Integrity Management and Risk Based Inspection of facilities

We take care of values that create value
Agenda

• Asset integrity management
• Risk Based Inspection (RBI)
• Risk Based Analysis
  – PoF, CoF, Risk
  – Time to next inspection
• Mitigating actions
  – Inspection
  – Monitoring
Why focus on integrity management?

• Eliminate unplanned shutdowns
• Improve plant performance – high uptime
• Optimise inspection and maintenance intervals
• Focus on area/equipment that needs closer follow-up
• Reduce cost because of focus on highlighted areas/equipment
• Determine the remaining lifetime of the asset/equipment
Integrity management

- A multidisciplinary exercise
Integrity management

INTEGRITY MANAGEMENT
- Topside inspection management
- Risk based inspection (RBI)
- Pipeline & subsea inspection management
- Well corrosion management
- Integrity project management

STRUCTURE
- Design
- Reassessment/modification
- Third party verification
- Global/local analyses

INSPECTION / MONITORING
- NDT inspection
- Advanced inspection
- NDT certification of inspectors & equipment
- Load & response sensors
- Monitoring systems

MATERIALS
- Material selection/verification
- Cathodic protection (CP)
- Coating & surface protection
- Corrosion control
- Laboratory service (testing/analyses)
- Failure assessments
Inspection planning
Perform inspection planning, execution and reporting of subsea inspections

Risk Based Analysis
Perform RBI for subsea and pipelines structures, both internal and external analysis.

Inspection services
GVI and NDT, Advanced NDT methods (ANDT)

Flexible riser integrity
VGM, PCM, Motion monitoring, structural analysis

Inspection planning
Perform inspection planning, execution and reporting of topside inspections

Risk Based Analysis
Perform RBI for pipework and equipment, both internal and external analysis.

FiGS surveys (CP)
Full CP inspection and modelling of all structures and pipelines (remaining life, time to next inspection, predict risk, optimize cost)

Advanced NDT (ANDT)
Various scanners and NDT sensors to detect and verify condition or defects

Corrosion modelling
Internal corrosion modelling, analysis, prediction and if-what with Software (CorPos)

Structural analysis
Free-span of pipelines, remaining life, FEED, conductors, wellhead fatigue etc.

Monitoring & sensor systems
Strain, movement, vibration etc.
Integrity management

- A multi-company exercise
  - Good cooperation between different contractors is essential for a successful integrity management process
How is integrity management performed?

- Systematic data management
  - Inspection and process parameters
- Process parameters vary by time
  - Should be followed up regularly
  - Traffic lights

- Tools
  - Software
  - Databases
  - NDT tools

Documentation
Asset Integrity Management

**Strategy**
- Risk based analysis/assessments (RBA)
- Define roles and responsibilities
- Define KPI’s and procedures

**Planning**
- Risk based inspection planning (RBI)
  - Inspection programs (NDT Inspections)
  - Corrosion and erosion monitoring programs (Corrosion probes)
  - Process monitoring programs (Chemical (MIC, Oxygen))
  - Vibration monitoring programs
  - Chemical treatment mitigation programs
  - Surface protection mitigation programs

**Analysing**
- Follow-up of inspection and findings
  - Fitness for Service and special studies (structural, materials, corrosion)
  - Failure assessment (laboratory testing and investigation)

**Reporting**
- Reporting and data gathering
  - Use the Integrity Management System (SAP/Workmate) to report KPI’s and data from inspection activities
  - Establish and follow-up corrective actions and mitigation activities
  - Collect, measure and evaluate monitoring/process data and prepare status reports and improvements

**Execution**
- Inspection (visual, NDT and monitoring)
  - Implementation and execution of the planned activities for inspection programs
RBI – Why Risk Based Inspection?

- Benefit for the Operator
  - Safe operation and reduced cost
- Focus inspection in High Risk systems
  - Based on safety, environmental or financial consequences
  - Reduce inspection in less critical systems
- Optimal planning of the inspection activity
  - Identify relevant degradation mechanisms
  - Apply the best inspection or monitoring method to mitigate the risk
What is Risk Based Inspection (RBI)?

- Risk Based Analysis
  - Risk
    » CoF
    » PoF
  - Time to next inspection
- Inspection planning
  - Risk based
- Corrosion Monitoring

\[ R = \text{CoF} \times \text{PoF} \]

» CoF: Consequence of Failure
» PoF: Probability of Failure
# Risk Matrix

The Risk Matrix is a tool used to assess and prioritize risks based on their potential consequences and likelihood of occurrence. It categorizes risks into five levels:

- **VH** - Very High Risk
- **H** - High Risk
- **M** - Medium Risk
- **L** - Low Risk
- **N** - Negligible Risk

## Probability (PoF) vs. Consequence (CoF)

<table>
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<th>B</th>
<th>C</th>
<th>D</th>
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### Probability (PoF) vs. INTERVAL

<table>
<thead>
<tr>
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<th>C</th>
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<td>RoF</td>
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RBI methodology is relevant for

- Process and utility systems
  - Pipework
  - Tanks/vessels
  - Coolers/Heat exchangers
  - Filters etc.
- Structures
- Pipelines
- Subsea installations
- Normally not rotating equipment
  - Pumps, compressors etc.
Detailed risk assessment - topside

- Define Risk of Failure for all tags
  - Pipework, tanks, vessels etc.
- CoF
  - Personnel/Safety
  - Environment
  - Economy
- PoF
  - Failure mechanisms
    » All relevant failure mechanisms
- Required information
  » Design/process parameters, fluid and shut down
  » Material, operating conditions, experience and inspection history
• Analysis group (loop)
  - Almost the same PoF
    » Same material
    » Approximately same process parameters
• Main purpose
  - Efficient PoF assessment
  - Simple update of process data
• Each pipe tag is assigned to a group
• Equipment is assessed individually
PoF assessment - Degradation Mechanisms

• Corrosion
  - General
  - Pitting
  - Crevice
  - Galvanic
  - Hydrogen embrittlement
  - Sulphide stress cracking (SSC)
  - Stress corrosion cracking (SCC)
  - Corrosion under Insulation (CUI)
  - MIC
  - CO$_2$/H$_2$S corrosion
  - ....

• Flow induced degradation
  - Particle erosion
  - Water/Droplet erosion
  - Cavitation

• Mechanical failure
  - Fatigue
    - Vibration
  - Brittle fracture

• Other failure mechanisms
RBI – Tanks and Vessels

• Basically the same method as for pipework
  – Separate assessment of individual parts
  – Different environments

• CoF
  – Separate CoF assessment

• PoF
  – Corrosion modelling
  – Inspection history
  – Experience
    » Acceptance criteria for maximum corrosion

• Inspection
  – Interval from Risk Matrix
  – Internal inspection might be a challenge
Inspection example

- Separator
  - Visual inspection
  - RT
  - UT
Inspection example

- Tank in type 316 stainless steel
- Seawater exposure
Inspection example

• Pipework
  - Duplex stainless steel
  - Fatigue crack
Monitoring

- Monitoring
  - Supplement to inspection
  - Alternative to inspection
- Inspection not efficient to ensure integrity
  - Failure mode
- Methods
  - Corrosion monitoring
  - Process monitoring
    » KPIs
    » Process/operational parameters
- Where and what to monitor
  - Risk assessment
Monitoring - Example

• To mitigate the probability of corrosion on CRAs
  – Localised corrosion
  – Random appearance
    » Fixed inspection points are in appropriate

• Initiation and growth of corrosion
  – Result from process or operational parameters exceeding critical levels
    » Temperature, oxygen content, etc.

• Monitoring programme
  – To control internal degradation

• External cracking can be managed by inspection
  – Stress corrosion cracking
  – Fatigue
FORCE RBI database (RuBl)
Inspection planning

- Baseline inspection
  - New installations
  - Verify initial condition of the installation
  - In addition to RBI programs
- Long term plan
  - Runs for several years
  - Describes inspection year for equipment and pipework
- Annual plan
  - Describes equipment and pipework to be inspected that year
  - Specifies time of inspection
Inspection Planning

• Result from the RBA
  - Time to next inspection for each tag
  - Degradation mechanism
  - Material/dimension/medium/coating/insulation etc.

• Inspection Planning
  - Number of inspection points, locations
  - Inspection method
  - Inspection frequency
  - Inspection drawings
  - Accessibility
  - Accept criteria
  - Reporting
Inspection Methods

- The most common inspection methods
  - Visual control (GVI, CVI)
  - Ultrasonic Testing (manual, TOFD)
    » P-scan (automated UT scan)
  - Radiographic Testing (isotope, RT, digital)
  - Eddy Current
  - Magnetic Particle Testing
  - Penetrant
  - Thermography
- Method selection
  - Dependent on expected failure mechanism
Inspection drawings

- Inspection drawings
  - Based on ISO drawings
  - Composite ISOs
- Inspection points
  - In accordance with the inspection plan
  - Unique numbers on each drawing
Inspection reporting

- High quality reports are necessary
- Simple and unambiguous criteria must be defined
  - Visual Inspection example
    » Grade 0 OK
    » Grade 1 Coating damage
    » Grade 2 General corrosion (< 1 mm)
    » Grade 3 Severe corrosion (1-3 mm)
    » Grade 4 Very severe corrosion (> 3 mm)
- All findings must be verified and included in the report
  - Description of the finding
  - Exact location
  - Wall thickness measurements
Inspection program update

- Need for update of RBA and inspection plan
  - Changes in process data
    » Modifications to process or production
    » Altered risk
  - Data from corrosion and erosion monitoring
  - Inspection results
  - History/incidents
    » Inspection/maintenance

- Update/optimize
  - Inspection frequencies
  - Number of inspection points
  - Locations

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**RBI Analysis** → **Inspection program** → **Implementation Work Packs** → **Execute inspection** → **Evaluate results** → **Actions** → **Follow-up actions/plans** → **Update Inspection Program**