Operational Pigging
A Frontline Tool to Control Internal Corrosion of Pipelines

Jozef Soltis / Daniel Sandana / Paul Birkinshaw

Paul Birkinshaw, MACAW Engineering
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1. Introduction
2. Corrosion management – the industry challenge
3. Internal corrosion in pipelines
4. Controlling internal corrosion in pipelines
5. The role of operational pigging
6. Wrap-up
It is widely acknowledged that operational pigging is a key frontline O&M activity for controlling internal corrosion in oil and gas pipelines.

- The term operational pigging can cover a wide range of pigging operations.

- In general it can be interpreted as ‘systematic online pigging for in-service pipelines as part of an established maintenance routine’.

- Operational pigging is often referred to as:
  - Production pigging
  - Routine pigging
  - Maintenance pigging
  - Combinations of the above
  - Can also cover ILI Pigging
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COST OF CORROSION

Science ➔ Mitigation ➔ Management

• $276B (NACE US Corrosion Costs Study 1998 – 3.1% GDP)
• ~30% can be prevented
• Elimination of corrosion by control technologies does not completely negate the overall economic cost
• Corrosion control cost analysis benefit balance…

3% GNP
PIPEDLE CORROSION STATISTICS

Main causes of pipeline failures

- Internal Corrosion
- Damage by others
- Construction Damage
- Pipe
- Earth movement
- Other

- External Corrosion
- Weld
- Overpressure
- Joint
- Valvefitting

Typical distribution of expenditure in pipeline corrosion activities

- Treatment Chemical
- Monitoring
- Corrosion Repairs
- Inspection
- Staff

Corrosion Management is important and costly
Getting to grips with corrosion requires a clear strategy and holistic approach to:

- Proactively identify **corrosion threats** and related risks
- Identify **mitigation controls** and conduct their implementation
- Ensure mitigation measures are **effective**
  - Corrosion monitoring
  - Inspection regimes
- Establish and implement **corrective actions**
  - Review and Upgrade CMS tools & assessment methods
- Performance monitoring and **auditing** of integrity management
  - Independent audits
  - Regular system reviews
- Balanced: Non-biased to stakeholders
  - **Industrial standards**
  - **Best practices**
- Transparent process
UK PIPELINES & REGULATORY FRAMEWORK

UK HSE Energy Division (ED)
- Setting strategy & priorities for pipelines

Key Instruments
- Health & Safety at Work Act 1974
- Pressure Systems Safety Regulations 2000 (PSSR)
- **Pipeline Safety Regulations 1996 (PSR)**
  - **Goal setting** approach to ensure risks are **ALARP**

- Major Accident Hazard (**MAH**) pipelines
  - 22,000km Gas & 1,100km other
  - Notifications / MAPD / Emergency Response

- Hazardous Industries Directorate (HID)
  - HSE pipeline inspectors

Recent HSE initiative – **KP4** programme
- Aging & Life Extension (ALE)
Only 31 Clauses (on 8.5 pages)

- **1-4 (Part I)** Definitions (including ‘Meaning of pipeline’)
- **5-17 (Part II)** General
- **18-27 (Part III)** MAH Pipelines
- **28-31 (Part IV)** Miscellaneous

**Clause 5 (Design)**

_The operator shall ensure that no fluid is conveyed in a pipeline unless it has been so designed that, so far as is reasonably practicable, it can withstand:_

- The forces arising from its operation;
- The fluids that may be conveyed in it; and
- The external forces and chemical process to which it may be subjected.

**Clause 13 (Maintenance)**

_The operator shall ensure that a pipeline is maintained in an efficient state, in efficient working order and in good repair._
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INTERNAL CORROSION IN PIPELINES

Internal corrosion is one of the dominant integrity threats in upstream hydrocarbon production and export pipelines.

- Maybe not the biggest cause of failure in upstream pipelines
- Probably the most costly to manage

The immediate consequence of failure through internal corrosion is usually a loss of containment

- Leading to an uncontrolled release of fluid
- Several serious consequences may then arise:
  - A hazardous condition
  - An environmental incident
  - Loss of production or service
  - Reputational damage
MANAGING INTERNAL PIPELINE CORROSION

In pipelines, the main internal corrosion threats prevalent include:

- Sweet (CO2) Corrosion
- Sour (H2S) Corrosion
- Microbiologically Influenced Corrosion (MIC)
- Erosion Corrosion
- O2 Corrosion
Sweet Corrosion (CO2)

Key mechanisms
- CO2
- Water cut
- Operating temperature
- Operating pressure
- pH

Corrosion rates can be modelled and calculated (e.g. NORSOK)
MANAGING INTERNAL PIPELINE CORROSION

Example of CO2 corrosion caused by condensation

Sweet Corrosion (CO2)

Hot Spots

• Gas systems
  • Condensation on upper or cold areas
• Liquid
  • Water dropout and settling in lower regions of the pipeline/vessel

Mitigation

• Corrosion Inhibition
• pH Control
• Internal Linings
• Corrosion resistant materials, duplex stainless, titanium etc.
• Removal/draining of water
• Control of dew point in gas systems to prevent condensation forming
MANAGING INTERNAL PIPELINE CORROSION

Microbiologically Influenced Corrosion (MIC)

Key mechanisms
- Occurs where bugs may be allowed to grow to large concentrations
  - Dead legs
  - Areas of debris
  - Low/intermittent flow conditions
  - Different types thrive at different temps

Bacterial levels are checked by specialists (pig trash)
- SRBs (Sulphate Reducing Bacteria)
- APBs (Acid Producing bacteria)
- IRBs (Iron Related Bacteria)
- LNBs (Low Nutrient Bacteria)
- Etc.

Planktonic vs. Sessile?
Anaerobic / Aerobic
Enumeration & Quantification (bug counting 😊)
MANAGING INTERNAL PIPELINE CORROSION

Microbial Influenced Corrosion (MIC)

Hot Spots

- Can occur anywhere there are microbes, water and nutrients
- Deadleg locations
- Areas under sand/scale deposits are vulnerable to MIC.

Mitigation

- Regular biocide dosing
- Kill dose of biocide
- Regular monitoring
- Removal of high concentration likelihood conditions
- Regular monitoring of dead legs
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• What are the corrosion risks?
• What risks should be given priority and where are the “hot spots”?
• Are our corrosion control measures and mitigation strategies effectively implemented?

• Are these mitigation strategies effective?
• What are the inspection requirements?
• What is the integrity condition of the line?

• What is the remaining life of the pipeline?
• What mitigation and repair strategies are required to extend operational life?

<table>
<thead>
<tr>
<th>Corrosion Threat</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen corrosion</td>
<td></td>
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</tr>
<tr>
<td>MIC</td>
<td>**</td>
<td></td>
<td></td>
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<tr>
<td>Erosion</td>
<td></td>
<td></td>
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<tr>
<td>Sweet Corrosion</td>
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<tr>
<td>Sour Corrosion</td>
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</tbody>
</table>
THE MACAW CORROSION CONTROL PROCESS

Corrosion Control Scheme

- ILI
- Hydro-testing

Inspection Prioritisation Tool Selection

Integrity Review

CRA
May consider ICDA and ECDA

CGA

FFP

CCS

CRA Validation and Optimisation
Corrosion Control Matrices (CCM)

- A list of critical physical and chemical activities, which need to be implemented to manage corrosion.

An individual CCM typically identifies:

- Control activity (e.g. pigging / CI Injection)
- Responsible person
- Location of control
- Frequency of control application
- Threshold and target
- Corrosion threat if target is exceeded
- Corrective action if target is exceeded
- Responsible person for remedial action
Key Performance Indicators (KPIs) are used to:

- Provide understanding and **visibility to management** on the integrity status of key activities in a system
- Demonstrate that corrosion is being adequately managed

Typical corrosion management KPIs:

- **Mitigation** – key process parameters, chemical dose rates
- **Monitoring** – fluid / chemical sampling, residuals, corrosion coupon /pobes, bacterial audits, etc.
- **Inspection** – work completion, overdue inspections, anomalies, failures
- **Pigging** – completion of cleaning pigging to schedule, pig trash analysis
Even with an over-arching CMS in place, it is its **implementation** which should be critically evaluated

- Many tools already exist to management asset integrity - it is the **correct application** of these tools that is critical

**Common obstacles** to effective implementation of IM systems:

- Excessive paper work
- Lack of visibility and readability of integrity status
- Lack of awareness in regard to implementation of actions
- Too many actions and lack of prioritisation
- Lack of communication between different organisation groups, e.g. Topsides vs. pipelines resulting in:
  - Disjointed decisions across organisation
  - Duplication of actions (not necessarily cost-effective)
  - Lack of transparency and consistency in design, operation, inspection, monitoring, etc.
‘INTEGRITY VISUALISATION’ TOOL DEVELOPMENT

AIVT (Asset Integrity Visualisation Tool):
- Display of current assessments & key threats
- Display by asset groups
- Numerous levels in the tool hierarchical layout for simple navigation
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Operational pigging can cover many basis:

- **Dewaxing** – preventing wax build-up on the pipe wall
- **Descaling** – removing / helping prevent scale formation or build-up
- **Liquids removal** in gas pipelines (condensates / produced water)
- **Dewatering** – preventing water holdup in oil or multiphase pipelines
- **Removal of** corrosion products
- **Removal of** sand / sediments
- **To help prevent** hydrate formation

Helping to maintain a clean internal pipeline surface and healthy pipeline environment 😊

‘Generally’ this all helps with internal corrosion management, but…
THE ROLE OF OPERATIONAL PIGGING

There are some exceptions to the rule:

• Depending on the operational conditions an internal pipe wall can develop protective oxide scales over time
• This helps to control new or developing corrosion threats
• Introducing pigging (or increasing pigging aggressiveness) can interfere with the formation of such protective scale, exposing the pipe surface to corrosion mechanisms
• This might be necessary (e.g. for ILI pigging)
• The post inspection treatment regime then becomes a critical follow-up (e.g. biocide treatment)

Other headaches can arise:

• Slugging affecting downstream facilities
• Debris & waste handling (e.g. NORM)
• Insufficient flow (slow flows / long pig runs)
• Challenging logistics
Pigging can help several with internal corrosion management several key ways.

This includes:
- Prevention of deposit build-up
- Prevention of water hold-up
- Deposit / debris sampling
- Preserving asset operability

Sometimes pigging is the primary mitigation (i.e. it can have more impact than CI or a chemical treatment alone)

There are also many side benefits to routine pigging…
# OPERATIONAL PIGGING CM BENEFITS

<table>
<thead>
<tr>
<th>Key Function / Task</th>
<th>Main Benefit</th>
<th>Additional Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevention of Deposit Build-up</td>
<td>Elimination of habitat for onset of associated corrosion mechanisms</td>
<td>Allows for optimisation of CCS elements</td>
</tr>
<tr>
<td></td>
<td>Improved CI effectiveness</td>
<td>Optimisation of chemical dosage rates</td>
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<tr>
<td></td>
<td>Improves effectiveness of chemical treatments</td>
<td>Optimisation of biocide deployment strategy</td>
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<tr>
<td></td>
<td>Reduction in pre-ILI cleaning requirements</td>
<td>Reduction of future cost and operational risks associated with ILI</td>
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<td></td>
<td></td>
<td>Improved ILI data quality</td>
</tr>
<tr>
<td>Prevention of Water Hold-up</td>
<td>Elimination of a key element required for a corrosion process</td>
<td>Allows for optimisation of other CCS elements</td>
</tr>
<tr>
<td></td>
<td>Reduced burden on topsides processing facilities (avoids slugging)</td>
<td>Reduced risk of bulk water carry-over to vulnerable downstream assets</td>
</tr>
<tr>
<td>Deposit / Debris Sampling</td>
<td>Monitoring for presence / type of corrosion products and bacteria</td>
<td>Leading indicator for the internal condition of pipelines</td>
</tr>
<tr>
<td></td>
<td>Monitoring for changes in pipeline operating conditions</td>
<td>Leading indicator for correct CCS set-up</td>
</tr>
<tr>
<td>Preserves Asset Operability</td>
<td>Maintains pipeline operability and operator’s familiarity with asset and operating procedures</td>
<td>Regular use and maintenance of pig traps and valves</td>
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<td>Active engagement of operator personnel in CMS process</td>
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</tbody>
</table>
However … routine pigging as part of CM (within a CCS) needs to be prescribed according to the identified corrosion threat(s)

- Start with a Corrosion Risk Assessment (CRA)
- Bring in other indicators to validate the CCS (e.g. ILI data)
- Use the correct tool(s) for the job:
  - Pig duty - e.g. for dewatering, deposit removal (wax / scale / sand & sediments etc.)
  - Correct Pig specification & sizing
  - Good pig maintenance
- Apply the optimum pigging frequency (need to consider the practicalities!!)
- Ensure timely follow-up at the receive location (e.g. pig recovery & trash analysis)
- Feedback to and update of CCS!
THE CMS FEEDBACK LOOP

- Required to feed corrosion control performance back into strategy
  - Optimisation of strategy
- Provides for timely change control of mitigation measures
  - Correct CI dosage, chemical treatments, pigging frequency etc. (CCMs)
- Provides focussed inspection strategy & frequency of routine & non-routine techniques
- Supports implementation of recommendations and corrective actions
- Optimises production, reliability, integrity and safety
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Internal corrosion in pipelines can be both **challenging and costly**

It requires **robust and diligent** approach

Implementation of an effective CMS can however **reduce operating costs** and environmental impact while maintaining both integrity and efficient and reliable pipeline operation

**Pigging** can also play a very important role in effectively managing internal pipeline corrosion in upstream pipelines

Can we do more with pigging here?

- Get more from trash analysis
- On-board product sampling
  - In addition to the usual operating data gathered by pig data loggers
- In-line deposit sampling
THAT’S ALL TODAY…
THANK YOU FOR JOINING THIS PRESENTATION.

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