Valhall Corrosion Events and Management

Learning Pack

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Valhall Corrosion Events - Summary

Summary

- Hydrocarbon leak HIPO on 6th March 2009 caused by Microbial Induced Corrosion (MIC)
  - resulted in crude and gas leak, First Aid Incident, emergency plant shutdown & muster.
- Valhall eventually shutdown for 10 weeks for corrosion inspection and repairs.
  - during which three further incidences of MIC and 44 anomalies identified.

Major Lessons

- **Behaviours of MIC were misunderstood**
  - Areas of high flow rate were previously thought unlikely to experience MIC, this assumption failed to identify internal pipe work scaling can provide environment for MIC activity.
- **Inadequate application of hazard Recognition, risk awareness and control of work**.
  - The initial inspection routine was inappropriate and directly led to exposure of the individual and the resultant FAI.
- 15 specific improvement opportunities identified as a result of the incident and plant investigations (7 organisational, 5 work process and 3 performance management).

Microbial Induced Corrosion

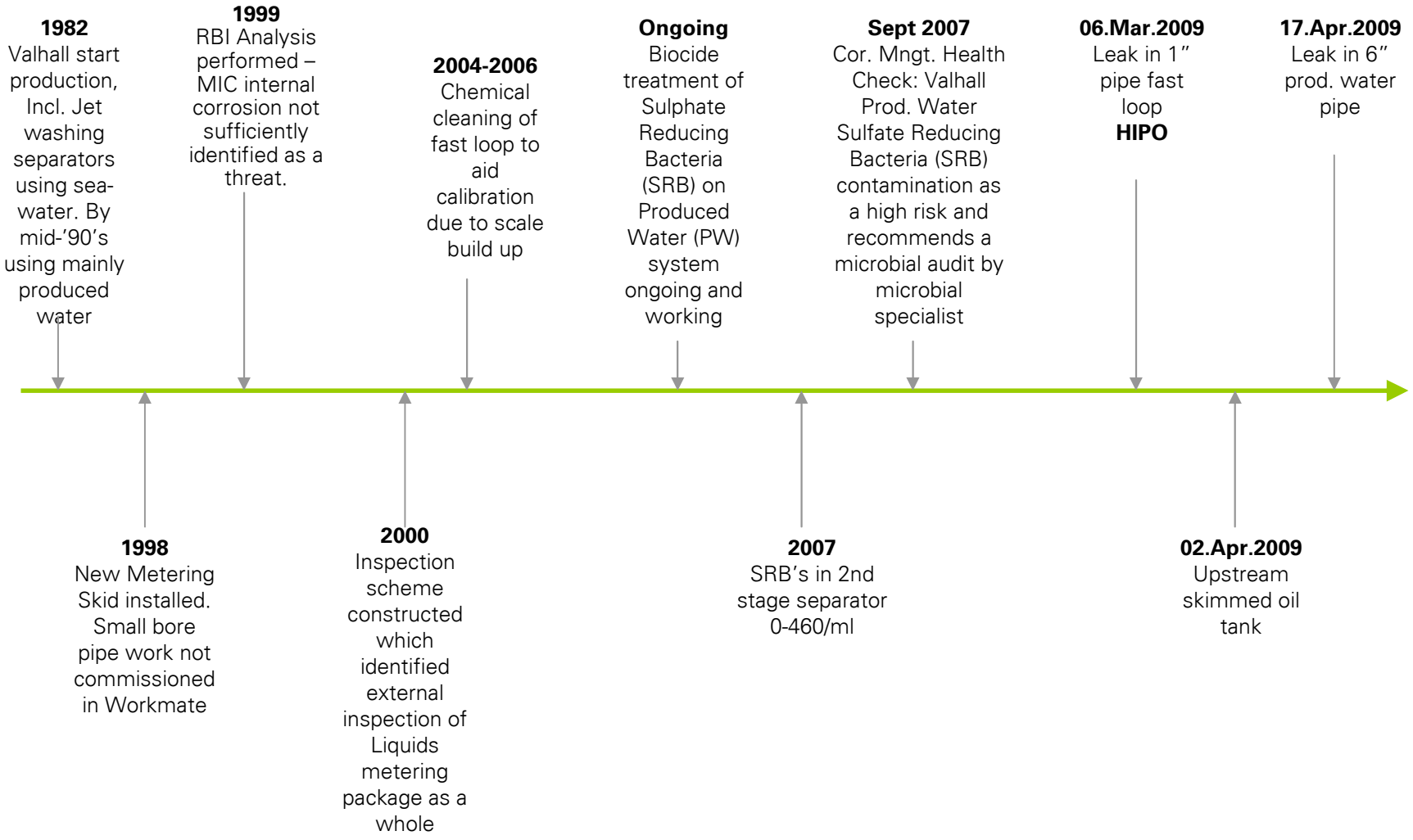
What is MIC?

- MIC is Microbial Induced Corrosion.
- MIC of carbon steel typically manifests itself as localised corrosion or pitting attack following the development of a surface biofilm.
- The anaerobic environments of oil and water transport pipework often support the growth of biofilms, which almost invariably contain sulphate-reducing bacteria (SRB), a major cause of MIC.
- SRB containing biofilms generate H2S.
- H2S results in formation of Iron sulphide within the biofilm.
- Iron sulphides are cathodic to bare steel and can have the effect of greatly increasing corrosion at anodic sites.

Why does MIC occur?

- MIC can occur in all systems that contain water with SRB's.
- Prediction of corrosion rates attributed to MIC is unreliable
  - uncertainty of the onset of localized corrosion/pitting ,whether it proceeds at a constant rate.
- Parameters that can influence MIC include pH, temperature, nutrition, velocity of fluids, presence of deposits.
- MIC is more likely to occur at locations with low fluid velocity such as in dead legs, under deposits, scale.
- All metals are susceptible to MIC. Carbon steels have generally been found to be most susceptible.
- MIC mitigation relies on effective biocide dosing regimes.

Reference - Valhall Timeline



Reference - Valhall Timeline

Events and response:

6th March 2009 "Metering fast loop" (F&G → ESD).

- Limited awareness of MIC, deemed low probability. Limited spot checking by X-ray outside the fast loop. No SD justified by residual corrosion risk. No additional resources.

2nd April 2009 "T-337 pressure increase" (No ESD).

- Start up after a compressor incident increased flare backpressure which burst a MIC in the produced water system.
- 15 days (6 + 9) shutdown looking for MIC with Eddy current and X-ray w. crew of 3.

17th April 2009 "6" produced water pipe" (No ESD).

- Restart attempt failed when a MIC burst in the prod. water system. Had been inspected in very close vicinity. Increasing realization of the criticality of adequate inspection rigour.
- 10 days shutdown, 100% inspection of prod. water system by Eddy current and X-ray, extended risk based approach. Increased offshore resources.

27th April 2009 "Condensate return to prod. water system". (F&G → ESD).

- Pipe burst during start up attempt. Contained highly volatile condensate.
- Realized technology gap. Changed to SLOFEC scanning successfully.
- 30+ team offshore. Task force onshore. True 100% inspection beyond produced water. RIB revision.

1st June 2009 "Successful restart".

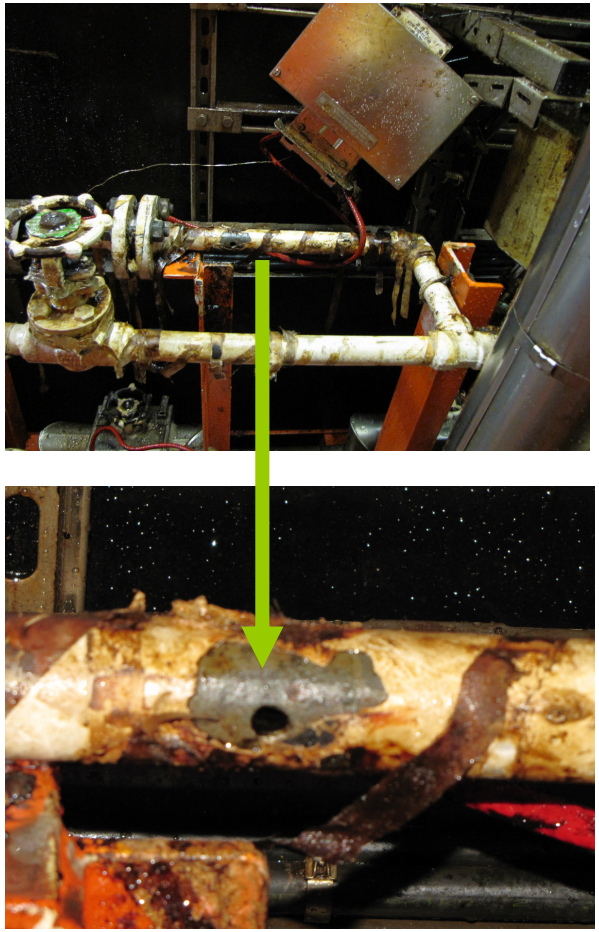
- 10 weeks of production loss and serious HSE incidents.

Valhall Corrosion Event (March 6th 2009)

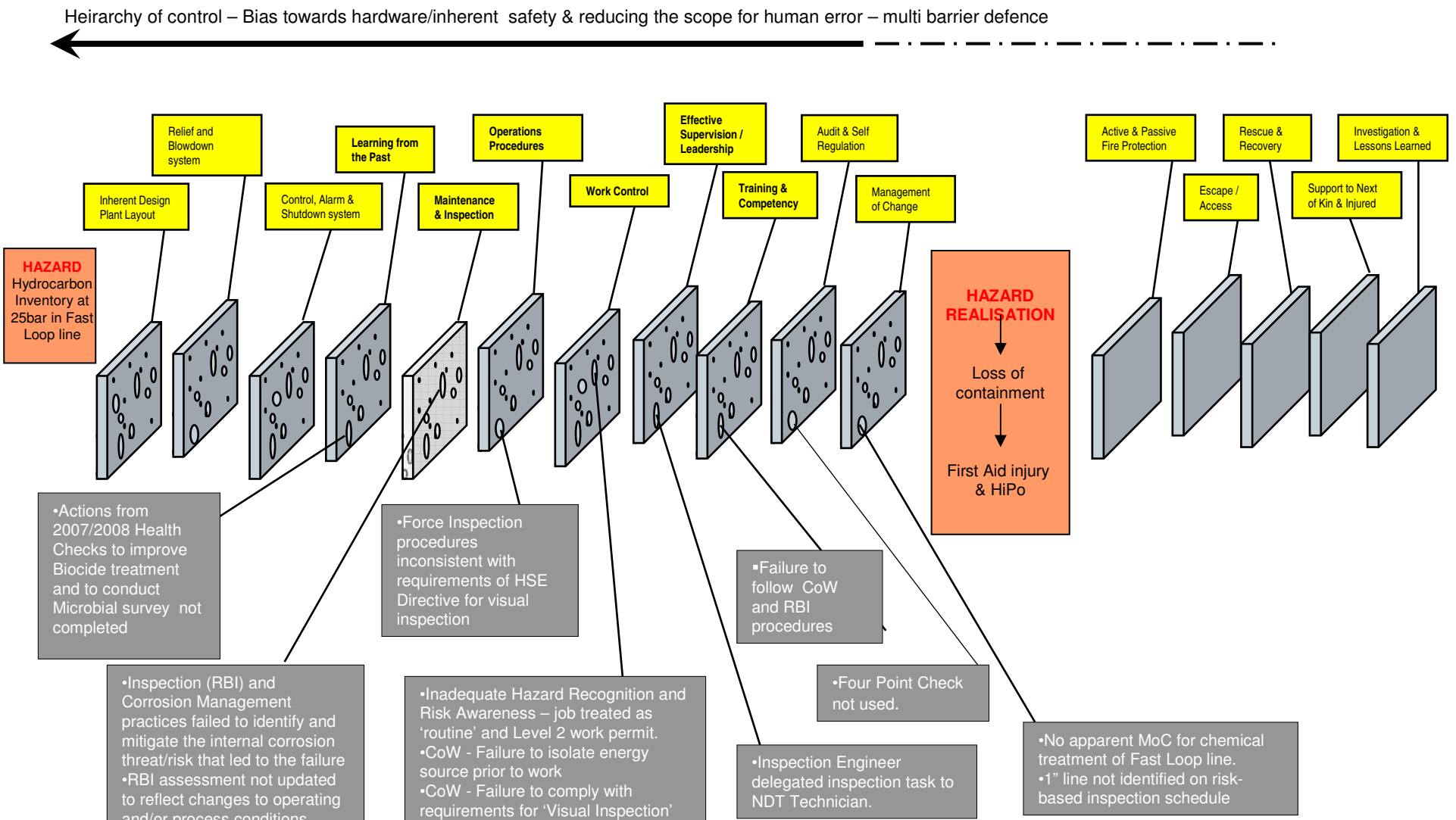
Summary of first event.

Hydrocarbon leak on metering skid – First Aid Incident – Emergency Plant Shutdown

- A 'seep' or sweating leak observed coming from an insulated 1" carbon steel pipe was prepared for inspection following removal of the insulation.
- The pipe was on the crude export metering skid and contained a mixture of crude oil and gas at 25 bar pressure.
- On removal of insulation, the leak was observed not to originate from the flange as originally expected.
- An inspector examining the pipe initially used a blade to scrape off paint at the leak site.
- During a later visit, the inspector touched the leak site with his finger and was sprayed in the face with oil under pressure.
- During hydrocarbon release, the hole enlarged to 10mm diameter.
- Valhall went to full Emergency Shutdown and muster.



Hazard Barrier Diagram

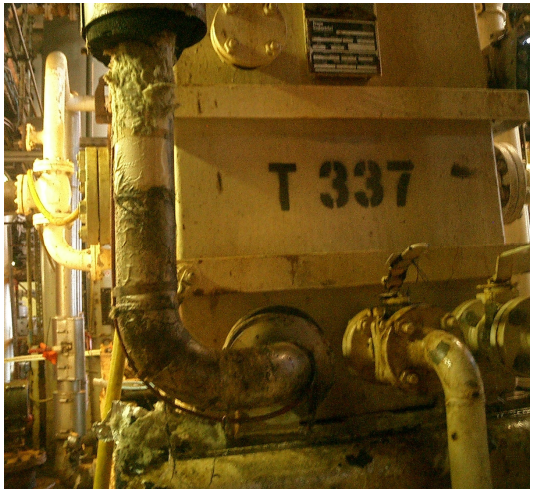


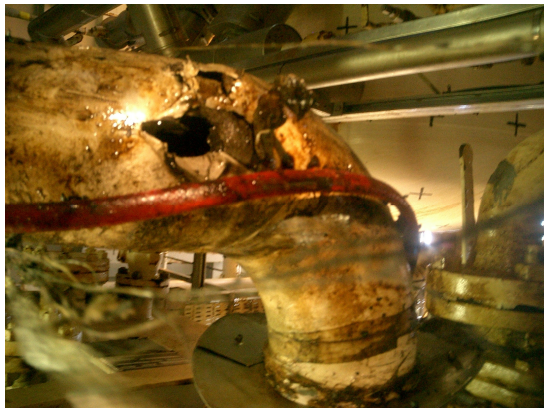
Valhall Corrosion Event (April 2nd 2009)

Summary of second event.

Targeted inspected discovers further incidence of MIC

- A leak in the Produced Water System followed a gas compression upset. Area isolated & upstream vessel drained.
- 25mm hole found in drain line.
- Areas of low flow and dead-legs were identified and inspected. 6 further MIC incidents observed.
- Investigation initiated to ensure appropriate analysis and response prior to restart.
- Management verification of process mitigations and corrosion mapping & repair effort.





Valhall MIC Response

The third event: Defining the Scope of Work

Unpredicted nature and location of corrosion required a new approach to immediate reaction inspection.

- Produced Water identified as being the main host of Sulphate Reducing Bacterias (SRB's)
- Considered potential contamination of other systems vs HC leak risks.
- Scope agreed by Ops, Process TA, Corrosion Mgmt TA, Inspection & CM Contractor.
- Produced Water System was 100% inspected.
- Risk Based "Hotspot" Execution – Water wetted surfaces eg Low spots, Sumps, Deadlegs etc.
  - Waste injection on drilling platform (DP).
  - Well systems, confined to slurry lines.
  - Crude Oil processing including the metering system.
  - Closed Drains System.

Oil Return from PW Flash Drum to Oil Return tank
Orientation of defect; 9 o'clock position on vertical pipe

Valhall Corrosion Event.
Summary of forth event.

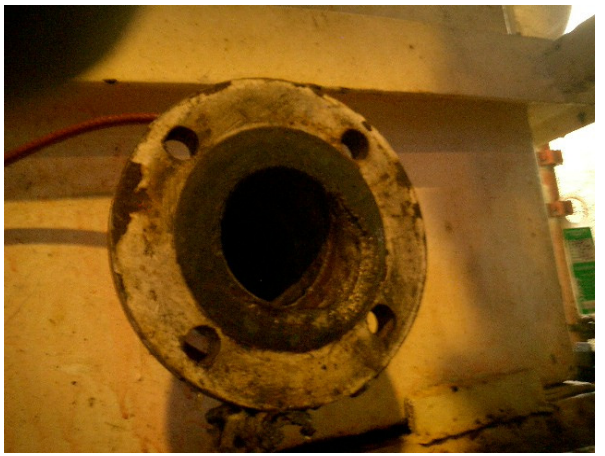
Targeted inspected discovers further incidence of MIC – in high flow pipework

- Leak in 6”produced water high flow pipework
- A 8 mm hole was discovered during preparation for plant restart following inspection program triggered two gas detectors & ESD.
- Critical Factor 1
  - Microbial induced Corrosion (MiC) mechanism in the produced water system
- Critical Factor 2
  - Inspection (RBI) and Corrosion Management practices failed to identify the corrosion risk in high level, high flow pipework

Valhall MIC project – Inspection

Following fresh focussed risk assessment an intense and prioritised inspection programme was initiated.

- Extensive inspection effort required to execute identified scope – 30+strong team.
- SLOFEC technology used
- Priority 1 scope Identified 44 anomalies
  - 23 MIC Related
  - 21 Non-MIC-related
- 19 spools replaced, 5 temporarily repaired & 20 scheduled for ongoing inspection following start-up
- Assurance processes followed by No go/Go verification reviews
- Priority 2 inspection scope identified for post start up inspection.



Lessons Learnt

Direct cause

- Cross contamination of oil production system with SRB via the produced water system.
- Inadequate awareness, inspection and mitigation as analysis did not identify oil system as at risk from SRB corrosion.
- Insufficient chemical injection (such as biocide and corrosion inhibitor) and sampling and analysis to control microbial activity.
- As a result MIC occurred within oil systems.

Underlying causes

- Improvement opportunities identified within:
  - **Organization** (7 subcategories with recommendations)
  - **Work Processes** (5 subcategories with recommendations)
  - **Performance Management** (3 subcategories with recommendations)