Integrity Management Lecture
14th October 2020.
About Presenter
Stephen Tate MiCorr

First Joined the Oil Industry in April 1980 (from Construction Industry)
OND Construction and Surveying, Guildford College. 1974
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
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
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

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

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1</td>
<td>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.</td>
</tr>
<tr>
<td>Category 2</td>
<td>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.</td>
</tr>
<tr>
<td>Category 3</td>
<td>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.</td>
</tr>
<tr>
<td>Category 4</td>
<td>These trunnions were previously sealed during construction prior to phase 1 SCCC Inspection. They can be in any orientation.</td>
</tr>
</tbody>
</table>

**SCC cracks**

**Pitting**
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

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Examples of Failures – Oil and Gas Process Leaks

Humberside 2001 – Int. Erosion (New WI Pt)

Gas Explosion – Damage Adjacent Plant

Sour Gas Leak 2011

BV Bolting Failure

- Intermittent Water Injection to dissolve Gas Hydrates
- 4in Line Break - Release
- Failed Block Valve
- 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.
Examples of Failures – Pipelines

Gas Pipeline Failure – New Mexico 2000

Internal BOL Corrosion – Common Cause

Mississippi – Multiple Fatalities 2009

Resulting Hydrotest Failure

The Missing Section of Pipe was ejected from the Crater

Warning to All – Essential to keep people clear of Ongoing Tests.
Examples of Failures – Pipelines

- 29th July 1995
- Failure on a 42 inch grade X60 natural gas pipeline approximately 3 km southeast of Rapid City, Manitoba. (Pup was X65)
- 19.6 m³ 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

- 21st March 2006
- Leak from Trans-Alaska pipeline
- At least 190,000 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 400,000 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.

With thanks to Alan Denney
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\textsuperscript{2} in the water.
- It was observed that despite of corrosion inhibitor (CI) injection; the areas within the pipe with BaSO\textsubscript{4} scale acted as a filter and restricted inhibitor access to the inner wall of the pipe.
- The BaSO\textsubscript{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

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

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Critical Dead Leg Management

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

Failure Site and Sludge Below.
Dead Leg Management

10-12 Piping Deadlegs per P&ID can be expected with Internal / External Corrosion Risks
Dead Leg Management + CUI

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

The Broken Bridge of Italy – RC Failure

Killed 43 and left 600 homeless

Forth Road Bridge Cable Corrosion

Acoustic Emission * + Visual Inspection – Is being used to monitor Cable corrosion (up to 40% 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.

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

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

Safety Earthing – Typ. Galvanic Corrosion

Newbury Railway – Corroded Signal Base

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Examples of Failures – Offshore Structures

Caisson Failures – Pump and Drains

Walkway and Staircase Failures

Boat Landings

Subsea Structural Failure

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

Coatings Failure

Blade Erosion

Load-out Integrity can be Short-lived

Atmospheric Corrosion

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.
**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 undertake 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](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
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 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

Corrosion assessment
Corrosion mitigation
Corrosion monitoring
Inspection
Review
Modifications – Repairs
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.
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

Risk Assessment
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

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.
Tools for Monitoring Corrosion / Erosion

<table>
<thead>
<tr>
<th>Corrosion Coupons</th>
<th>Corrosion Probes</th>
<th>UT Parent Metal Scan at Probe / Coupon Sites</th>
<th>TOFD</th>
</tr>
</thead>
</table>

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)

Past Covered under Alan Denney lecture on Welding/NDT

- Electro-magnetic
- Radiographic
- Ultrasonic

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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).

**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.

ER probe metal loss results with the introduction of corrosion inhibitor at maximum production.

- E: Inhibitor injected for 1 day only
- F: Inhibitor injection for 5 days
- G: Inhibitor injection stopped
- H: Inhibitor injection resumed

Corrosion rate reduced to approx 0.04 mm/yr

Corrosion rate increasing from 0.2 to 0.8 mm/yr
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

- 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

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

Weld Probe Counter (Electrochemical Noise Measurement)

Reference Electrode

Weld Metal

Parent Metal
Linear Polarization Resistance (LPR) Probes

Less Commonly Used – More for Laboratory Use

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.

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

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Linear Polarization Resistance (LPR) Probes

Combined results of residuals and general corrosivity

Residual Fall  Residual Rise

LPR Rise  LPR Fall

Time

Residuals, ppm

LPR mpy

= 0.046 mmy

= 0.020 mmy

<table>
<thead>
<tr>
<th>Description</th>
<th>Analysis performed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slugcatcher A</td>
<td>Residuals &amp; Corrosivity</td>
</tr>
<tr>
<td>Slugcatcher B</td>
<td>Residuals &amp; Corrosivity</td>
</tr>
<tr>
<td>Lean MEG Inj</td>
<td>Residuals &amp; Corrosivity</td>
</tr>
</tbody>
</table>

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Positioning

- **TOL 12 O’Clock**
- **O.K For Wet Gas (Orientation Less Critical)**
- **BOL 5 O’Clock**
- **Better Than 6 O’clock For Liquids (Less Debris)**

Watch Orientation
Positioning

Watch Future Maintenance / Accessibility!
Fitting Removal

1. Retrieval Tool
2. Pressure Equalisation (Fitting Retrieval Process)
3. Retriever Removed (With Fitting)
4. Valve Closed
Wide Range of Access Fittings Available

- Thread Cap
- Plug Assembly
- Mechanical to Hydraulic Fitting Adapter
- Flareweld Fitting
- Pressure Retaining Cover

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
Modern System

Gas Import – BOL Transmitter (White) / ER Probe and HD Cap (Blue)
Acoustic Methods and Advanced WT Monitors
Sand monitors are non-intrusive devices that utilize the acoustic noise generated by sand particles to derive a sand production measurement. They utilise the fact that the sand, while transported with the flow, impacts the pipe wall due to inertia in pipe bends and creates noise but can be confused by other background / process noise – **It's not possible to completely isolate from other noise**.

Can OPEN or use Sand Probe or FLIR Camera
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.
Increased Accuracy v. Manual UT

Up to 600 Deg. C

Plus Temperature Compensation
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.*
Pipeline Surveys / Fault Finding

UKOPA – Product Loss Incidents

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Product Losses due to External Corrosion

Size of Defect

UKOPA Pipeline External Corrosion Failures by Coating Type

Mainly Pinhole Type Defects / Coating Punctures

Unwrapped or Defective Field Joints

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Pipeline Surveys / Fault Finding

- Coating Defect
- Head Phones
- Increase in Signal Volume at Defect
- Ground Contact Through Spikes of Boots

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Pipeline Surveys / Fault Finding

CIPS Survey

CIPS + DCVG

Combined CIPS & DCVG

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Pipeline Surveys / Fault Finding

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Pipeline Surveys / Fault Finding

Comparison CIPS Graph (November 2014) vs (September 2017) vs (August 2018)

Localised CP – Plant Earthing Fault (2014)

Extended CP – Plant Earthing Fault (2018)
<table>
<thead>
<tr>
<th>Common MFL Pig</th>
<th>Specialised High Res MFL Pig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre ILI Geometry Pig</td>
<td>Pre Cleaning Pig</td>
</tr>
</tbody>
</table>
Internally 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

Brand New ER Probe Element
## Pipeline Surveys / Fault Finding

<table>
<thead>
<tr>
<th>Location Tag</th>
<th>Corrosion Rate</th>
<th>Extended Period Corrosion Rate</th>
<th>Metal Loss</th>
<th>Probe Span</th>
<th>% Life Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>JB5 Carbon Steel</td>
<td>203.9 μm/yr</td>
<td>406.8 μm/yr</td>
<td>382.26 μm</td>
<td>508 μm</td>
<td>24%</td>
</tr>
<tr>
<td>JB5 Duplex</td>
<td>Negligible</td>
<td>0.4123 μm/yr</td>
<td>16.13 μm</td>
<td>508 μm</td>
<td>96%</td>
</tr>
<tr>
<td>JB4 Carbon Steel</td>
<td>1420 μm/yr</td>
<td>448.2 μm/yr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JB4 Carbon Steel</td>
<td></td>
<td>583.2 μm/yr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Period 1</td>
<td></td>
<td>754.5 μm/yr</td>
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<tr>
<td>JB3 Carbon Steel</td>
<td>2.818 μm/yr</td>
<td>1.49 μm/yr</td>
<td>14.47 μm</td>
<td>508 μm</td>
<td>97%</td>
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<tr>
<td>JB2 Carbon Steel</td>
<td>0.492 μm/yr</td>
<td>0.7631 μm/yr</td>
<td>23.8 μm</td>
<td>508 μm</td>
<td>95%</td>
</tr>
<tr>
<td>JB1 Carbon Steel</td>
<td>Negligible</td>
<td>2.105 μm/yr</td>
<td>16.4 μm</td>
<td>508 μm</td>
<td>96%</td>
</tr>
</tbody>
</table>

### Effects of Plant – Copper (Cu) Earthing Connections
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

- Enact Change
- Analyse and recommend action
- Produce Integrity Reports/Statement
- File inspection report
- Review CDR Required?
  - No
  - Yes
    - Raise CDR, issue and update register
    - Follow CDR Process

Inputs: IIP (Class and Risk Assessment), SAP

Create Inspection workbooks

Review CDR history & Inspections

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

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Inspection of Floating Units

Failed Coatings

Maintenance Support Vessel

Temporary Access Scaffolds

FPSO
Inspection of Floating Units

Often Difficult Access for FPSO / FSO Vessel Inspection
Inspection of Floating Units

Complex / Labour Intensive Structural Inspections

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Inspection of Floating Units

Maintenance Support Vessel

FPSO

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In Situ Structural Repairs can be very costly
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 result in global structural failure but would result 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.
Inspection of Coatings

<table>
<thead>
<tr>
<th>Corrosion</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat A</td>
<td>Light Scale (1-3mm thick)</td>
</tr>
<tr>
<td></td>
<td>Estimated metal loss &lt; 0.5mm</td>
</tr>
<tr>
<td>Cat B</td>
<td>Moderate Scale (&gt;3-6mm thick)</td>
</tr>
<tr>
<td></td>
<td>Estimated metal loss 0.5mm to 2mm</td>
</tr>
<tr>
<td>Cat C</td>
<td>Severe Scale (&gt; 6mm thick)</td>
</tr>
<tr>
<td></td>
<td>Pit / metal loss &gt; 2mm = &lt; 5mm</td>
</tr>
<tr>
<td>Cat D</td>
<td>Scale detaching (significant visible loss)</td>
</tr>
<tr>
<td></td>
<td>Deformation or penetration &gt; 5mm</td>
</tr>
</tbody>
</table>

Ri 1 (0.05% breakdown)
Ri 2 (0.5% breakdown)
Ri 3 (1.0% breakdown)
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

Presented by Stephen Tate – Technical Services and Projects – TOTAL
E&P UK Limited, Total House, Tarland Road, Westhill, AB32 6JZ
Use of DRONES for Internal / External Inspections

Hi – Resolution Drones
PIPELINE DRONES

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

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E&P UK Limited, Total House, Tarland Road, Westhill, AB32 6JZ
Reactive
- Do Nothing
  - Too Early
  - Scheduled Maintenance
  - Too Late
  - Resume Production

Preventive
- Do Nothing
- Monitor Health
- Predict Events
- Perform Maintenance
- Resume Production

Predictive
- Digital Solutions
- Identify Root Cause
- On-Time Maint.
- Resume Production

Proactive

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Reactive</th>
<th>Planned</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td>40%</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>60%</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>80%</td>
<td>20%</td>
<td></td>
</tr>
</tbody>
</table>

(Best Cost / Facility of the Future)

(Today’s Average Facility)
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: 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:

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.

<table>
<thead>
<tr>
<th>EXPOSED STRUCTURES AND PIPELINES</th>
<th>Stabber/ Proximity/ Drop Cell</th>
<th>Cell to Cell</th>
<th>Dual Cell (Field Gradient)</th>
<th>FiGS (Field Gradient)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential profile</td>
<td>Possible</td>
<td>Possible</td>
<td>Not Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Anode current</td>
<td>Not Possible</td>
<td>Not Possible</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Anode wastage</td>
<td>Not Possible</td>
<td>Not Possible</td>
<td>Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Coating damages</td>
<td>Not Possible</td>
<td>Limitations</td>
<td>Limitations</td>
<td>Possible</td>
</tr>
<tr>
<td>Steel current density</td>
<td>Not Possible</td>
<td>Not Possible</td>
<td>Limitations</td>
<td>Possible</td>
</tr>
<tr>
<td>Current drain to e.g. piles, wells &amp; substructures</td>
<td>Not Possible</td>
<td>Not Possible</td>
<td>Limitations</td>
<td>Possible</td>
</tr>
<tr>
<td>Outer sheath damage on flexible pipes</td>
<td>Not Possible</td>
<td>Not Possible</td>
<td>Not Possible</td>
<td>Possible</td>
</tr>
<tr>
<td>Correction of pipe routing</td>
<td>Not Possible</td>
<td>Not Possible</td>
<td>Not Possible</td>
<td>Possible</td>
</tr>
</tbody>
</table>
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