Operational Pigging
A Frontline Tool to Control Internal Corrosion of Pipelines

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Paul Birkinshaw, MACAW Engineering
18th November 2015

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

INTRODUCTION

It is widely acknowledged that **operational pigging** is a key frontline O&M activity for controlling **internal corrosion** in oil and gas pipelines

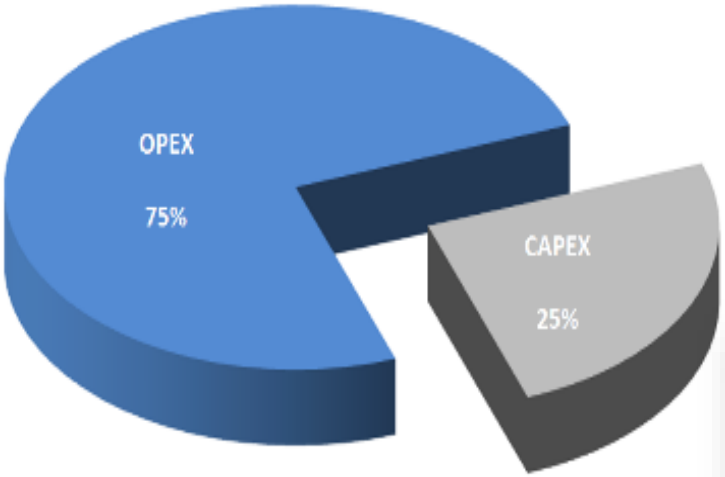
- The term operational pigging can cover a wide range of pigging operations
- In general it can be interpreted as ***'systematic online pigging for in-service pipelines as part of an established maintenance routine'***
- Operational pigging is often referred to as:
  - Production pigging
  - Routine pigging
  - Maintenance pigging
  - Combinations of the above
  - *Can also cover ILI Pigging*

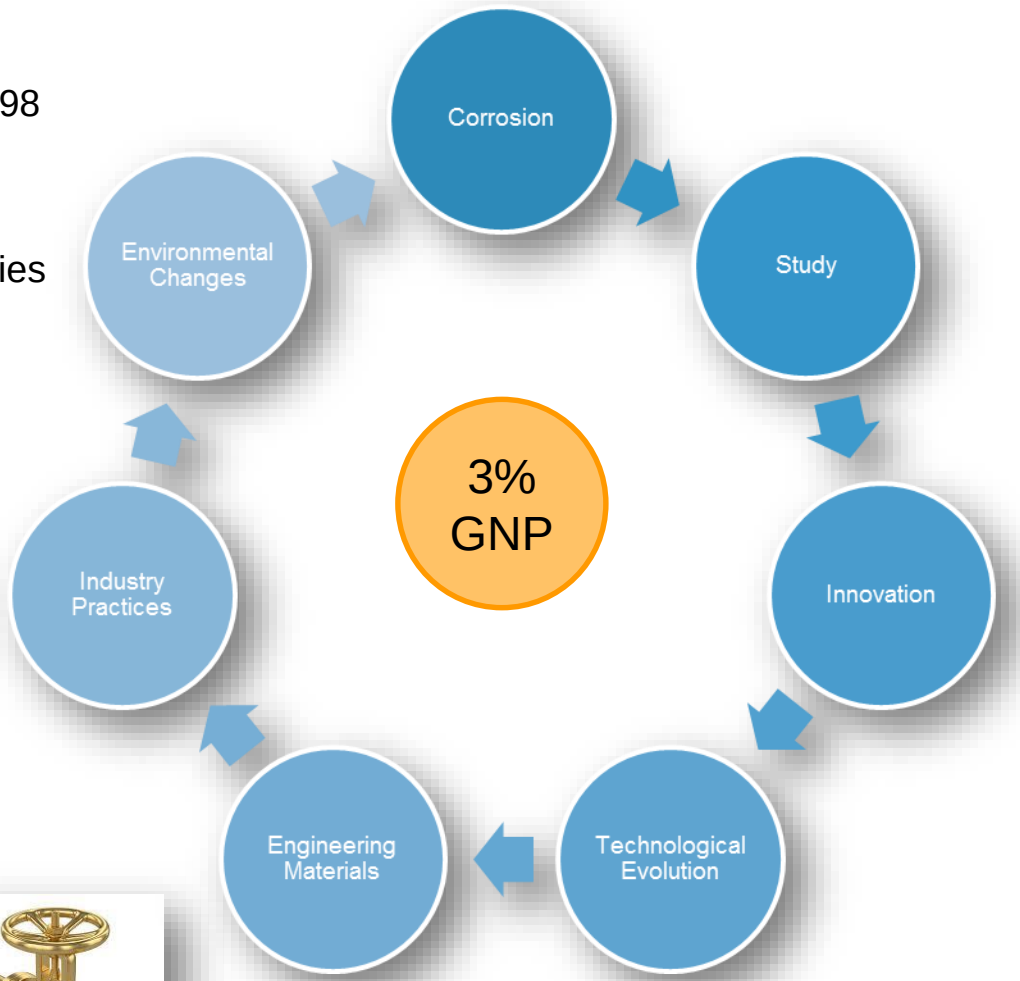
CONTENT

COST OF CORROSION

Science ➡ Mitigation ➡ Management

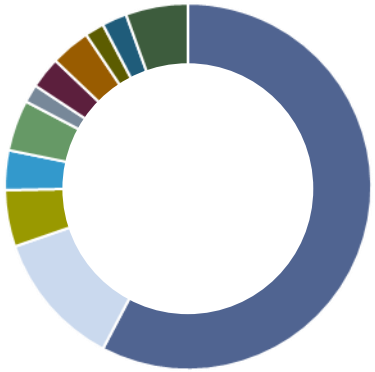
- $276B (NACE US Corrosion Costs Study 1998 – 3.1% GDP)
- ~30% can be prevented
- Elimination of corrosion by control technologies does not completely negate the overall economic cost
- Corrosion control cost analysis benefit balance…





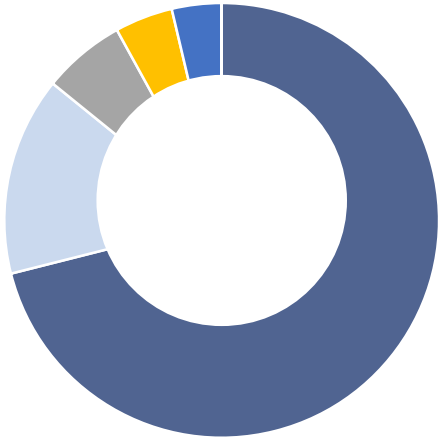
PIPELINE CORROSION STATISTICS

Main causes of pipeline failures



- Internal Corrosion
- External Corrosion
- Damage by others
- Weld
- Construction Damage
- Overpressure
- Pipe
- Joint
- Earth movement
- Valvefitting
- Other

Typical distribution of expenditure in pipeline corrosion activities



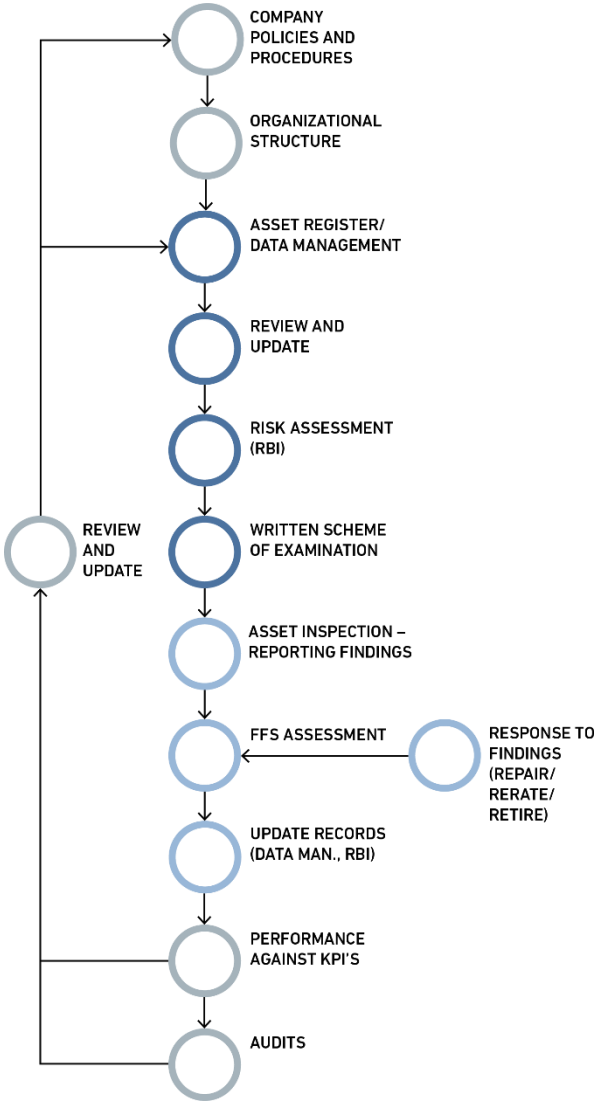
- Treatment Chemical
- Inspection
- Monitoring
- Staff
- Corrosion Repairs

Corrosion Management is important and costly

CORROSION MANAGEMENT

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

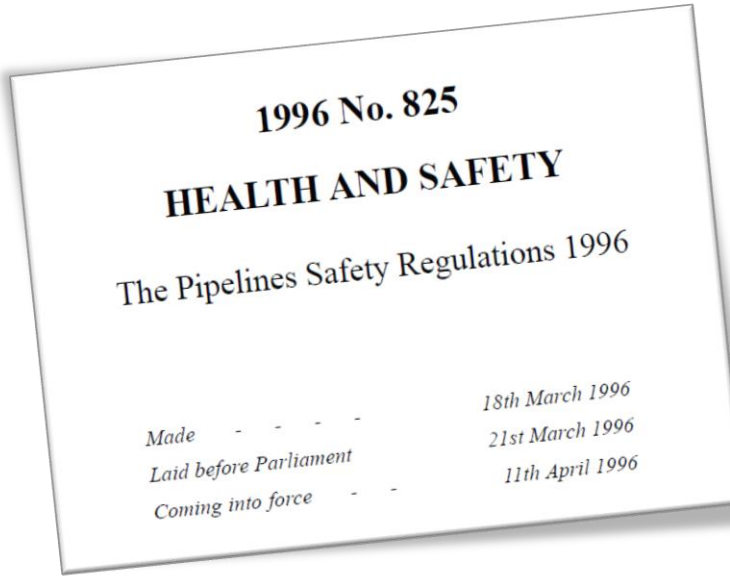
Recent HSE initiative – **KP4** programme

- Aging & Life Extension (ALE)

PIPELINE SAFETY REGULATIONS (PSR)

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



1996 No. 825

HEALTH AND SAFETY

The Pipelines Safety Regulations 1996

Made - - - - 18th March 1996

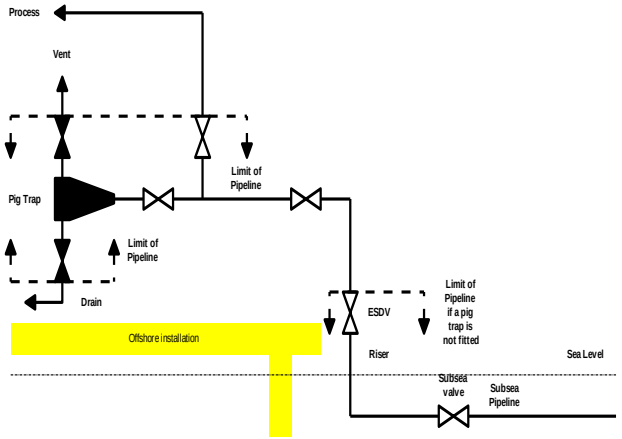
Laid before Parliament 21st March 1996

Coming into force - - 11th April 1996

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.*

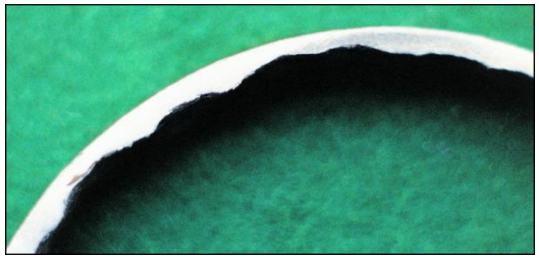


Clause 13 (Maintenance)

The operator shall ensure that a pipeline is maintained in an efficient state, in efficient working order and in good repair.

CONTENT

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

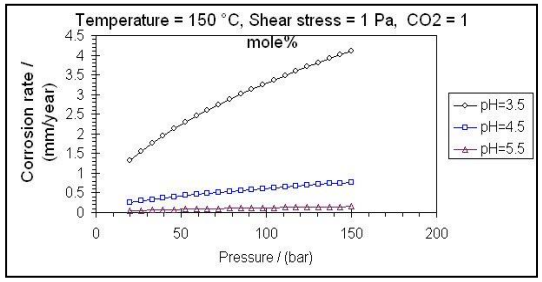
- Several serious **consequences** may then arise:
  - A **hazardous** condition
  - An **environmental** incident
  - **Loss** of production or service
  - **Reputational** damage

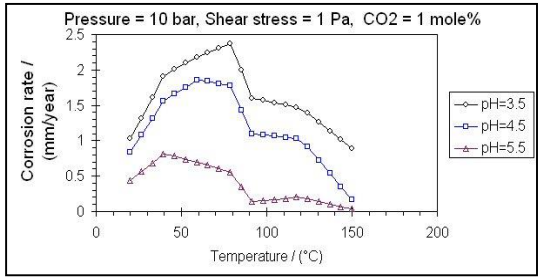
MANAGING INTERNAL PIPELINE CORROSION

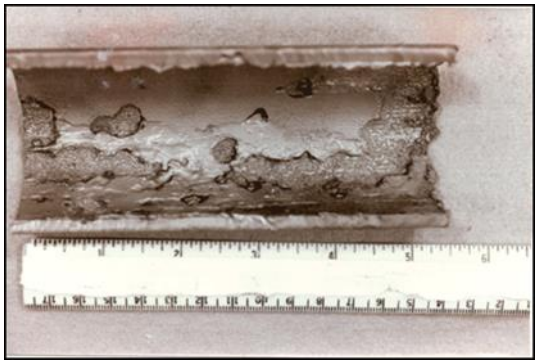
In pipelines, the main **internal corrosion** threats prevalent include:

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

MANAGING INTERNAL PIPELINE CORROSION







Example of CO2 corrosion on a riser

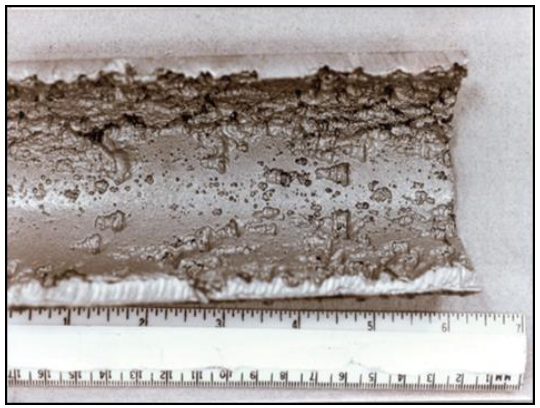
Sweet Corrosion (CO2)

Key mechanisms

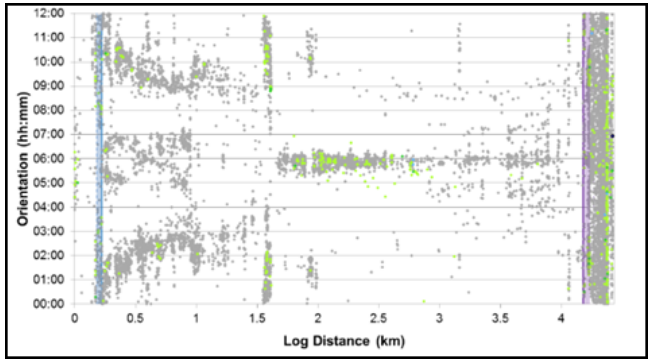
- CO2
- Water cut
- Operating temperature
- Operating pressure
- pH

Corrosion rates can be **modelled** and calculated (e.g. **NORSOK**)

MANAGING INTERNAL PIPELINE CORROSION



Example of CO2 corrosion caused by condensation



Sweet Corrosion (CO2)

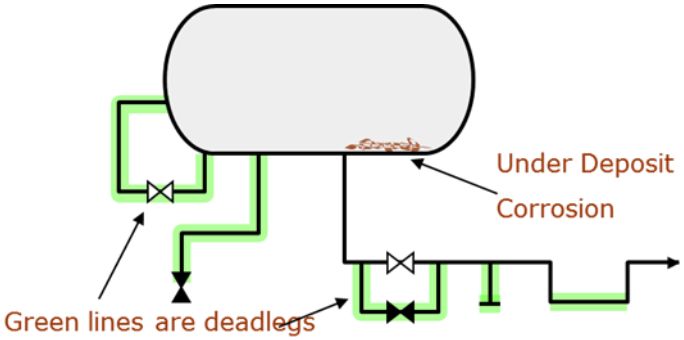
Hot Spots

- 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** (ö) (˙ ˙)~
- 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

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Bacterial levels are checked by specialists (**pig trash**)

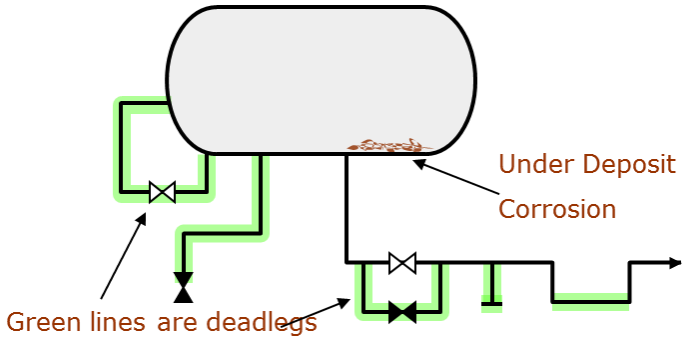
- SRBs (Sulphate Reducing Bacteria)
- APBs (Acid Producing bacteria)
- IRBs (Iron Related Bacteria)
- LNBs (Low Nutrient Bacteria)
- Etc.

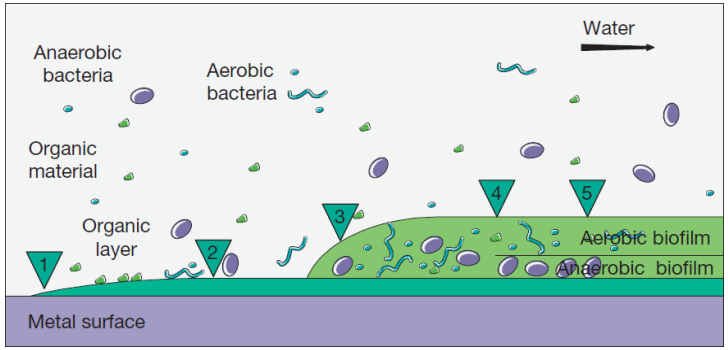
Planktonic vs. Sessile?

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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CONTROLLING INTERNAL PIPELINE CORROSION

- 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?

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

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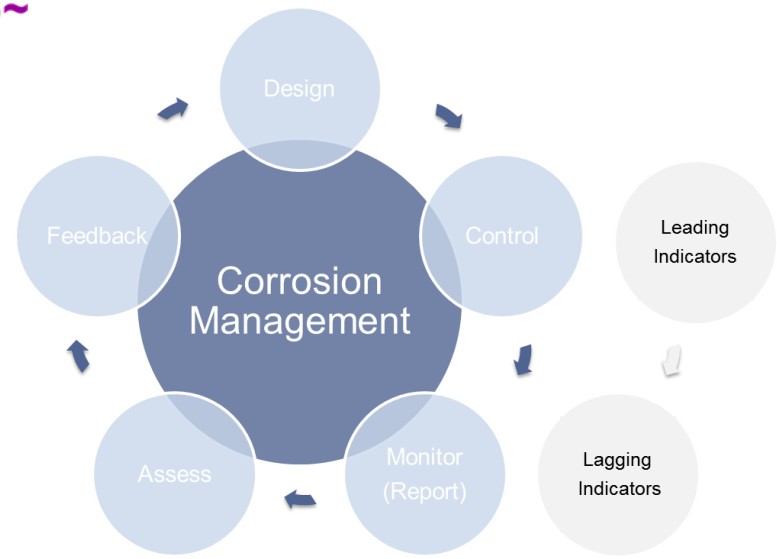
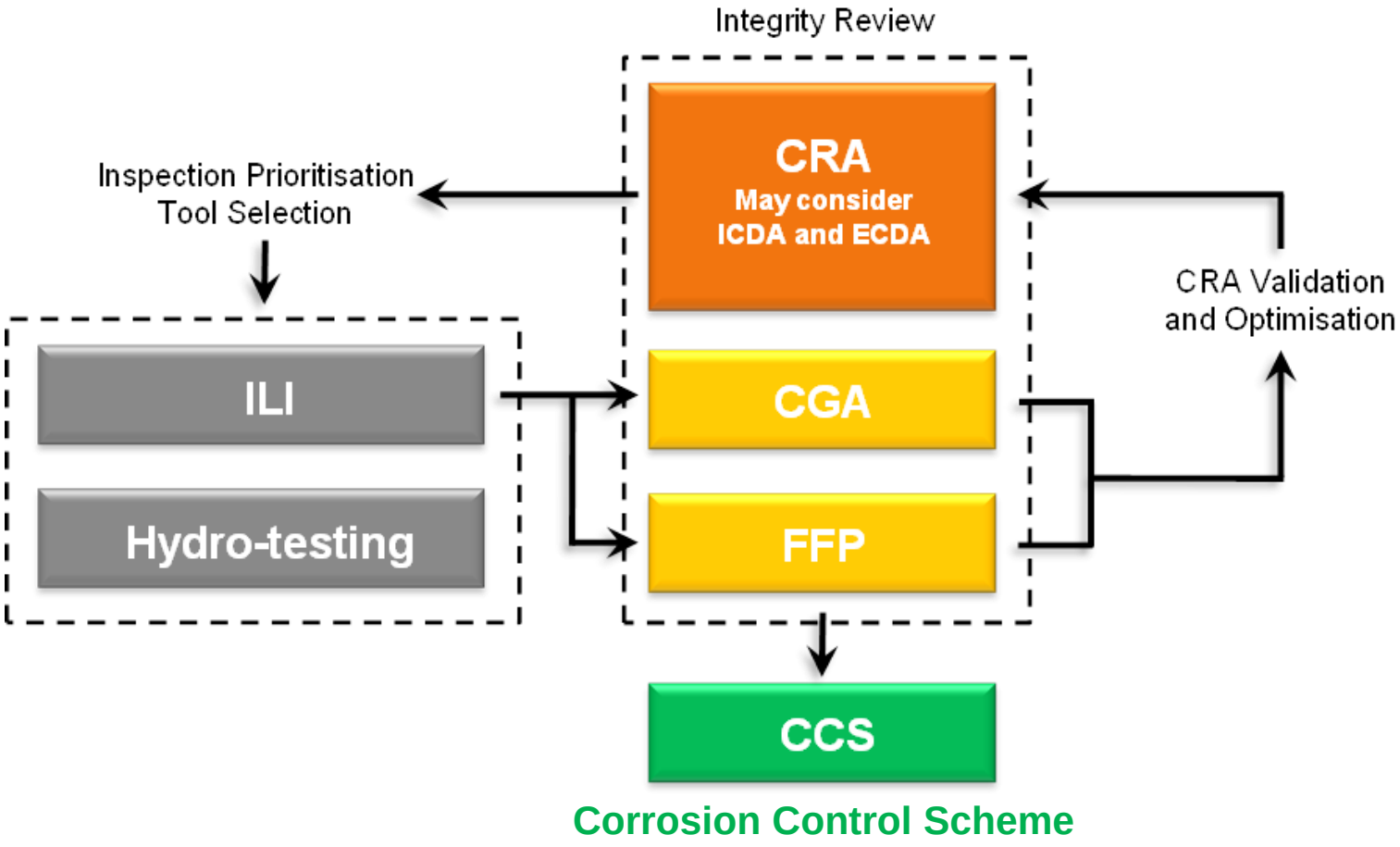
- What is the **remaining life** of the pipeline?
- What mitigation and repair strategies are required to **extend operational life**?

	Corrosion Threat		
	High	Medium	Low
Oxygen corrosion			
MIC			
Erosion			
Sweet Corrosion			
Sour Corrosion			



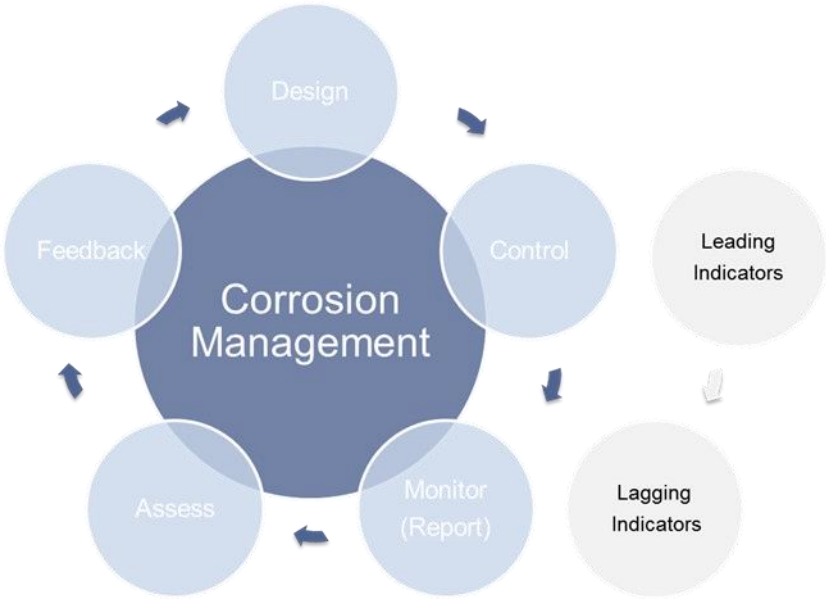
THE MACAW CORROSION CONTROL PROCESS



CCS - CORROSION CONTROL MATRICES

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

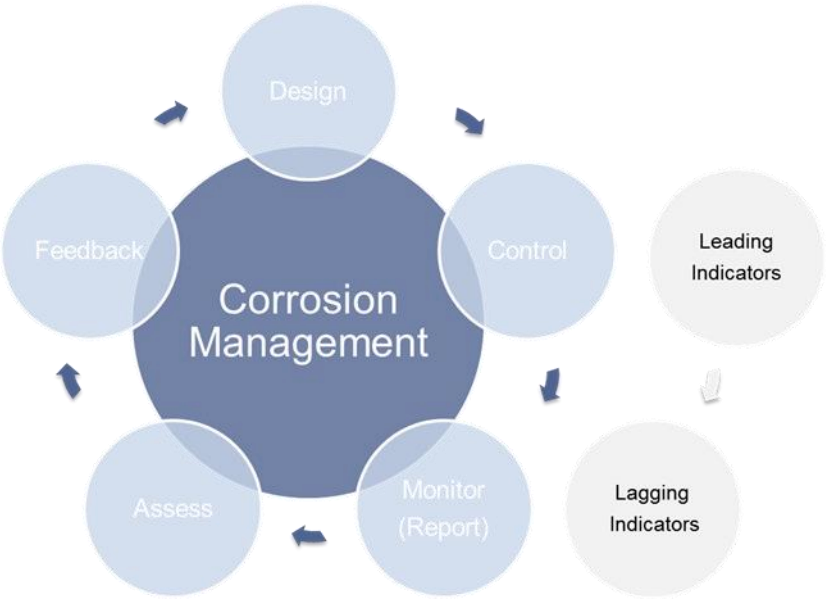
- **Threshold and target**
- Corrosion **threat if target is exceeded**
- Corrective **action if target is exceeded**
- **Responsible** person for remedial action

CCS - KEY PERFORMANCE INDICATORS

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

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CMS IMPLEMENTATION CHALLENGES

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

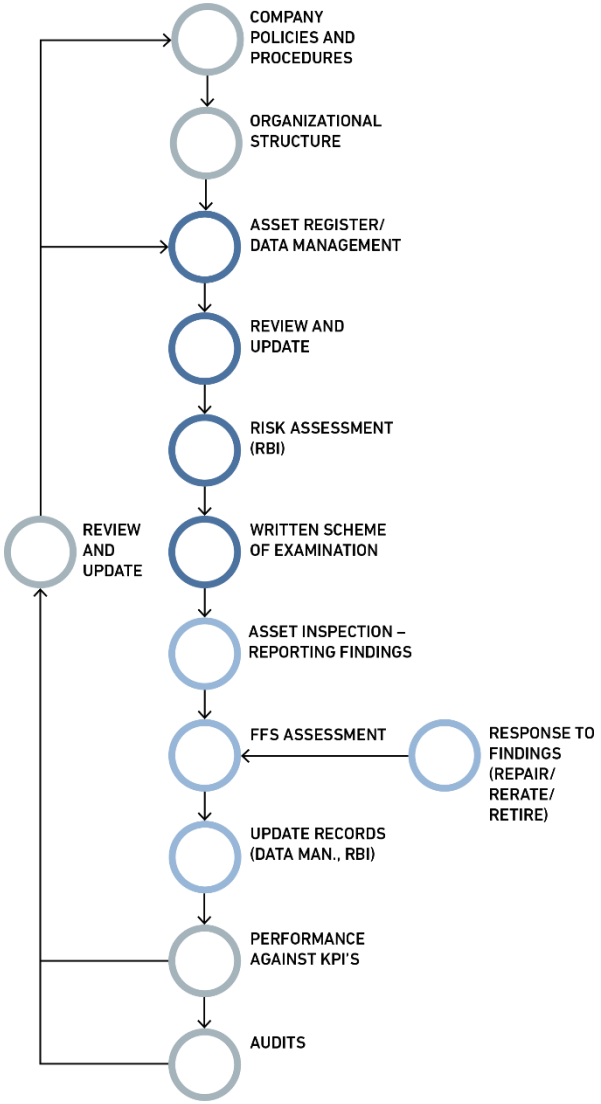
•Lack of visibility and readability of integrity status

•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:

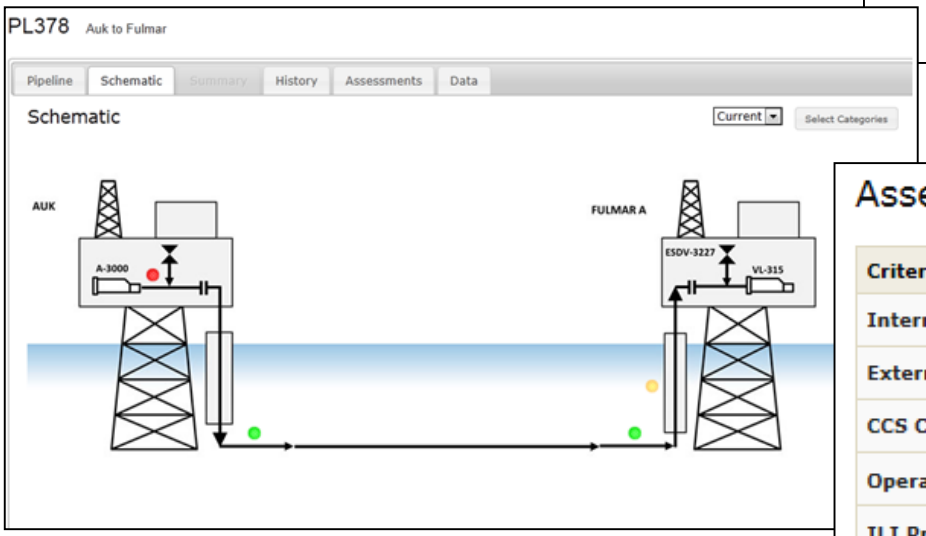
- Disjointed decisions across organisation
- Duplication of actions (not necessarily cost-effective)
- Lack of transparency and consistency in design, operation, inspection, monitoring, etc.

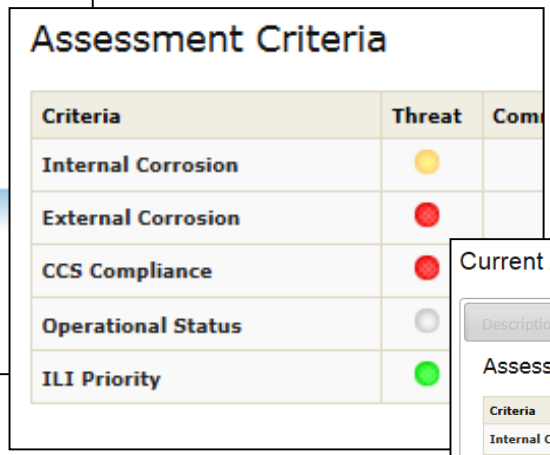


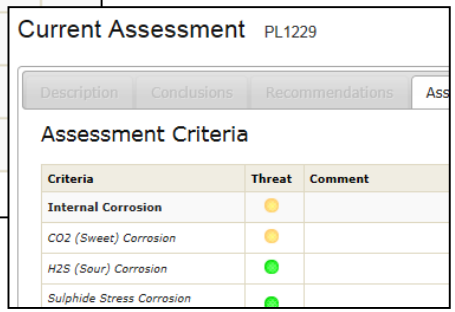
‘INTEGRITY VISUALISATION’ TOOL DEVELOPMENT

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







CONTENT

THE ROLE OF OPERATIONAL PIGGING

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**

THE ROLE OF OPERATIONAL PIGGING

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

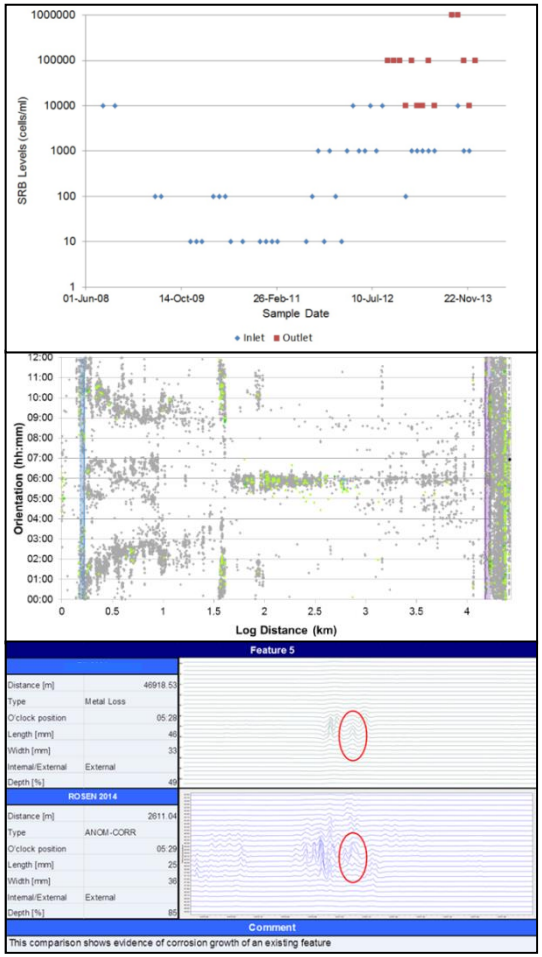
Key Function / Task	Main Benefit	Additional Benefits
Prevention of Deposit Build-up	Elimination of habitat for onset of associated corrosion mechanisms	Allows for optimisation of CCS elements
	Improved CI effectiveness	Optimisation of chemical dosage rates
	Improves effectiveness of chemical treatments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

OPERATIONAL PIGGING CM BENEFITS

However … **routine pigging** as part of CM (within a CCS) needs to be **prescribed** according to the identified corrosion threat(s)

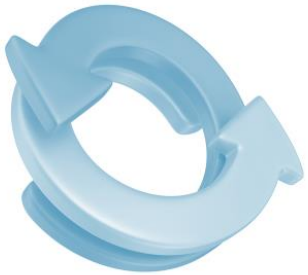
- Start with a Corrosion Risk Assessment (**CRA**)
- Bring in other indicators to **validate** the **CCS** (e.g. ILI data)

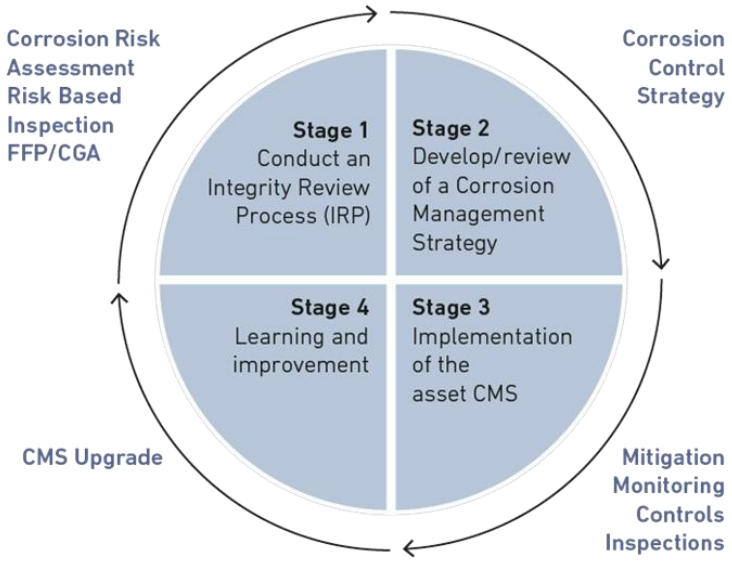
- Use the correct tool(s) for the job:
  - Pig duty - e.g. for dewatering, deposit removal (wax / scale / sand & sediments etc.)
  - Correct Pig specification & sizing
  - Good pig maintenance
- Apply the **optimum** pigging frequency (need to consider the **practicalities**!!)
- Ensure **timely follow-up** 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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SUMMARY

- Internal corrosion in pipelines can be both **challenging and costly**
- It requires **robust and diligent** approach

- Implementation of a 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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