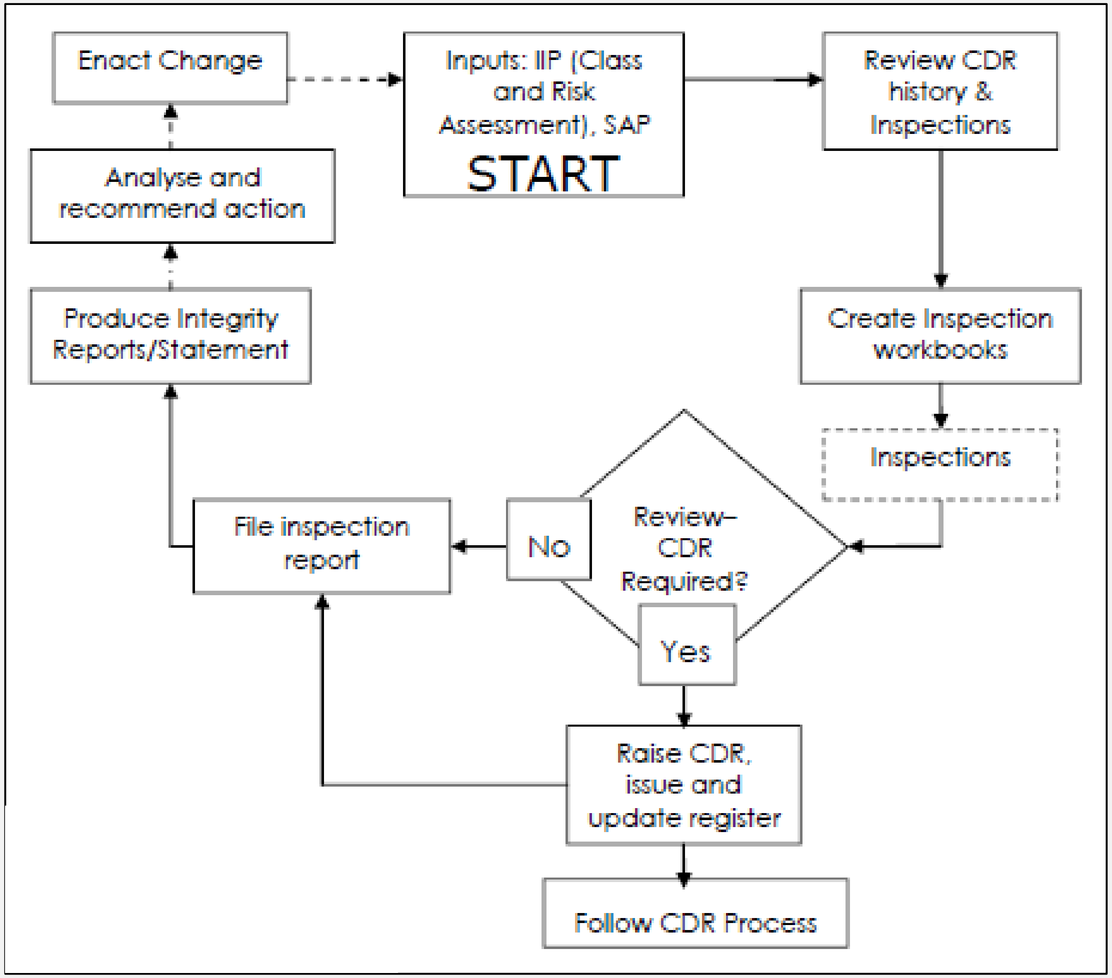
Post – Service Condition

Inspection of Floating Units

CLASS REQUIREMENTS

- Traditionally, all cargo and ballast tanks require full inspection every 5 years (unless risk based).
- DNVGL General Visual Inspections (typically taking around half a shift), followed by Rope Access Team (RAT) inspections to perform Close Visual Inspection work at height and to take thickness readings.
- The RAT inspections will also look at the “Special Areas” (usually fatigue hot spots) and pipework.
- Ideally, DNVGL and our own inspection team are onboard at the same time.

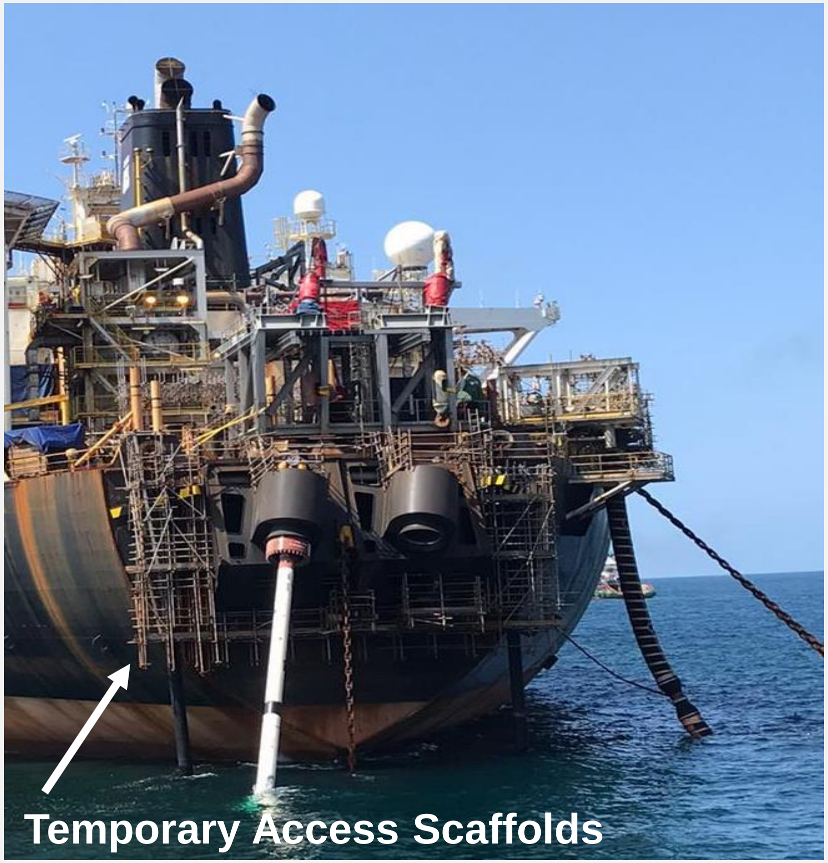
Inspection of Floating Units



- Why we're inspecting:
  - ❑Leaks
  - ❑Cracks
  - ❑Pitting
  - ❑Corrosion
  - ❑Buckling
  - ❑Deformation
  - ❑Coating damage

Inspection of Floating Units

Maintenance Support Vessel



FPSO

Inspection of Floating Units

Often Difficult Access for FPSO / FSO Vessel Inspection

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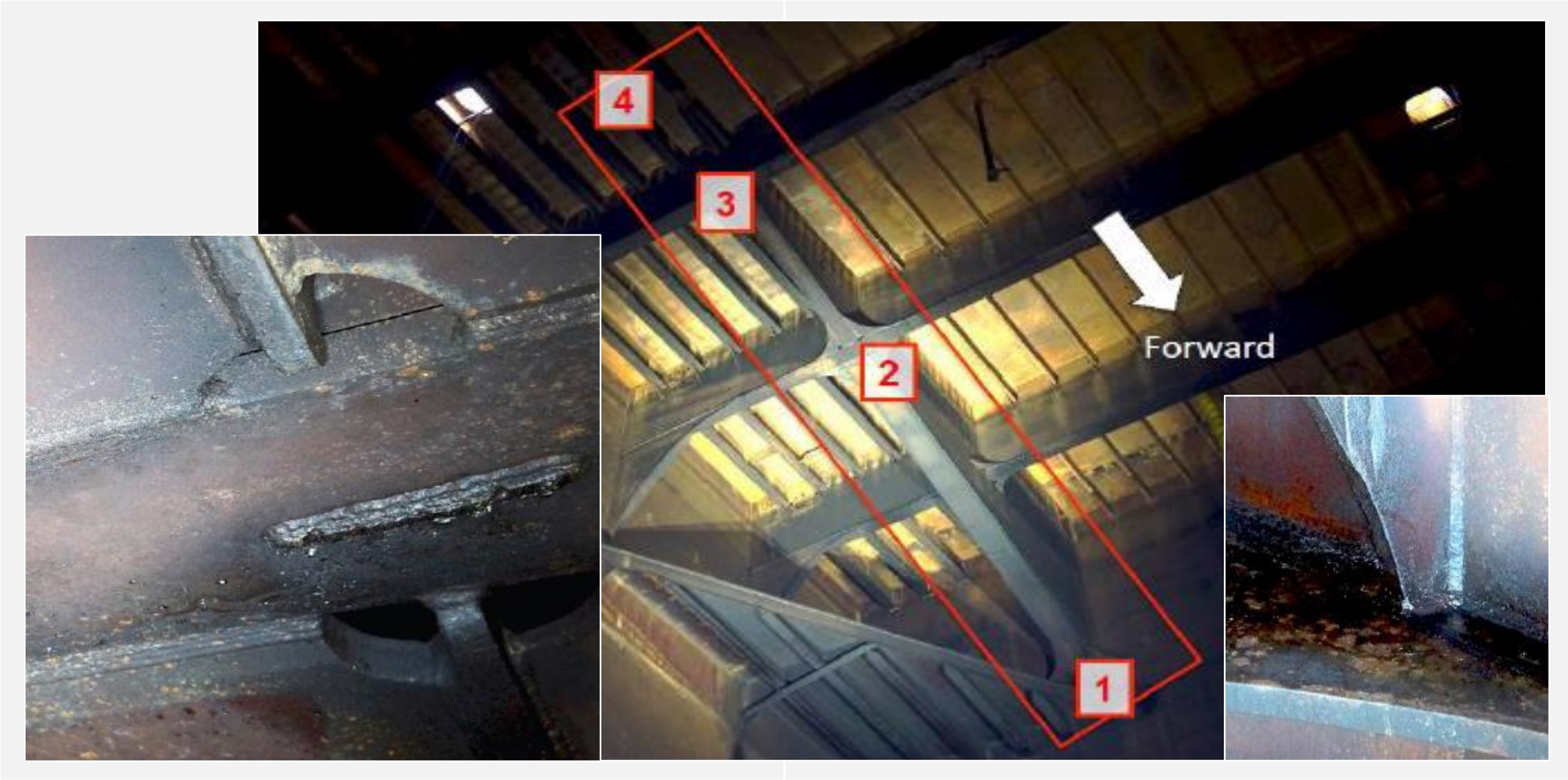
Inspection of Floating Units



Complex / Labour Intensive Structural Inspections

Inspection of Floating Units

Maintenance Support Vessel

FPSO

Inspection of Floating Units

In Situ Structural Repairs can be very costly

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Inspection of Structures

Structural Integrity Definitions

Primary Structures

Primary Structure consists of the structural members that form the main load paths to the piled foundations, the failure or impairment of which may lead to extensive structural deformation, significant reduction of the load bearing capacity of the structure globally and potentially result in progressive collapse.

Secondary Structures

Secondary structure consists of the various forms of steelwork which transfer global and local loading to the primary structure, the failure of which may not results in global structural failure but would results in localised deformation and reduction of load bearing capacity.

Tertiary Structures

Tertiary structures consist of key non-load bearing structures which do not contribute towards transferring global or local loadings, which however are components of SCE's and serve as a vital function for an appropriate working environment.

Safety Structures

Safety structures may not form a specific structure but exist as a part of a structure or group of structures that combine to form whole or a part of a safety system. These may be defined as areas and components supporting safety equipment, life saving appliances and means of escape.

Non-Structural Attachments & Assemblies

Non-Structural Attachments & Assemblies consist of minor attachments and assemblies which do contribute towards transferring global or local loadings and are not necessarily essential components of SCE or Safety systems. They may however provide support for system components or provide a non-vital function for providing an appropriate working environment.

Typical Subsea Inspection frequency of offshore structures

4 years-high exposure
5 years-medium exposure
6 years -low exposure

Offshore Structure Corrosion Assessment Techniques :

- -Acoustic emission testing
- -Alternating current frequency measurement (ACFM)
- -Gamma ray flooded member detection (FMD)
- •CP Measurements
- -Anode counts and anode depletion
- -potential measurements
- -Coating Surveys

Inspection of Coatings

Ri 1 (0.05% breakdown)

Ri 2 (0.5% breakdown)

Ri 3 (1.0% breakdown)

Corrosion	Description
Cat A	Light Scale (1-3mm thick). Estimated metal loss < 0.5mm
Cat B	Moderate Scale (>3-6mm thick). Estimated metal loss 0.5mm to 2mm
Cat C	Severe Scale (> 6mm thick). Pit / metal loss > 2mm = < 5mm
Cat D	Scale detaching (significant visible loss). Deformation or penetration > 5mm

Ri 4 (10% breakdown)

Ri 5 (Cat. A) (40-50% breakdown)

Cat B

Cat C

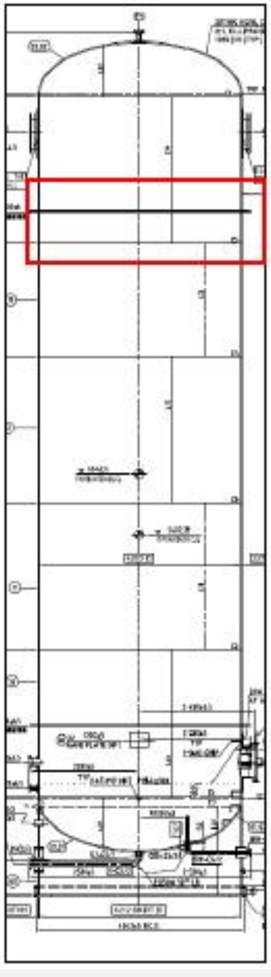
Inspection of Coatings

FABRIC MAINTENANCE

- Keep on top of it to prevent much larger costs in future
- Must be seen to be addressing Asset Life Extension (KP4) balanced by realistic CoP dates.
- Knowing what happens at the end of field life is also a key input

Future Inspection / Post COVID Trends

Use of DRONES for Internal / External Inspections



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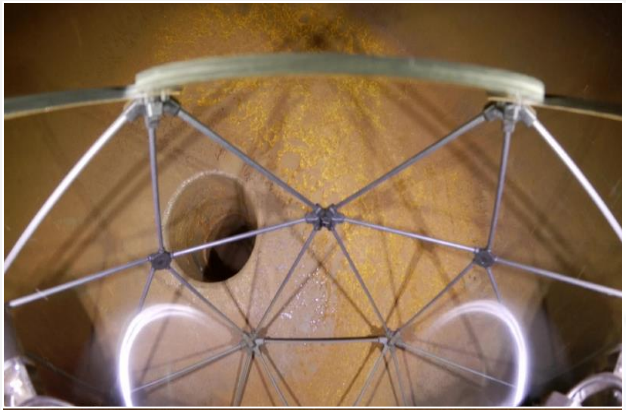
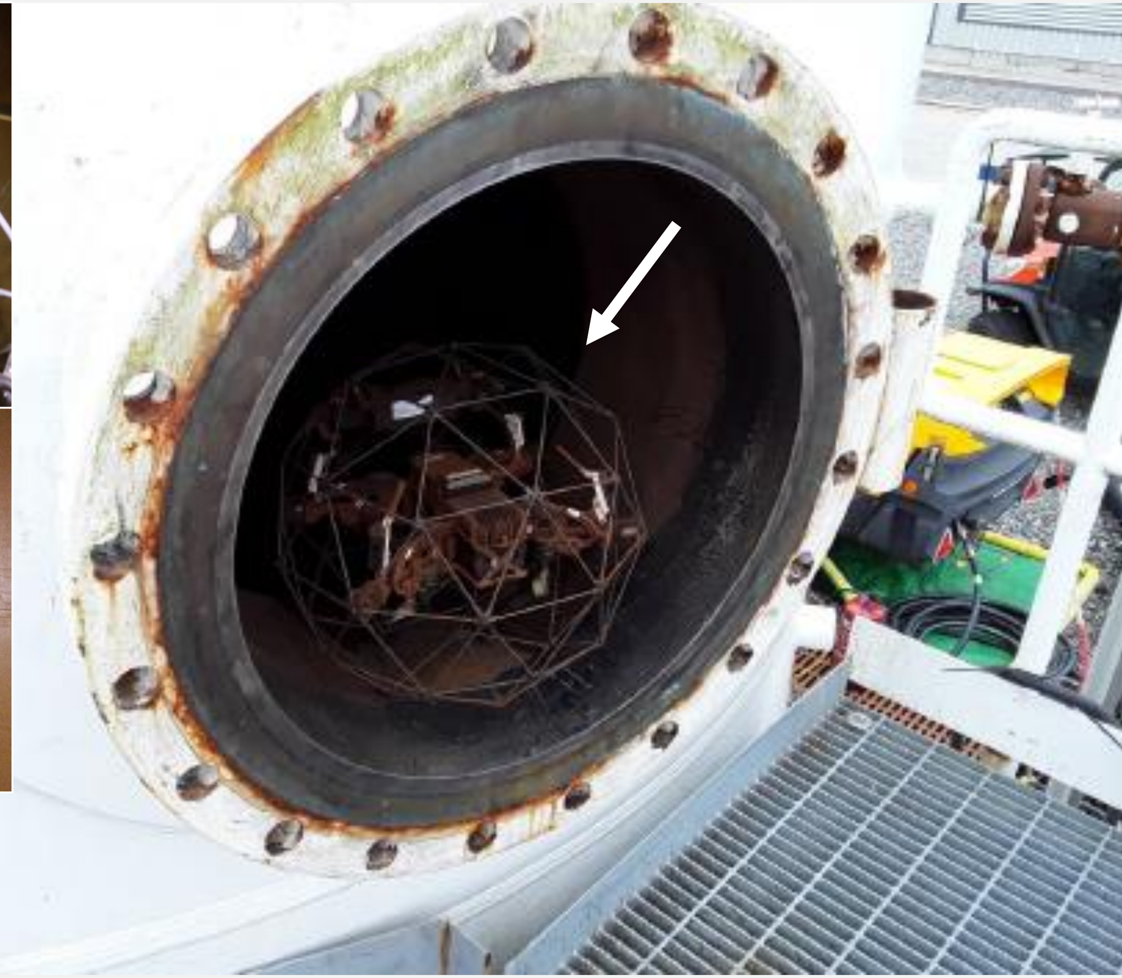
Use of DRONES for Internal / External Inspections

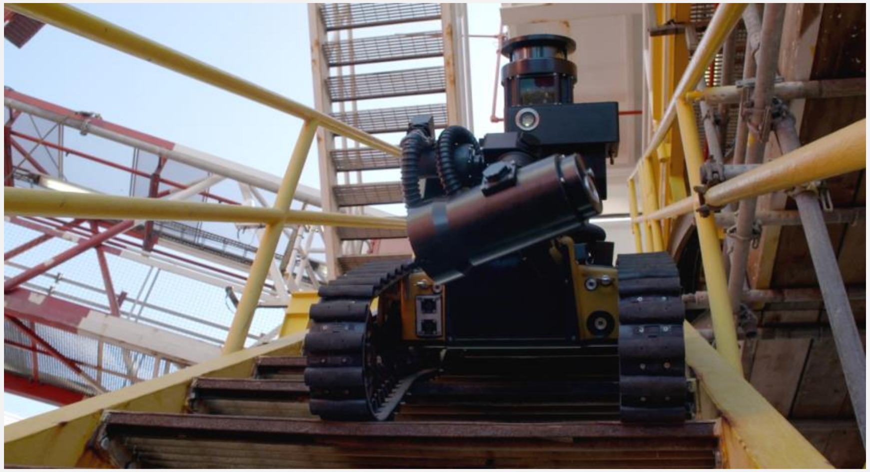


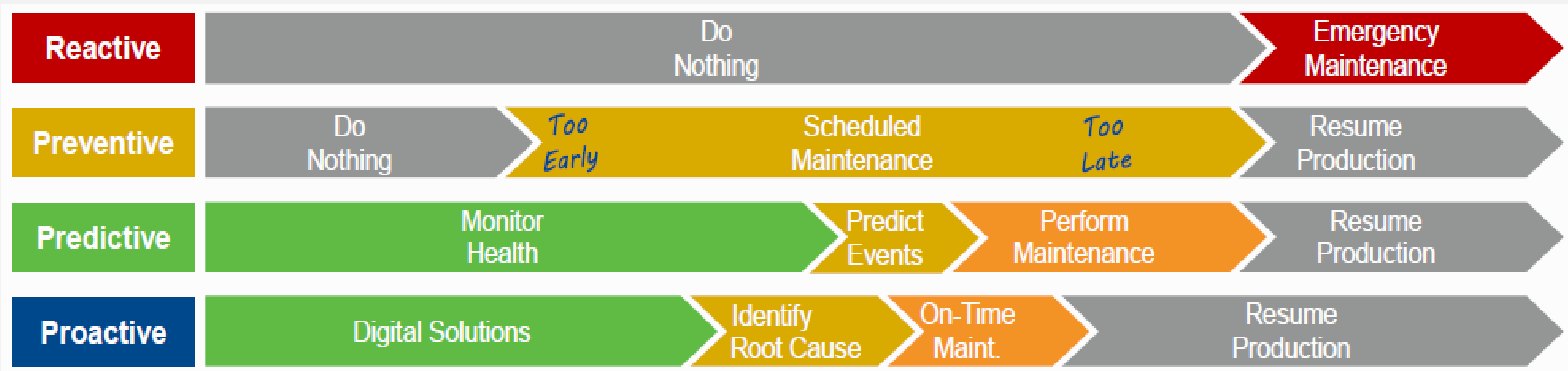


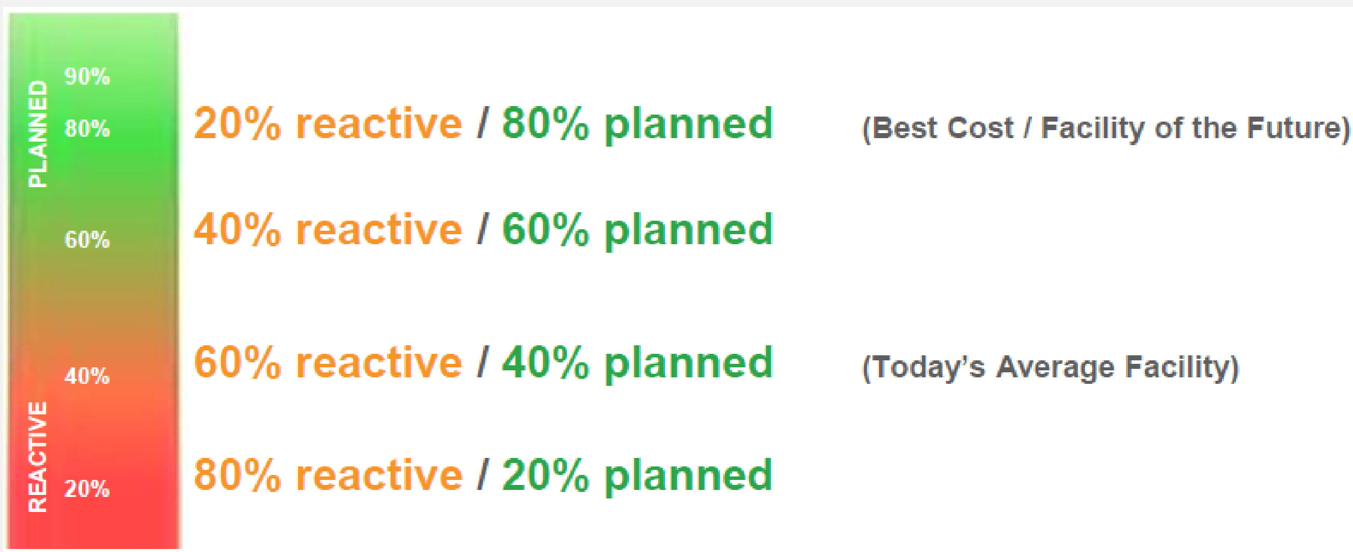
Hi – Resolution Drones

PIPELINE DRONES

Offshore Inspection Robots




Reactive
Do Nothing
Emergency Maintenance
Preventive
Do Nothing
Too Early
Scheduled Maintenance
Too Late
Resume Production
Predictive
Monitor Health
Predict Events
Perform Maintenance
Resume Production
Proactive
Digital Solutions
Identify Root Cause
On-Time Maint.
Resume Production


PLANNED
REACTIVE
90%
80%
60%
40%
20%
20% reactive / 80% planned
(Best Cost / Facility of the Future)
40% reactive / 60% planned
60% reactive / 40% planned
(Today's Average Facility)
80% reactive / 20% planned

AI / CONDITION MONITORING Sensors for System Health

Vibration

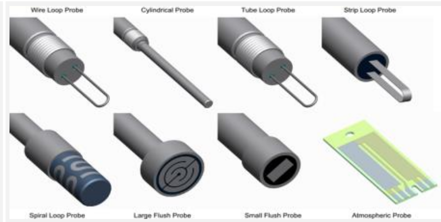
Temperature

Pressure

Flow

Test Coupons

Bio Probe



ER Probes

Sand Probes

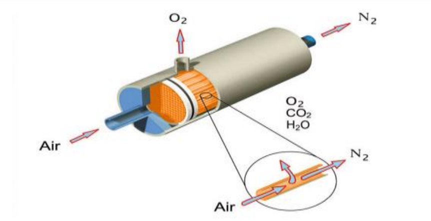
Acoustic Sensor

Wall Thickness Monitors

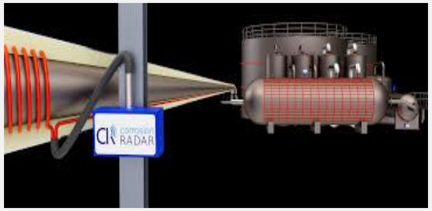
CI Tank Level Indicator

Choke Valve Actuators

Online Orbisphere



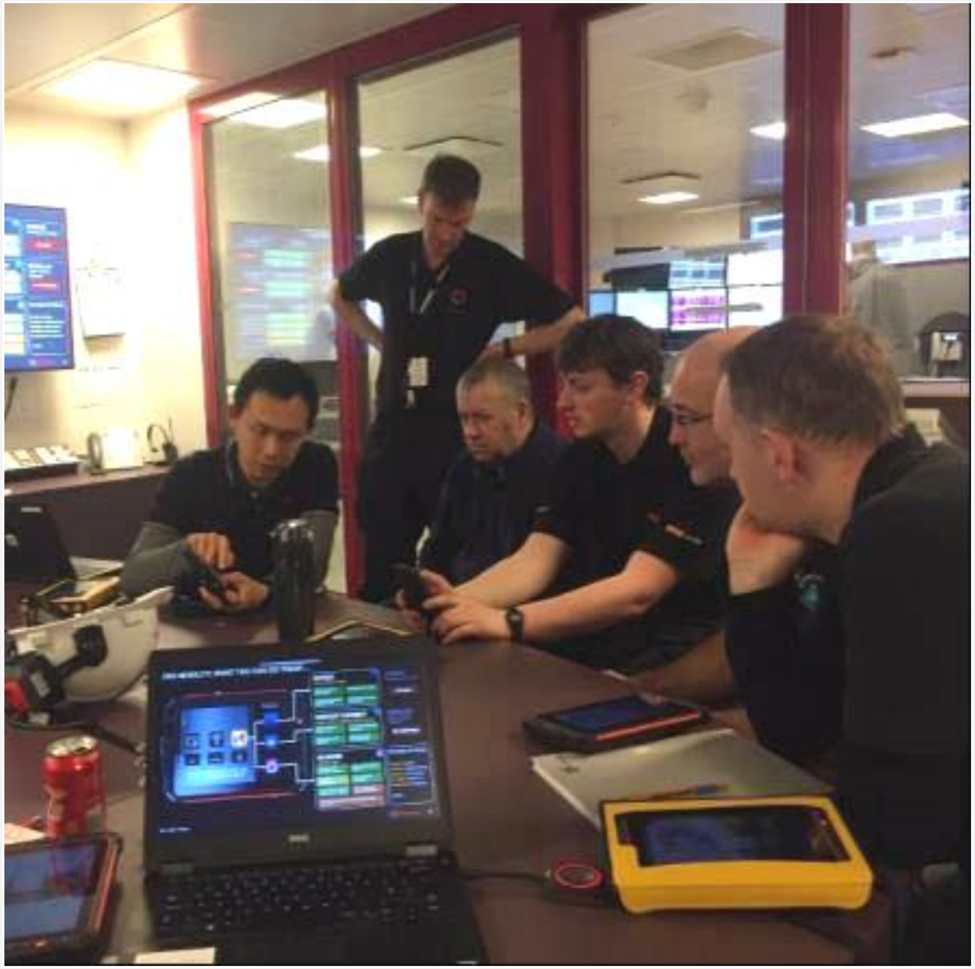
N2 Blanket Gas Analyser



CUI / Moisture Sensor

Dew Point Analyser

REMOTE Working / Avoid Visits / AR



Shell – "Technologies like Augmented Reality (AR) and Virtual Reality (VR) can unlock business value for our operations across the entire lifecycle of a project, from initial planning through construction to operations".

Improved information Flow - SME's (Subject Matter Experts) to Field Technicians and for Training them.

Q&A Session

Q. How can Drones be used more in Hazardous Areas ?

A. Things do seem to be moving in that direction recently
but removal of all explosive contaminants prior to work,
would be an essential pre-requisite.

Refer: https://www.flyability.com/articles-and-media/can-a-drone-be-used-as-a-formal-inspection-tool

Q. Boat Landings, how can these be better protected ?

A. Elastomeric Coatings are one option.

Refer: https://www.teknos.com/industrial-coatings/showroom/protecting-worlds-largest-offshore-wind-farms-turbine-foundations-with-elastomeric-polyurea-coating/

Refer: http://www.armawrap.com/corrosion.htm

Refer: https://www.onepetro.org/conference-paper/SPE-193241-MS

Q. Has artificial intelligence any part in the monitoring process?

A. Yes, this certainly appears to be a developing area.

Refer:
https://www.researchgate.net/publication/268522546_Artificial_Intelligence_for_the_Assessment_on_the_Corrosion_Conditions_Diagnosis_of_Transmission_Line_Tower_Foundations

Q. CP and coating surveys (subsea and splash zone areas) – how would AI fit in here?

A. Again, this does seem to be a rapidly developing area:

Refer: https://www.offshore-mag.com/business-briefs/equipment-engineering/article/14174786/artificial-intelligence-emerging-as-useful-tool-for-assessing-marine-coating-conditions

Q. We have sacrificial anodes which will be inspected visually and 'estimate' the wastage. Do you think there will be another way we can check this out more thoroughly?

A. The FORCE Figs System would a good method I suggest.

EXPOSED STRUCTURES AND PIPELINES	Stabber/ Proximity/ Drop Cell	Cell to Cell	Dual Cell (Field Gradient)	FiGS (Field Gradient) FiGS
Potential profile	Possible	Possible	Not Possible	Possible
Anode current	Not Possible	Not Possible	Possible	Possible
Anode wastage	Not Possible	Not Possible	Possible	Possible
Coating damages	Not Possible	Limitations	Limitations	Possible
Steel current density	Not Possible	Not Possible	Limitations	Possible
Current drain to e.g. piles, wells & substructures	Not Possible	Not Possible	Limitations	Possible
Outer sheat damage on flexible pipes	Not Possible	Not Possible	Not Possible	Possible
Correction of pipe routing	Not Possible	Not Possible	Not Possible	Possible

Q. How can we check effectiveness of all these anodes (i.e. throwing power) throughout say a structure and feed it into a Digital Twin?

A. Beasy Software are well established in this area and worth consulting with.

Refer: https://www.beasy.com/digital-twin.html

Q. Do you think there are ‘smart’ probes we can potentially use say to get the potentials at different parts of the structure? This could be for both ICCP and SACP.

A. Suggest FORCE as above.

Q. You also mentioned in one of your slides an issue surrounding defective field joints. There has been a lot of talk for subsea on going away without FJC – did the defect on the FJC correspond to high WT loss?

A. Not on this occasion and I have seen other unwrapped Field joints located from C-Scan Overline Surveys without Ongoing corrosion (not always lucky though). If it is a small dia. pipeline and the unwrapped joint is of low surface area, it could receive corrosion protection from the ICCP system.

Thank you for Attending – You may send any further questions to: **stephen.tate@external.total.com**