Corrosion Mitigation by Chemicals and Materials
Chemicals - Why Necessary?
Corrosion Mitigation by Chemicals

**Typical Flow Situation / Corrosion Hotspots**

**TOL** Corrosion (Gases, CO2, H2S etc.)

**BOL** Corrosion (Water and Solids)
Injection Process
Corrosion Mitigation by Chemicals

INJECTION QUILL FUNCTION

Ensures EVEN Distribution of Chemical
Corrosion Mitigation by Chemicals

**INJECTION QUILL MATERIALS**

PVC, Kynar, 316 SS, or Hastelloy C-276
Corrosion Mitigation by Chemicals

INJECTION QUILL FITTING

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Chemical Types

- **There Are 2 Main Types**

- **Integrity Chemicals** – Biocides, Inhibitors, Scavengers.
- **Production Chemicals** – De-Mulsifiers, Scale Control.
Corrosion Mitigation by Chemicals

BIOCIDES.

• **TYPICAL APPLICATIONS INCLUDE:**

  • **REGULAR DOSING, e.g. WATER INJECTION SYSTEMS.**
  • **KILL (HIGH) DOSING OF VESSELS, WHEN POOR MICROBIAL RESULTS REC’D.**
  • **PRESERVATION, PRIOR TO EXTENDED SHUTDOWN / OUTAGE.**
Corrosion Mitigation by Chemicals

BIOCIDES.

Regular Bio-ciding is Critical to Long-term Protection of Pipelines
Corrosion Mitigation by Chemicals

**BIOCIDES.**

BOL Corrosion Internally on Line Shut-in *Without* Bio-ciding

2 x Defects Not Visible on Walk By

After Scab Removal

Weeping As Found

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SCAVENGERS.

- **There Are 2 Main Scavenger Types**
  - Hydrogen Sulphide Scavenger.
  - Oxygen Scavenger.
Corrosion Mitigation by Chemicals

H2S.

Good H2S Control by H2S Scavengers, Essential to Preserving Export Route.
Corrosion Mitigation by Chemicals

OXYGEN SCAVENGER.

• ESPECIALLY IMPORTANT FOR WATER INJECTION.
• PRESENCE OF OXYGEN IS A RAPID CORROSION.
Corrosion Mitigation by Chemicals

SEAWATER MONITORING - 1.

Residual Sulphite comes from the Applied Oxygen Scavenger (Too much can also cause Integrity Issues).
Corrosion Mitigation by Chemicals

*SEAWATER MONITORING -2.*

Dissolved Iron Counts are also Monitored / Trended
Corrosion Mitigation by Chemicals

INHIBITORS.

Condensing water without inhibitor

water saturated gas and CO₂

Stratified liquid and corrosion inhibitor
Corrosion Mitigation by Chemicals

INHIBITORS.
Corrosion Mitigation by Chemicals

INHIBITORS.

Towards an Outage, Dosing may exceed Min req. by a Sig. Amount. Similarly at Production Re-start.
Corrosion Mitigation by Chemicals

INHIBITORS.

Actual Dosing ppm rarely exactly matches Target Dosing, as there is always a Time Lag on any Dosing Adjustments v. Production Rates
Corrosion Mitigation by Chemicals

**MONITORING RESIDUALS**

Target Residual 50ppm in this Example but requirement varies with Partitioning Properties of the Chemical in Question.
Inhibitors - Residuals.

Dosing is related to Total’ Produced Fluids but Produced Fluids are a Mix.
Production Chemicals
• **De-mulsification**’ is the breaking of a crude oil emulsion into oil and water phases:

• **Essential for Export and Further Processing.**

• **There are two main types of de-mulsifiers in use.**

  • **Oil soluble de-mulsifier** - organic and soluble in crude oil.
  • **Water soluble de-mulsifier** - surfactants soluble in water.
Corrosion Mitigation by Chemicals

DE-MULSIFIERS.

Action of De-mulsifier over Time.
Corrosion Mitigation by Chemicals

DEHYDRATION GLYCOL- 1

pH and Residual H2O must be constantly Monitored
Corrosion Mitigation by Chemicals

**DEHYDRATION GLYCOL- 2**

pH and Residual H2O in Glycol Systems must be similarly Monitored
Corrosion Mitigation by Chemicals

**SCALE CONTROL.**

- **SCALING IS A BIG ISSUE IN PROCESS BOTH PLANT AND PIPELINES:**
  - *Scales e.g. barium sulfate*, interfere with fluid flow, enhance corrosion, *causes* production losses, result in equipment replacement, damage equipment and may host bacteria.
  - *barium sulfate* deposits have long plagued oil field and gas production operations.

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Monitoring is Essential
### Corrosion Mitigation by Chemicals

#### KPI – KEY PERFORMANCE INDICATORS

<table>
<thead>
<tr>
<th>Export Streams, Treatment and Analysis</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Dehydration</td>
<td>Export gas on spec for dew point and Lean TEG water content &amp; pH In spec.</td>
</tr>
<tr>
<td>Gas Export H2S</td>
<td>Export gas on spec for H2S with scavenger trials continue with average export H2S at approx 2ppm. Permanent injection solution to be identified along with installation of injection atomiser quills.</td>
</tr>
<tr>
<td>Fluids Separation (plugcatcher, Coalescer, PW Flash Drum)</td>
<td>Demulsifier trial ongoing and positive indication of reduced oil carryover although still higher than spec from flash drum - alternative sampling and analysis started to identify if problem is specific to a particular vessel</td>
</tr>
<tr>
<td>Export Condensate</td>
<td>Export condensate on spec. IP reported ISSW always between 0 - 0.02%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEG Storage</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis</td>
<td>n/a MEG storage analysis reinstated</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEG Regeneration and Treatment</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MEG Condition, Water &amp; Salts content</td>
<td>Water and salt content OK but, MEG system blockages still a concern. High levels of black sticky deposits consisting of organics and iron based material causing issues with the plant. Ongoing analysis to identify source of solids in upstream filters and the deasal brine.</td>
</tr>
<tr>
<td>Regen Chemical treatment</td>
<td>Pre treatment chemicals not currently in use. Carbonate still out of action - 251g bags on site as back-up.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EWTP &amp; OWTP Treatment and Analysis</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis</td>
<td>n/a Analysis being reviewed and cut back where possible. Residual NH4 being reviewed possible interference from Cl. Investigation ongoing</td>
</tr>
<tr>
<td>EWTP Chemical treatment</td>
<td>n/a Polymer performance much better - running down old stock in sludge centrifuge. Lab tests looking for alternative coagulant</td>
</tr>
<tr>
<td>Key figures for Discharge(OIW, COD)</td>
<td>EWTP performance is very good - COD and BOD levels in ADP4 discharge now driven by Site drains contamination. Ammonia levels affected by Cl but review with SEPA to charged discharge limit started</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Utilities Chemical Treatment and Analysis</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Medium</td>
<td>Nitrile levels are low but addition of inhibitor will increase pH which is currently OK</td>
</tr>
<tr>
<td>Hydraulic fluid</td>
<td>n/a</td>
</tr>
<tr>
<td>Fire water</td>
<td>Fire water chlorine residual is low</td>
</tr>
</tbody>
</table>

**KPI’s Measure**

Performance against Agreed Criteria and Traffic Light Results
Operational Issues / Injection Interruptions

- **Industry Aims for 85% or Better Chemical Availability.**
- **Injection can be interrupted or dosing reduced for following reasons:**
  
  - Skid / Pump Failure.
  - Injection Quill Failure.
  - Planned or Unplanned Shutdown.
  - Stock Shortage Onboard / Shipping Delay (Weather etc).
  - Chemicals causing Issues with Solids Production.
Corrosion Mitigation by Chemicals

SKID / PUMP FAILURE.

All Skids – Permanent or Temporary must be maintained and kept calibrated. Flow Meters and Pumps must remain Operational at All Times.

Residual Protection – After Injection Ceases May only be a Few Hours!
ISSUES WITH SOLIDS PRODUCTION.

Deposits

- Unknown Black Sticky Deposit
  - MEG Pre-Treatment filters
  - MEG Regen Column
  - MEG Desal
  - MEG Heat Exchangers
  - Lean MEG Booster Pump Strainers

Physical Analysis (%wt Sample as Received):

- Loss on Drying (105°C): 75.8%
- Loss on Ignition (105-550°C): 16.2%
- Ash Residue (550°C): 8.0%

Chemical Analysis (%wt Ash Residue):

- Iron (Fe): 60.5%
- Manganese (Mn): 0.23%
- Chromium (Cr): <0.05%
- Nickel (Ni): <0.05%
- Copper (Cu): <0.05%
- Lead (Pb): <0.05%
- Zinc (Zn): <0.05%
- Silicon as Silica (SiO₂): 0.58%
- Aluminium (Al): 0.12%
- Titanium (Ti): <0.05%
- Sodium (Na): 0.48%
- Potassium (K): <0.05%
- Magnesium (Mg): 0.12%
- Calcium (Ca): 0.24%
- Strontium (Sr): <0.05%
- Barium (Ba): <0.05%
- Sulphate (SO₄²⁻): 2.52%
- Phosphorus (P): 0.08%

Chemicals May Cause D/S SOLIDS !
POTENTIAL SHIPPING DELAYS (WEATHER etc).

Interruption to Supply or Reduced Dosing!

Typical Chemical Cube
Safety

- **Be aware of all legislative and HSE guidance.**
- **Excess chemical usage can be problematic!**
- **Environmental concerns (disposal / spillage etc).**
- **Integrity concerns (many neat chemicals are corrosive).**
- **Risk to personnel.**
Corrosion Mitigation by Chemicals

Chemicals are Hazards!

Commonly used Chemicals include:

• WAX, SCALE AND CORROSION INHIBITORS, BIOCIDES.
  • DE-OILING AND ANTI-FOAMING AGENTS.
  • OXYGEN AND HYDROGEN SULPHIDE SCAVENGERS.

These chemicals include substances such as:

ALCOHOLS, ALKYL/BUTYL BENZENES, (POLY) AMINES,
ALDEHYDES AND ANHYDRIDES.

Detrimental Health effects include:

BURNS, DERMATITIS, EYE
AND RESPIRATORY IRRITATION AND ASTHMA.
Corrosion Mitigation by Chemicals

HSE GUIDANCE / LEGISLATION.

Chemical injection

Offshore COSHH essentials

Control approach 3

Containment
Corrosion Mitigation by Materials Selection
Use of CRA’s
Reactivity and Relative’ Costs of CRA’s

<table>
<thead>
<tr>
<th>Reactivity series of metals</th>
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<tbody>
<tr>
<td><strong>Element</strong></td>
</tr>
<tr>
<td>Potassium</td>
</tr>
<tr>
<td>Sodium</td>
</tr>
<tr>
<td>Calcium</td>
</tr>
<tr>
<td>Magnesium</td>
</tr>
<tr>
<td>Titanium</td>
</tr>
<tr>
<td>Aluminium</td>
</tr>
<tr>
<td>Carbon</td>
</tr>
<tr>
<td>Zinc</td>
</tr>
<tr>
<td>Iron</td>
</tr>
<tr>
<td>Lead</td>
</tr>
<tr>
<td>Hydrogen</td>
</tr>
<tr>
<td>Copper</td>
</tr>
<tr>
<td>Silver</td>
</tr>
<tr>
<td>Gold</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td>Titanium</td>
<td>8000</td>
</tr>
<tr>
<td>Iron</td>
<td>250</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>1500</td>
</tr>
<tr>
<td>Aluminium</td>
<td>1500</td>
</tr>
<tr>
<td>Titanium alloys</td>
<td>25000</td>
</tr>
</tbody>
</table>

The reason for common (95%) use of Non Exotic Iron / Steel, is immediately obvious.
Uses of Corrosion Resistant Alloys (CRA’s)

- **Carbon Steel remains the most commonly used ‘Day to Day’ material (Norm. with Sacrificial Barrier or Coating).**

- **Alloys are expensive and only used where they can be justified on grounds such as:**
  - **Highly Aggressive / Highly Corrosive Conditions.**
  - **High Flow Rates.**
  - **Hygiene Reasons, e.g. Food Production.**
  - **But remember – they are usually very thin walled.**
Partial Use of Alloys

- **CRA’S** HAVE SPECIFIC APPLICATIONS.

- **PARTIAL USE IS** OFTEN MORE APPROPRIATE:
  - **AS LINERS.**
  - **AS INSTRUMENT FEEDS.**
  - **AS FLOW ENABLERS.**
  - **AS DECORATIVE / EASILY MAINTAINABLE SURFACES.**
Hastelloy® and Incoloy® are both members of the “superalloy” family, also known as high-performance alloys and have several key characteristics in common. They both possess excellent mechanical strength, especially at high temperatures, and they are both highly resistant to corrosion and oxidation.
Corrosion Mitigation by Materials

Alternative Use of Liners

Jointing

Much Lower Cost

Claddings are OK For Short Lengths

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Corrosion Mitigation by Materials

As Instrument Feeds

Filled wet legs (water, glycol) protect sensor from being exposed to excessively high temperature

Insulate & heat trace so lines don't freeze in winter shutdowns

Transmitter is under the pipe to retain wet legs

316L is Common
Corrosion Mitigation by Materials

As Flow Enablers

Super Duplex Stainless Steel - Often Used for High Flow / High Erosion Risk Conditions

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Corrosion Mitigation by Materials

As Decorative Surfaces

1928 Chrysler Building NYC, 1st Major Use of Stainless Steel in Architecture. Type 302
Installation Issues
Corrosion Mitigation by Materials

Good Installation Essential
Great Care Required At All Stages.

• **SUCCESSFUL USE OF CRA’S – CORROSION RESISTANT ALLOYS, JUST LIKE PROTECTIVE COATINGS, IS DEPENDANT ON:**

• **GOOD SYSTEM DESIGN.**
• **GOOD INSTALLATION PROCEDURES.**
• **CORRECT APPLICATION AND FLOW CONDITION.**
• **CORRECT CHOICE OF MATERIALS.**
Corrosion Mitigation by Materials

CRA Liners Can Buckle

Scan of Long-Distance Pipeline

Pipe Lay Error
Corrosion Mitigation by Materials

Seawater Piping

often used for Marine Applications and Fire Mains

**THIN** 3mm Cunifer 90/10 Copper Nickel Piping, showing Repair

Has **GOOD** Corrosion Resistance but **POOR** Erosion Resistance

fer (FE) – Iron Max. 2%
Pitting and Crevice Corrosion of Stainless Piping is Common in Marine Environments (Unless Coated)
Corrosion Mitigation by Materials

Stainless Alloy Limits

According to Service Application and Installation Methods

Alloys will require Protective Coatings Above Critical Temperatures.
Corrosion Mitigation by Materials

Aberdeen Branch

Stress Corrosion Cracking

<table>
<thead>
<tr>
<th>Properties</th>
<th>Ferritic</th>
<th>Austenitic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toughness</td>
<td>Moderate</td>
<td>Very high</td>
</tr>
<tr>
<td>Ductility</td>
<td>Moderate</td>
<td>Very high</td>
</tr>
<tr>
<td>Weldability</td>
<td>Limited</td>
<td>Good</td>
</tr>
<tr>
<td>Thermal expansion</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Stress corrosion cracking resistance</td>
<td>Very high</td>
<td>Low</td>
</tr>
<tr>
<td>Magnetic properties</td>
<td>Ferromagnetic</td>
<td>Non-magnetic</td>
</tr>
</tbody>
</table>

Seawater Deluge System Can Cause This! i.e. Chloride Contamination to Hot Surfaces
THANK YOU FOR YOUR ATTENTION
ANY QUESTIONS?