Energy Transition' via Chemistry and Engineering

Corrosion and Integrity Assurance for the Energy Transition: Lessons from Oil and Gas and Emerging Systems

Stephen Tate – ICorr Past President, 28/10/26

Presenter Bio



Stephen Tate - Immediate Past President, MBA, PG. Dip Eng. MICorr.

Long-Standing, ICorr - Institute of Corrosion Committee Member
ICorr Aberdeen Chair for 2016 / 2017 Session and for 2019 / 2020 Session.
ICorr National Vice President 2020-2022 and National President 2022-2024.
SPE Corrosion Conference Co-Chair 2021.
Significant Operator Experience – Amoco / BP / British Gas / ConocoPhillips / Fairfield Energy / INOC / QGPC / Qatar Gas / SNAM / Shell / Talisman Energy / Total Energies.
Mainly Working through – Aberdeen Corrosion Engineers (ACEL) / CAN / Oceaneering.

Global Cost of Corrosion and Failure Impacts

1. **Safety Impact of Corrosion**
2. **Financial Impact of Corrosion on Society**
3. **Environmental Impact of Corrosion**
4. **Role of Corrosion Professionals**
5. **Need for Education / Mentoring**
6. **Prevention, Cost Considerations**
7. **Summary**

Close up of shiny and rusted metal chains (source: www.alamy.com)



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Safety and Integrity Impacts Examples from the Energy Sector: Lessons Learnt

Global Cost of Corrosion and Failure Impacts…. What Can Happen?





Victim is still dealing with the effects of multiple broken bones and chemical burns three years later.

- 2026 – at Peterhead Sheriff Court in May 2026. **Peterhead Firm fined £350,000 by HSE after corroded chemical tank burst left worker injured**

(source: BBC).

On June 21, 2023, a severely corroded 700-tonne chemical storage tank burst at the Tetra Technolog ies UK Limited offshore supply base in Peterhead, releasing nearly 481,000 litres of calcium chloride ($CaCl_2$) brine. The catastrophic rupture critically injured a contractor, leaving him with life-changing spinal fractures and chemical burns.

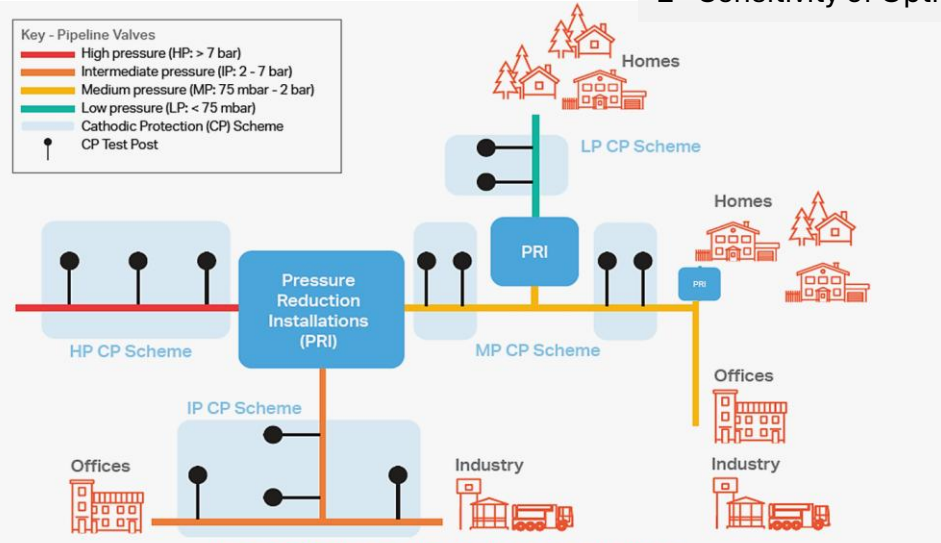
Corrosion Related – Gas Explosion Risks (1)

Prevention Options

0 - Reactively replace pipeline failures (i.e. the baseline position)

1 - Targeted proactive repair (preferred option)

2 - Sensitivity of Option 1 to interruptions to supply valuation



UK Gas System – CP and Pressure Breakdown (courtesy of CADENT)

Corrosion Related – Gas Explosion Risks (2)



Explosion severely damaged the Hotel which was later demolished.

- 1983 – **Aberdeen,**
- The Royal Darroch Hotel, **A failed gas service' pipe led to 6 Deaths and Multiple Injuries.** Scottish Gas were ordered to pay ~£3M in compensation to the victims.

(source: Historic Aberdeen)

THE ROYAL DARROCH... - Historic Aberdeen & Shire - Scotland | Facebook

- Only 1 week later, the adjacent Cults Hotel, suffered a leak traced to a medium pressure (MP) main in the road.

Corrosion Related – Gas Explosion Risks (3)



- 2022 – **HSE**



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Environmental Impacts Examples from the Energy Sector: Lessons Learnt

Environmental Impacts of Corrosion



Corrosion can cause leaks and spills, leading to environmental pollution.

"Steelmaking **to replace corroded steel could account for ~4–9% of global CO_2 emissions by 2030** under modelled scenarios applying EU/US emissions-reduction targets globally."

Source: Iannuzzi and Frankel (2022)

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Environmental (MIC Related) Spill





- 2023 – **£6.1M. Overall Clean-Up Cost of Oily Water Spill from Perenco operated Pipeline at Wytch Farm** (source: BBC)
- Environment Agency account identified £2.4 million specifically for clean-up, with the remainder covering the initial response costs, surveys and other payments.

BBC News

Left Images - Resulting contamination to Ower's Bay and Poole Harbour.

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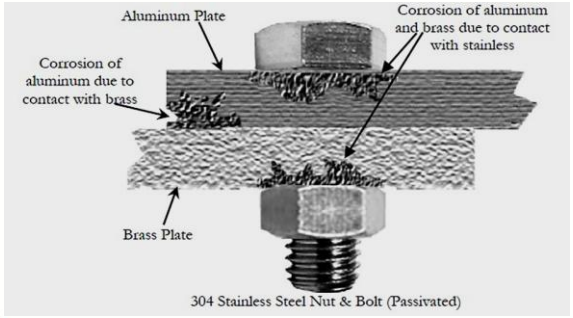
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Net Zero Technologies:
Recent Corrosion Issues

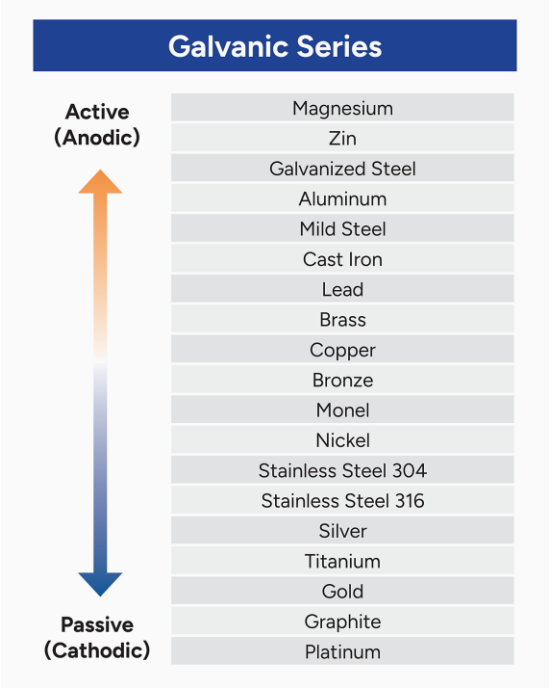
Corrosion Related – NZ Integrity Risks (Solar Energy)



Oxidation Corrosion - US Gov.



Crevice Corrosion - US Gov.



Galvanic Series- US Gov.

- **US Gov. Energy**

Corrosion is a major threat to the structural integrity, safety, and lifespan of both **solar PV systems.** The following **3 types** of corrosion are **most commonly seen** in solar PV systems.

- **Oxidation Corrosion** is commonly seen in rooftop solar PV components like inverter cabinets, combiner boxes, and conduit unions. Heat accelerates corrosion reactions on rooftops systems exposed directly to the sun's heat.
- **Galvanic Corrosion** in solar PV systems often occurs where stainless steel fasteners are paired with steel or aluminium frames. Improper grounding or fastener selection damages the safety and reliability of electrical/safety bonding.
- **Crevice Corrosion** within Solar PV parts Crevice corrosion occurs at the microscopic contact surfaces between two metals. When two materials are in contact, surface irregularities result in gaps along the contact surface and create pockets where an electrolyte is trapped causing corrosion.

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Corrosion Related – NZ Integrity Risks (Wind Farms) -



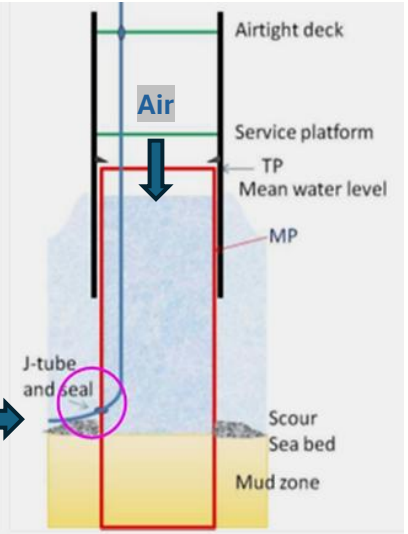
Monopile Abfad' Image

Cordis EU Adobe' Image

- Ongoing Issue – **Boat Landings.** As the industry has expanded offshore, corrosion protection requirements have become far more demanding. Saltwater, sea spray and constant exposure to the marine environment accelerate corrosion, making long term protection essential.
- **Tidal and Splash Zones:** Boat landings endure repeated wetting and drying cycles, high oxygen exposure, and mechanical abrasion from docking boats, which strips away protective surface layers and may lead-on to loss of structural integrity and potentially collapse.

Corrosion Related – NZ Integrity Risks (Wind Farms) - 2

- Power cable routed through the MP wall close to the seabed
- Cable protection system (seal)
- If seal fails a narrow gap is created
- Dimensions variable:
  - Length
  - Width
  - Depth



Monopile Cut-Away by
Dr David Buxton
Intertek CAPCIS

- **MIC** - Early Wind Farm Monopile Issues.
- **CAPCIS** (a specialised corrosion consultancy originally out of UMIST and now part of Intertek CAPCIS) is a leading global authority on diagnosing and mitigating - Microbiologically Influenced Corrosion (MIC) within offshore wind farm monopile foundations.

Initially, many offshore wind foundations were designed to be water and airtight so that any corrosion of the monopile foundations (both in the trapped seawater and the associated air space) would naturally stop, as the dissolved oxygen was depleted. **However,** this approach was not practical due to leaking cable seals (allowing ingress of aerated seawater) and/or regular opening of the airtight hatch (fully replacing the oxygen in the air space), which meant that there was no effective internal corrosion control, thereby running the risk of metal loss and localised thinning of the monopile but also, more crucially, introducing problems associated with corrosion fatigue of the monopile structure. **Current codes,** (including DNV-RP-0416:2021 Corrosion protection for wind turbines • BS EN ISO 24656:2022 Cathodic protection of offshore wind structures now recognise this problem and require an effective corrosion control system to be incorporated within the monopile, this could include one or more of:
a) Protective coatings, b) Cathodic protection, c) Chemical treatment (to the trapped seawater).

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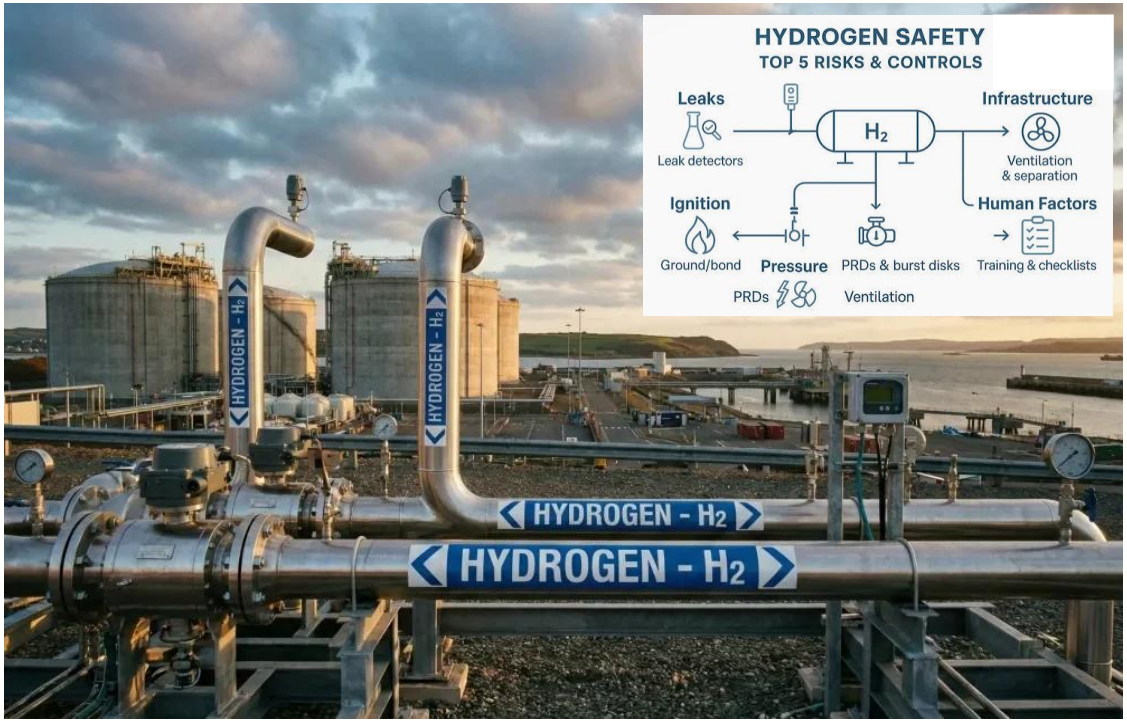
Corrosion Related – NZ Integrity Risks (Carbon



- **CCUS - Carbon dioxide corrosion** is a major operational challenge in **Carbon Capture and Storage (CCUS)** systems.
- It damages equipment, pipelines, and storage infrastructure.
- Carbon Capture and Storage: Institute of Corrosion
- When water condenses, other impurities dissolve in the water, as well as the CO_2.
- The presence of other impurities can increase the likelihood of corrosive phases forming, either by reducing the water solubility, or via chemical reactions between different impurities.
- **Acid dropout** is the most significant concern for pipeline operators, whereby highly corrosive aqueous phases, such as nitric and sulphuric acid, can form, as a result of reactions between water, NOx, SOx, O_2 and H_2S impurities.
- **Source:** Gareth Hinds of the National Physical Laboratory (NPL and ICorr Past President).

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Corrosion Related – NZ Integrity Risks (Hydrogen Transport)



- **Hydrogen**
- Transporting hydrogen presents **unique physical and safety hazards** compared to conventional gases like natural gas or methane.
  - **Hydrogen Embrittlement:** Hydrogen atoms infiltrate metal walls (such as steel pipelines), reducing ductility, fracture toughness, and increasing fatigue crack growth. [1, 2]
  - **Leakage:** Because hydrogen has the smallest molecular size and low viscosity, it can escape easily through tiny gaps, seals, and threaded joints. [1, 2, 3]
  - **Invisible Leaks:** Pure hydrogen is odourless, making leaks difficult to detect without specialised sensors.

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Financial Impacts

Lessons Learnt

Financial Impacts – Why Corrosion needs more Advocates

Annual cost of corrosion in UK ≈ **Annual budget for UK education**

Economic Impact of Corrosion

Corrosion costs the UK around £100 billion annually, between 3-4% of GDP, affecting public infrastructure of all types and individuals.

Preventable Corrosion Costs

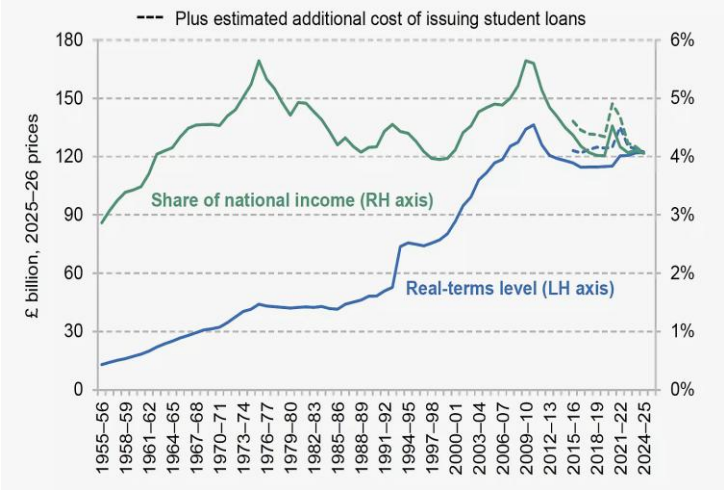
15-35% of corrosion-related costs can be avoided through better design, material choice, and timely maintenance.

Policy and Sustainability

Corrosion control supports infrastructure resilience, net-zero goals, public safety, and reduces carbon emissions.

Public Trust and Safety

Corrosion failures can cause amenity and school closures, bridge restrictions, and utility failures, all eroding public trust.



UK education costs over the years (source: HM Treasury)

Solutions to Corrosion Problems

- Appropriate Education, training and mentoring to increase Competency and Corrosion awareness. STEM and onwards.
- Correct Materials selection to match Asset Life.
- Effective / Continuous Corrosion Management.
- **Greater Interaction** between Engineering Institutes – Corrosion / Materials / Mechanical / Structural / Welding etc.



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Role of Corrosion Professionals:

Role of Corrosion Professionals

- Fundamental Research
- Development of Products (alloys, coatings, inhibitors)
- Design
- Engineering
- HSE Compliance – COMAH and Safety Cases
- Asset Integrity Management
- Plant & Equipment Engineering
- Plant & Equipment Inspection
- Plant & Equipment Safety



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Prevention / Cost Considerations:

Societal Impacts and Advances

- Advances by Corrosion Engineers / Scientists / Chemists mean that your **car no longer looks like this after a few years**

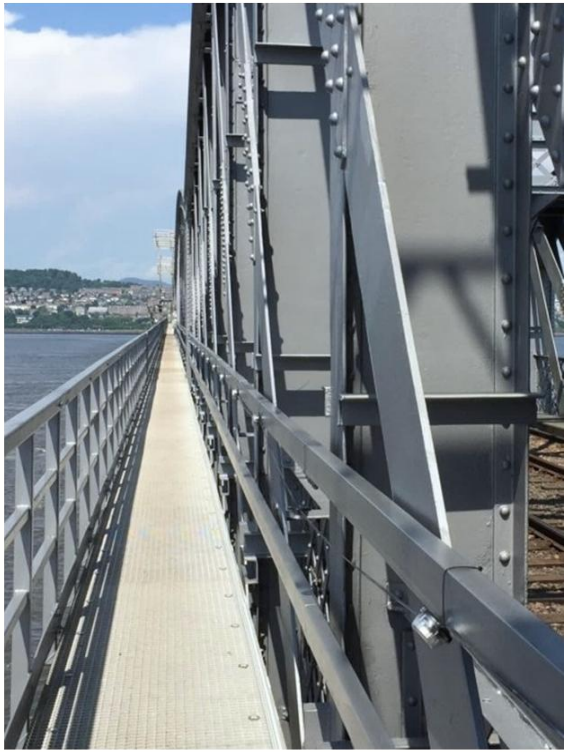




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Active Prevention (Applied Coatings)

- Corrosion and associated costs **cannot be eliminated completely**
- **~£10 to £30 billion / year could be saved in the UK**
- **Optimised** corrosion prevention practices can:
  - Improve safety
  - Protect the environment
  - Save a lot of money
  - Reduce inconvenience to the Public, i.e.:
    - **Prevent or reduce water and gas leaks**
    - **Enable more reliable journeys** by preventing corrosion of roadside and trackside infrastructure
    - **Extend life of public infrastructure**
      - e.g., Forth Road Bridge (FRB) cable corrosion led to wires failure. Partial mitigation by dehumidification. FRB replacement could have cost even ~£2.4 billion. A new bridge was built due to weight limits on the damaged FRB."



Refurbished Tay Bridge (Dundee, UK's longest rail structure – restoration cost: £75 million (source: www.networkrail.co.uk)

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Cathodic Protection (CP) – A common mitigation

Cathodic Protection is not normally a stand-alone mitigation measure. It is part of an overall cost-effective corrosion protection system. Coatings reduce CP Anode requirements.

We need to consider the intended coating system. For example, FBE (fusion bonded epoxy) coating vs. 3LPP (3-layer polypropylene)

FBE coating is a cheaper product but has higher coating breakdown and **needs mechanical protection** which will increase installation costs, as pipeline anodes are installed offshore at pipelay.

FBE coated pipe





3LPP coated pipe

Cathodic Protection (CP) - Retrofitting

- Retro-fitting of CP anodes may need to be considered if:
    - Anode current drain occurs (unintentionally) to nearby infrastructure.
    - Design did not consider all components.
    - Life extension is required beyond originally intended field life.

- Anode skids can be connected in this case.
- Skids are relatively inexpensive, but offshore installation of these can be costly.







(source: forcetechnology.com)

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Chemicals Management (1)

Key Functions

- **Asset Protection:** Doses corrosion inhibitors, scale inhibitors, and biocides to prevent pipeline degradation and blockages.
- **Process Enhancement:** Injects de-mulsifiers, hydrate inhibitors, and anti-foaming agents to optimise oil, gas, and water separation.



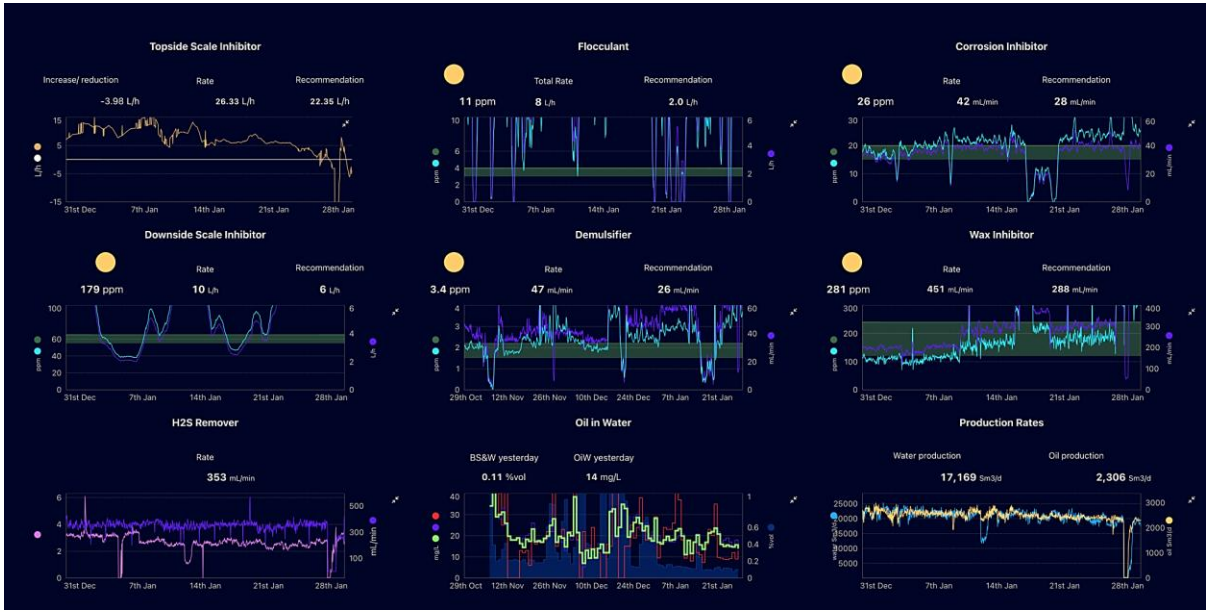
Permanent Chemical-Injection-Units_ Image Proserv



Temporary Skids - Image ICR-CIU

Chemicals Management (2) / Matrices / Dashboard

- A chemical injection dashboard is an **essential** monitoring and optimisation tool to track, control, and automate the dosing of production chemicals (such as corrosion inhibitors, scale inhibitors, and de-mulsifiers v. pre-set criteria). **Key Features and Capabilities: Real-Time Monitoring of** injection rates, pump statuses, tank levels and communication links **live** across all operating facilities.



Modern Dashboard – Image Eigen

Summary

- **Corrosion Degradation causes:**
  - Significant Safety and Environmental Threats.
  - **Can only be managed by** competent Corrosion Engineers and Scientists.

  Continuing shortage of ‘home-grown’ Corrosion Professionals.
  - **Prevention methods** require Certified Engineers, Scientists, Installers, Inspectors.

- Remember that new Net Zero Technologies also have Corrosion Threats which require ongoing management.

Global Cost of Corrosion and its Impacts

Thank you for your attention.
Any Questions?

Advancing Corrosion Science & Engineering



Institute of Corrosion
Corrosion House, 5 St Peters Gardens,
Marefair, Northampton, NN1 1SX
www.icorr.org

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