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Risk Based Inspection (RBI) in Asset Integrity management - Overview

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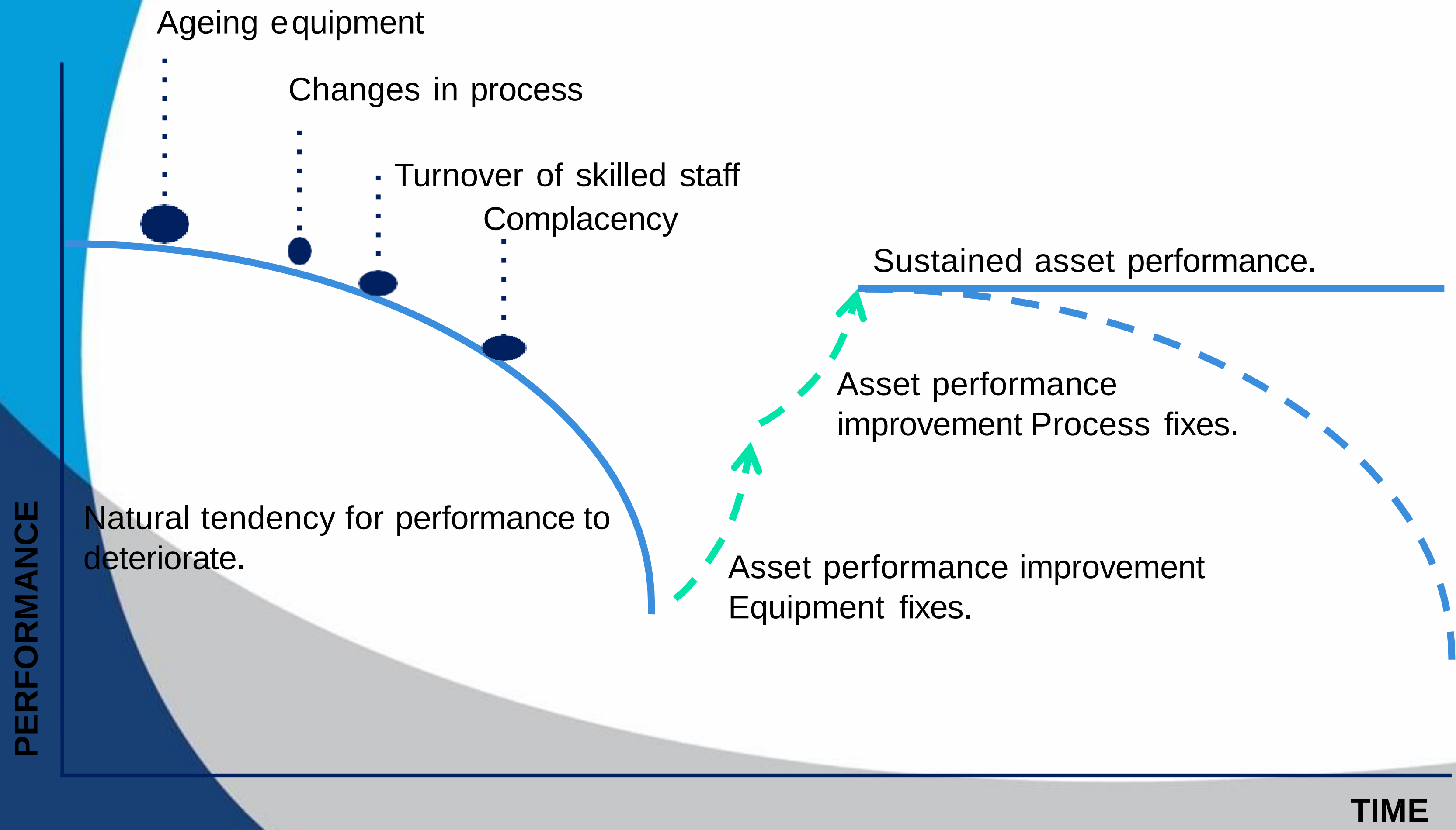
What is Asset Integrity Management?

ISO PAS 55:1 defines **asset** as an "item, thing or entity that has potential or actual value to an organisation".

Asset Integrity Management:UK Health and safety Executive defines Asset Integrity Management as the means of ensuring that the people, systems, processes and resources that deliver integrity are in place, in use and will perform when required over the whole lifecycle of the asset.

Why is Asset Management Important?



Asset management approach Overtime

AIM

Maintenance

1900s	1930s	1980s	2000s
- Fix it when it breaks	- Maintain it before it breaks - Regular, time-based maintenance routines	- RCM - Expert judgment - Predictive maintenance - Online condition monitoring - Enterprise systems	- Dynamic risk-based inspection plans - Predict condition of asset to end of life - “What if” analysis for future dates or different maintenance regimes - Predict repair or replacement date based on ‘acceptable’ risk
Reactive	Preventative	Proactive	Risk based

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O&G and Petrochemical AIM

- Structures – Structures Integrity Management System(SIMS).
- Pressure systems - (fixed, static or process equipment) – RBI.
- Other equipment- (rotating, electrical, instruments etc.) – RCM (Reliability Centred Maintenance).
- Pipelines – PIMS (Pipelines Integrity Management System).

Pressure vessels, columns, tanks, boilers, heat exchangers, piping etc.:

- pressure containment within the range of temperatures is the primary function.
- degradation rate may not be linear.
- failures can be instantaneous – impossible to predict, with potentially catastrophic outcome.

RBI Methodology

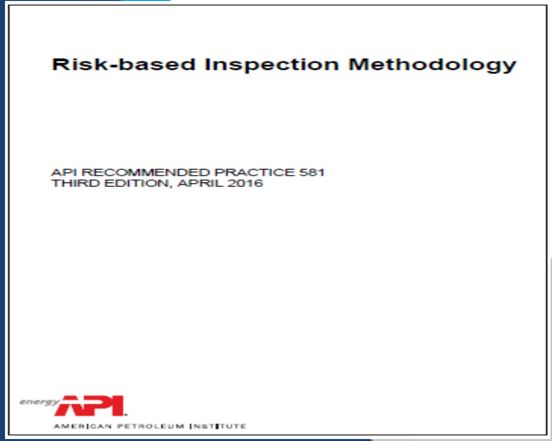
API RP 580


Risk-based Inspection

API RECOMMENDED PRACTICE 580
THIRD EDITION, FEBRUARY 2016

energy API
AMERICAN PETROLEUM INSTITUTE

API RP 581


Risk-based Inspection Methodology

API RECOMMENDED PRACTICE 581
THIRD EDITION, APRIL 2016

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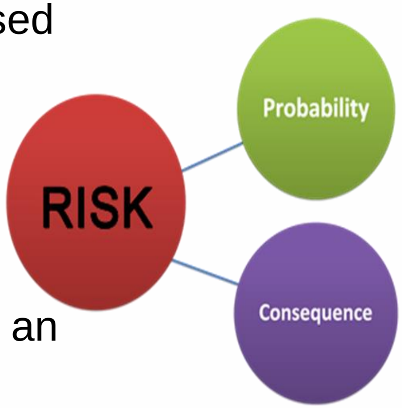
- The two standard defines RBI as a risk assessment and management process that is focused on loss of containment of pressurised equipment in processing facilities, due to material deterioration. These risks are managed primarily through equipment inspection.



- A loss of integrity (containment) could have an adverse impact on the safety of personnel, asset/facilities, environment or on production and revenue.

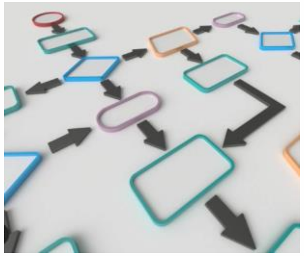
- Inspection efforts are focused on the process equipment with the highest risk.

- In other words; RBI is a systematic process to evaluate RISK and factoring it into concerning decisions of WHEN, WHERE and HOW to inspect.

RBI Methodology

Qualitative approach

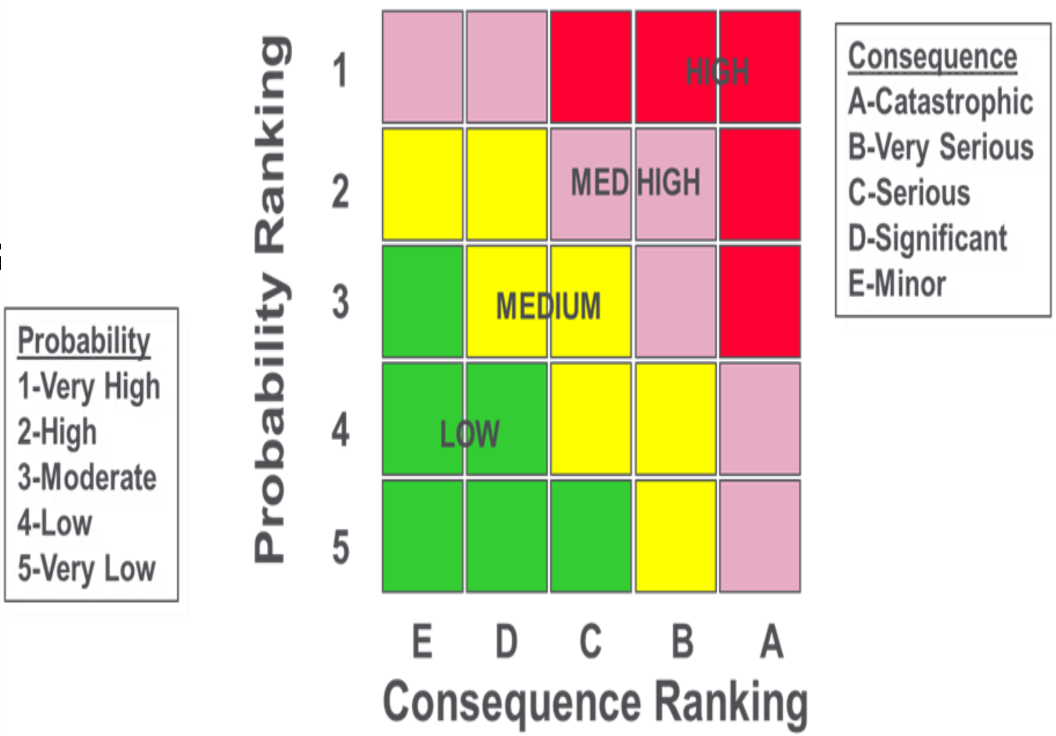
Quantitative Approach



Semi –Quantitative Approach

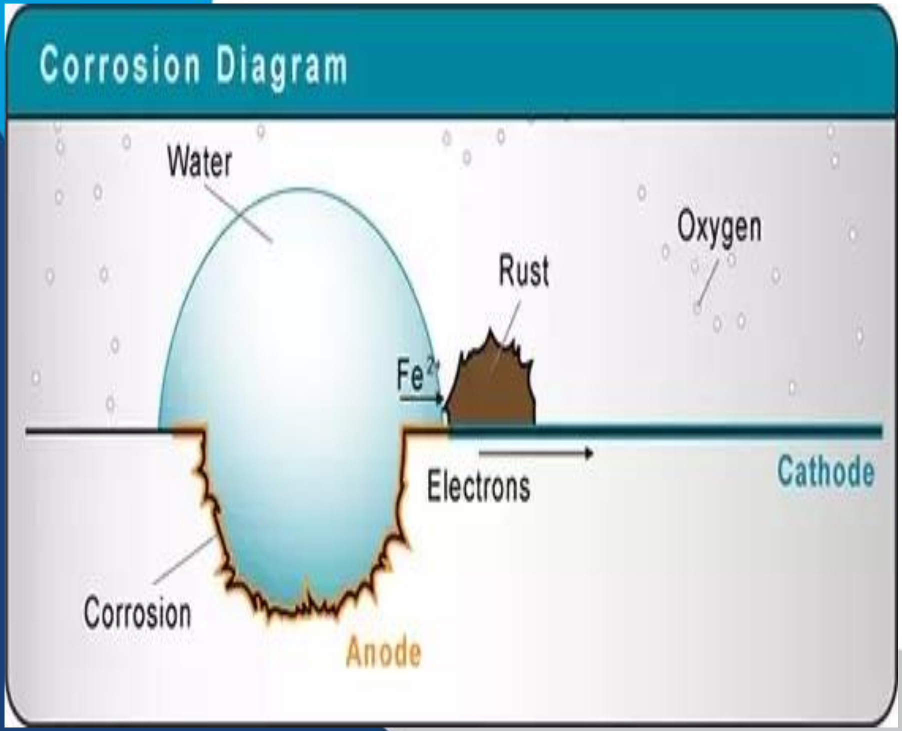
Steps to RBI Build FE and Piping Circuits

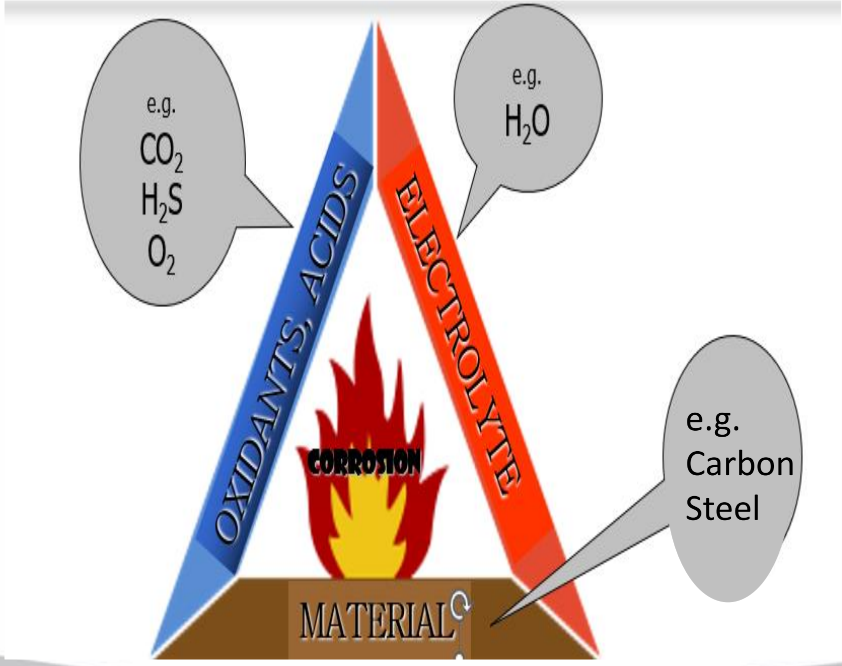
- Scope of work.
- Data gathering.
- Corrosion Risk Assessment.
  - Systemisation and Circuitis of Components.
  - Damage mechanism determination.
  - PoF Assessment.
  - CoF Assessment.
  - Risk Ranking.
- Inspection plan.



What is Corrosion

NACE/ASTM G193: Corrosion is the deterioration of material, usually a metal, that results from a chemical or electrochemical reaction with its environment.
An active material will corrode if exposed to oxidants or acids in presence of electrolyte.





The Corrosion triangle.

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Corrosion Control/Mitigation

Corrosion control is the principle of removing at least one of the three necessary components for corrosion to occur. This can be achieved by;

- Replacing steel with glass reinforced plastic pipework in seawater systems.
- Dehydration of gas/oil pipelines to remove free water that would allow internal corrosion.
- Keeping insulation dry to prevent corrosion under insulation.
- De-aerating (removal of oxygen from) seawater prior to downhole injection.
- Coating to isolate a metal from water

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Key to Damage Mechanisms – API 571

DM#	Damage Mechanism
1	Sulfidation
2	Wet H_2S Damage (Blistering/HIC/SOHIC/SSC)
3	Creep and Stress Rupture
4	High-temperature H_2/H_2S Corrosion
5	Polythionic Acid Stress Corrosion Cracking
6	Naphthenic Acid Corrosion
7	Ammonium Bisulfide Corrosion (Alkaline Sour Water)
8	Ammonium Chloride Corrosion
9	Hydrochloric Acid Corrosion
10	High-temperature Hydrogen Attack
11	Oxidation
12	Thermal Fatigue
13	Sour Water Corrosion (Acidic)
14	Refractory Degradation
15	Graphitization
16	Temper Embrittlement
17	Decarburization
18	Caustic Stress Corrosion Cracking
19	Caustic Corrosion
20	Erosion/Erosion-Corrosion
21	Carbonate Stress Corrosion Cracking (ACSCC)
22	Amine Stress Corrosion Cracking
23	Chloride Stress Corrosion Cracking
24	Carburization
25	Hydrogen Embrittlement
26	~~Steam Blanketing~~ Withdrawn. See #30.
27	Thermal Shock
28	Cavitation
29	Graphitic Corrosion of Cast Irons
30	Short-term Overheating—Stress Rupture (Including Steam Blanketing)
31	Brittle Fracture
32	Sigma Phase Embrittlement
33	885 °F (475 °C) Embrittlement
34	Spheroidization (Softening)
35	Stress Relaxation Cracking (Reheat Cracking)
36	Sulfuric Acid Corrosion
37	Hydrofluoric Acid Corrosion
38	Flue Gas Dew Point Corrosion
39	Dissimilar Metal Weld Cracking
40	Hydrogen Stress Cracking in Hydrofluoric Acid
41	Dealloying (Dezincification; Denickelification)
42	CO_2 Corrosion
43	Corrosion Fatigue
44	Fuel Ash Corrosion
45	Amine Corrosion
46	Corrosion Under Insulation
47	Atmospheric Corrosion
48	Ammonia Stress Corrosion Cracking
49	Cooling Water Corrosion
50	Boiler Water and Condensate Corrosion
51	Microbiologically Influenced Corrosion
52	Liquid Metal Embrittlement
53	Galvanic Corrosion
54	Mechanical Fatigue (Includes Vibration Fatigue)
54	Mechanical Fatigue (Includes Vibration Fatigue)
55	Nitriding
56	~~Vibration-Induced Fatigue-~~ Withdrawn. See #54
57	Titanium Hydriding
58	Soil Corrosion
59	Metal Dusting
60	Strain Aging
61	~~Sulfate Stress Corrosion Cracking~~ Withdrawn
62	Phosphoric Acid Corrosion
63	Phenol (Carbolic Acid) Corrosion
64	Ethanol Stress Corrosion Cracking
65	Gaseous Oxygen-enhanced Ignition and Combustion
66	Aqueous Organic Acid Corrosion
67	Brine Corrosion
68	Concentration Cell Corrosion
69	Hydrofluoric Acid Stress Corrosion Cracking of Nickel Alloys
70	Oxygenated Water Corrosion (Non-boiler)

Corrosion Risk Assessment methodology

Data Collection

- Design and construction data.
- Material selection records.
- Corrosion mitigation & monitoring records.
- Operating and process data.
- Inspection and maintenance history.
- Management of change (MOC) records.

Data Processing

- Assign corrosion loops and piping circuits.
- Populate spreadsheets.
- Identify damage mechanisms.

Risk Assessment

- Damage rate or likelihood.
- Consequences.
- Upload to RBI software/manually identify the risk.
- Risk ranking.

Example of RBI Build- Multiphase System

RBI RISK ASSESSMENT WORKSHEET					Probablilty of Failure			Consequence of Failure			Risk Assesment - Unmitigated			Mitigation	Risk Assesment - Mitigated			
Syst	Item	Features / Sub componen	Failure Mechanis	Failu Mo	Means Of Estima	Probabi	Justification	Category	Level	Justification	Impa	Probabil	Risk	Risk Mitigati	Impa	Probab	Ris	Comments
Multiphase	2nd Stage Separator	LTCS +3mm CA (NACE) Operating at 76degC, 5.5barg	External - General Atmospheric Corrosion	Leak	Semi-quantitative approach. Inspection history, Client's procedure and engineering judgement.	4	**Assumptions:** For the unmitigated case, it is assumed that no design corrosion allowance is included for the vessel and that no coating is applied to the external surface of the shell. **Considerations:** The item (vessel) and all its external features are exposed to general atmospheric corrosion. PoF is medium/likely (4). Corrosion rate of 0.127mm/yr >0.1mm/yr <= 0.5mm/yr).	Safety and health Impacts Environmental Impact Financial Impact	S1 E2 F4	Significant - Reputation - Regional media attention Pinhole leak - May cause Significant injury & result in reversible health effects Minor - Reportable incident to regulator with follow up Loss of 2 week full production (including repair cost) Impact is based on Financial category	4	4	22	Barrier-Coating + CA	4	1	9	**History:** **Condition: Judgement**
Multiphase	2nd Stage Separator	LTCS +3mm CA (NACE) Operating at 76degC, 5.5barg	Internal - CO2/H2S Corrosion	Leak	Semi-quantitative approach based on NORSOK M506, heat/mass balance data and client's procedure	5	**Assumptions:** Uninhibited corrosion rate of 0.48 mm/yr (based on Temp 68 degC, Pressure 5 barg, 5 mole% CO2, Shear stress 1Pa, pH 6.1). **Considerations:** The PoF is medium (4) according to table F-1, 0.1mm/yr<0.48mm/yr <= 0.5mm/yr.	Safety and health Impacts Environmental Impact Financial Impact	S1 E2 F4	Significant - Reputation - Regional media attention Pinhole leak - May cause Significant injury & result in reversible health effects Minor - Reportable incident to regulator with follow up Loss of 2 week full production (including repair cost) Impact is based on Financial category	4	5	24	Barrier-CI Injection + CA	4	3	18	**History:** **Condition: Judgement**
Multiphase	2nd Stage Separator	LTCS +3mm CA (NACE) Operating at 76degC, 5.5barg	Internal - MIC	Leak	Qualitative approach. Engineering Judgement and client's RBI Procedure.	3	**Assumptions:** Assume water and solids such as sand/scale/etc. are present in fluid mixture. Assume unmitigated case with no biocide injected. **Considerations: R**ecent microbiological survey enumerated high levels of SRB, GHB and APGHB. A high sulphide and H2S result suggest the presence of metabolically active SRB with a high potential for corrosion.	Safety and health Impacts Environmental Impact Financial Impact	S1 E2 F4	Significant - Reputation - Regional media attention Pinhole leak - May cause Significant injury & result in reversible health effects Minor - Reportable incident to regulator with follow up Loss of 2 week full production (including repair cost) Impact is based on Financial category	4	3	18	Barrier-Unmitigated	4	3	18	**History:** **Condition: Judgement**
Multiphase	2nd Stage Separator	LTCS +3mm CA (NACE) Operating at 76degC, 5.5barg	Internal - Underdeposit Corrosion	Leak	Qualitative approach. Engineering Judgement and client's Procedure.	5	**Assumptions:** Assume water and solids such as sand/scale/etc. are present in fluid mixture. Assume that internal corrosion threats exist (CO2, H2S, MIC). Assume unmitigated case with no biocide injected. **Considerations:** Based on the assumptions, the MIC threat rated in accordance with client's procedure is a high. PoF (5).	Safety and health Impacts Environmental Impact Financial Impact	S1 E2 F4	Significant - Reputation - Regional media attention Pinhole leak - May cause Significant injury & result in reversible health effects Minor - Reportable incident to regulator with follow up Loss of 2 week full production (including repair cost) Impact is based on Financial category	4	5	24	Barrier-Unmitigated	4	3	18	**History:** **Condition: Judgement**
Multiphase	2nd Stage Separator	LTCS +3mm CA (NACE) Operating at 76degC, 5.5barg	Internal - Sand Erosion	Leak	Qualitative approach. Engineering Judgement and client's Procedure.	5	**Assumptions:** With no data on vessel/nozzle velocities available, assume that some velocites are within erosional limits. Assume no CA for unmitigated case. **Considerations:** Sand has been reported during earlier life, no understanding of current sand behaviour as no sand monitoring in place. Considering the history of sand and exercising engineering judgement a high PoF (5) can be assigned.	Safety and health Impacts Environmental Impact Financial Impact	S1 E2 F4	Significant - Reputation - Regional media attention Pinhole leak - May cause Significant injury & result in reversible health effects Minor - Reportable incident to regulator with follow up Loss of 2 week full production (including repair cost) Impact is based on Financial category	4	5	24	Barrier-CA	4	4	22	**History:** **Condition: Judgement**

Inspection Plan

Inspection planning is determined by the following,

- Scope – what to inspect.
- Location –where to inspect.
- Extent – how much to inspect.
- Frequency – when to inspect.
- Method/techniques – how to inspect.

Inspection results (identification of damage mechanisms, rates of deterioration etc) should be used for comparison or validation of initial PoF assessment.

Example of inspection Plan

5 Year Inspection Plan – Fixed Equipment

	2024					2025				2026			2027			2029					2030			2031						2032
Equipment ID	Inspection - IVI	Inspection - NII	Inspection - Sample WT measurements	Inspection - Visual	(blank)	Inspection - IVI	Inspection - NII	Inspection - Visual	(blank)	Inspection - NII	Inspection - Sample WT measurements	Inspection - Visual	Inspection - IVI	Inspection - NII	Inspection - Visual	Inspection - IVI	Inspection - NII	Inspection - Sample WT measurements	Inspection - Visual	(blank)	Inspection - IVI	Inspection - NII	Inspection - Visual	Corrosion Monitoring	Inspection - IVI	Inspection - NII	Inspection - Sample WT measurements	Inspection - Visual	(blank)	Inspection - IVI
H-4501																														
External - Chloride Pitting													1																	
External - ClSCC													1																	
External - General Atmospheric Corrosion				3																										
Internal - CO2/H2S Corrosion													2																	
Internal - Galvanic Corrosion																														
Internal - MIC																														
Internal - Organic Acid Corrosion													1																	
Internal - Pref. Weld Corrosion													1																	
H-4502													4																	
H-4503A																4														
H-4503B								2																						
H-4504A																4														
H-4504B								2																						
H-4505A																4														
H-4505B																												2		

Benefit of RBI

- Develop mitigation plans to manage risks at the equipment level.
- Enable overall reduction in risk for the equipment assessed.
- Improve understanding of current risk.
- A tool for continuous improvement.
- Increased efficiency of performed inspections and cost. optimisation by prioritisation.

Key Takeaways from experience

- Dynamic risk demands an adaptable RBI process to incorporate changes in operations, process fluids or equipment modifications.
- Inspection does not reduce risk directly, but it is a risk management activity that may lead to risk reduction.
- Prioritise inspection frequency based on the highest-risk damage mechanism, which may influence the inspection of others.
- Using CRA materials often increases inspection frequency but makes inspections more challenging.
- Despite using CRA materials, the first in-service inspection is vital to detect fabrication defects.
- The inspection plan or WSE should specify the relevant damage mechanisms, exact locations and techniques for validating them.

Key Takeaways from experience

- Selecting the right locations and techniques is crucial in RBI, as inspecting unlikely spots with improper method is ineffective.
- When assessing damage mechanisms, avoid unlikely scenarios that are difficult to detect with NII, as they can complicate the. For instance, detecting internal stress cracking in CRA-clad vessels via NII is nearly impossible without IVI.
- Changes in conditions could lead to unexpected failure under extreme conditions, even if an inspection doesn't reveal any issues.
- One damage mechanism may progress to a point where another mechanism takes over, like pitting leading to stress corrosion creaking.
- A recent inspection is most accurate for current conditions. If operating conditions change, deterioration rates may no longer be valid, requiring a revised PoF assessment.

Thank you

Any Questions?