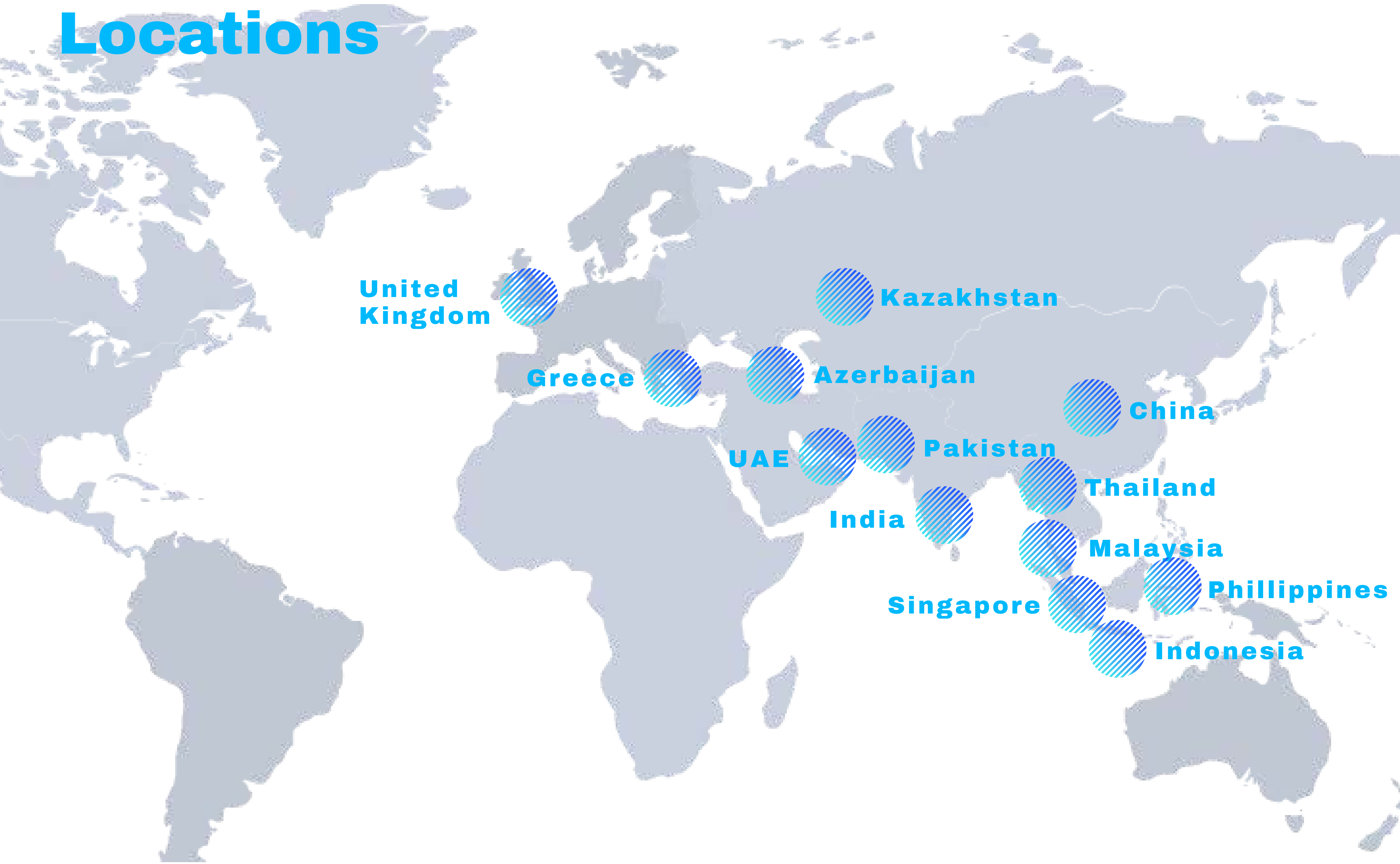
GLOBAL TECHNICAL SOLUTIONS

TWI | Global Technical Solutions

Global Locations



Introduction

TWI provides authoritative and impartial expert advice, knowhow and safety assurance through engineering, materials and joining technologies; enabling our Industrial Members to design, create and operate the best products possible.

The Global Technical Solutions team extends engineering consultancy and technical support outside the U.K. including; South and East Asia, India, China, North and South America and The Middle East.

We typically work closely with national regulators, multinational oil and gas operators, national oil companies, contractors and manufacturers of oil and gas production equipment, production and utility systems to maintain facility integrity, reduce loss of process containment and extend the reliability and useful life of producing assets. Our principal engineers and consultants are able to draw on more than 50 years of research and industry experience in whole life integrity management, fracture mechanics, joining and welding, and process safety.

We apply our knowledge and experience to provide cost-effective solutions for our clients across the oil, gas, process and power generation sectors. Our solutions are often employed in maintaining the integrity of ageing assets and to extend their useful life.

Our client list and track-record reflects the fact that we operate in the global marketplace. We have provided services to major oil and gas operators in more than 80 countries worldwide, and we constantly ensure that we are responsive and that our services are customised to the needs of the client.

TWI offers extensive knowledge and experience with:

Asset Integrity Management Solutions

Integrity Management Software

01

Asset Integrity Management Solutions

Asset Integrity Management Solutions

We provide asset integrity management solutions to a global client base. Whether the asset is an onshore terminal, offshore production platform or processing plant, we have the technical knowledge, experience and resources to support all aspects of asset integrity management, with a particular focus on ageing assets and maintaining operational integrity.

We are experts in:

- Structural pipeline integrity
- Fitness-for-service
- Risk based inspection
- Failure investigation
- Simulations for structural integrity assessment
- Joining and welding technologies
- NDT and inspection services
- Corrosion assessment and management

Asset integrity management services offered include:

- Audit and gap analysis of asset integrity and process safety management systems
- Development and implementation of risk-based inspection (RBI) schemes
- Cathodic protection system design, installation and performance audits
- Review of materials selection and corrosion control philosophies and strategies
- Asset life planning during new developments
- Life extension and remnant life studies for ageing assets
- Regulatory compliance issues, codes and standards work
- Placement of specialist in the client's organisation to champion AIMS, PIMS and PMS
- Preparation of asset integrity and process safety management manuals and procedures for oil, gas, process and pipeline facilities
- Risk based inspection planning and implementation for oil, gas, process and power generation facilities
- Defect assessment, life extension and fitness-for-service studies
- Inspection, maintenance and repair (IMR) management
- Protective coating systems
- Sacrificial and impressed current cathodic protection systems
- Corrosion inhibition, chemical treatment and corrosion monitoring
- Failure investigation
- Joining and welding consultancy
- Risk assessment, safety case preparation, HAZID and HAZOP facilitation

We recently updated the asset integrity management system and procedures for ADNOC Onshore.

We recently updated the operating, maintenance and inspection manuals and procedures for SCOTS pipeline in Sudan.

02

Structural Pipeline Integrity

Structural and Pipeline Integrity

TWI engineers have unrivalled experience in delivering optimised integrity services through various methods of fitness-for-service assessments, engineering critical assessment (ECA), defect assessment, crack and lamination assessment, corrosion growth analysis and remnant life assessment.

We have unrivalled experience in interpreting inspection and NDE data, providing fitness-for-service assessments and corrosion growth analyses, leading to optimised ongoing integrity management through scheduled repairs and inspection intervals.

Since 2013, we performed ECDA for over 2.000 km of onshore natural gas pipelines for a number of pipeline operators in Central Asia

Since 2012, we have completed a numbor of RBI studies for operators of onshore plants and offshore production facilities in Central Asia.

We recently provided engineering and inspection services as part of the rehabilitation and modernisation of the SOCAR refinery in Azerbaijan.

TWI SEA structural and pipeline integrity services include:

- Fitness-for-service assessments
- Defect assessment
- Remnant life assessment
- Corrosion growth analysis (including raw signal data comparison)
- Crack and lamination assessment (fracture and fatigue)
- Engineering critical assessment (ECA)

03

Fitness-for-Service (FFS)
Failure Investigation Services

Fitness-for-Service (FFS)

Fitness-for-Service (FFS) is a standard and best practice used in the oil and gas industry to determine the fitness of in-service equipment for continued use. Our experts are highly experienced in the development and application of FFS techniques, particularly for the avoidance of brittle and ductile fracture and also general and local metal loss. TWI can help solve problems that may arise throughout the lifecycle of a component – from design to decommissioning – minimising risk and cost.

To summarise, the most important benefits of utilising Fitness-for-Service inspection are:

- Support design, fabrication and operation
- Plant life management
- Improve equipment availability
- Optimise maintenance and inspection scheduling
- Improve equipment safety
- Determine equipment residual life
- Integrate lessons learnt from previous equipment failures
- Life extension programmes
- Re-rating or operation change

TWI staff are actively involved in the ongoing research and development of industry standards such as British Standard BS 7910, 'Guide on methods for assessing the acceptability of flaws in metallic structures,' API Fitness-for-Service: API 579-1/ASME FFS-1 and the UK nuclear industry's fracture assessment code R6, 'Assessment of the integrity of structures containing defects.'

Failure Investigation Services

Throughout the past 6 decades, TWI has conducted thousands of failure investigations for some of the world's largest industrial companies.
Our expert engineers have undertaken numerous fabrication problem-solving projects and on-site failure investigations across different industry sectors, including pipelines and process equipment, with particular expertise in fracture, fatigue, corrosion and hydrogen embrittlement of welds, joints and coatings. Our engineering failure analysis consultants can help with the design, development, qualification and implementation of effective safety cases and repairs, including on-site support to ensure that you can return your products or assets to safe, efficient operation as quickly as possible.

Combining the expertise of our specialist engineering experts with the access to the cutting edge technology and our state of the art facilities, TWI is able to provide the right information to our customers at the right time.

04

Risk Based Inspection (RBI)

Risk Based Inspection (RBI)

Risk Based Inspection is a procedure used for designing optimised inspection plans based on knowledge of the risk of failure. The RBI process is predominantly utilised by the industry for the examination of equipment such as pipelines, industrial plants, pressure vessels and heat exchangers. It allows for the development of an optimal inspection strategy for reliability, availability and provides assurance that assets can operate safely. Web-based RBI software means users find it easier to access the application without the need to install it on their laptop. Web-based RBI software can be easily integrated with the SAP system and can also display a summary of RBI assessment results in the form of a dashboard. In addition, top management can monitor risk assets through the RBI dashboard.

TWI develops desktop and web-based RBI software for process plant and pipelines in accordance with applicable standards such as API RP 580, API RP 581 and TWI's proprietary procedures. The web-based RBI software is developed according to client needs, which can be integrated with SAP and can also display a summary of the RBI assessment results in the form of a dashboard. Every asset change in SAP will automatically update asset data in the RBI software.

The first step in conducting an RBI assessment is data input. Data input on the web-based RBI software is based on design data, operation data, corrosion monitoring data, inspection data, maintenance history data and others. Based on the data input, the web-based RBI software will automatically determine the active potential damage mechanism (DM).
Based on the active DM, the damage factor (DF) value will be automatically calculated. From the DF value, component type and factor management system (FMS), the probability of failure (PoF) value will be obtained.

The consequence of failure (CoF) value will be calculated automatically based on input data on the RBI software web.
From the PoF and CoF values, the risk of each equipment can be obtained. Based on the risk ranking, inspection intervals for each equipment can be scheduled. The results of risk and inspection intervals are displayed on the web-based RBI software as shown in Figure 1 and can also be displayed on the RBI dashboard. Top management can access the risk summary on the RBI dashboard.

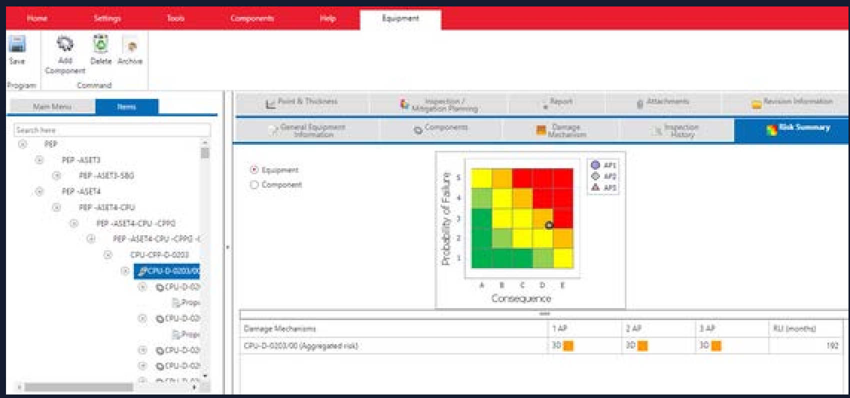


Figure 1: Equipment Risk on Web-Based RBI Software

Risk Based Inspection (RBI)

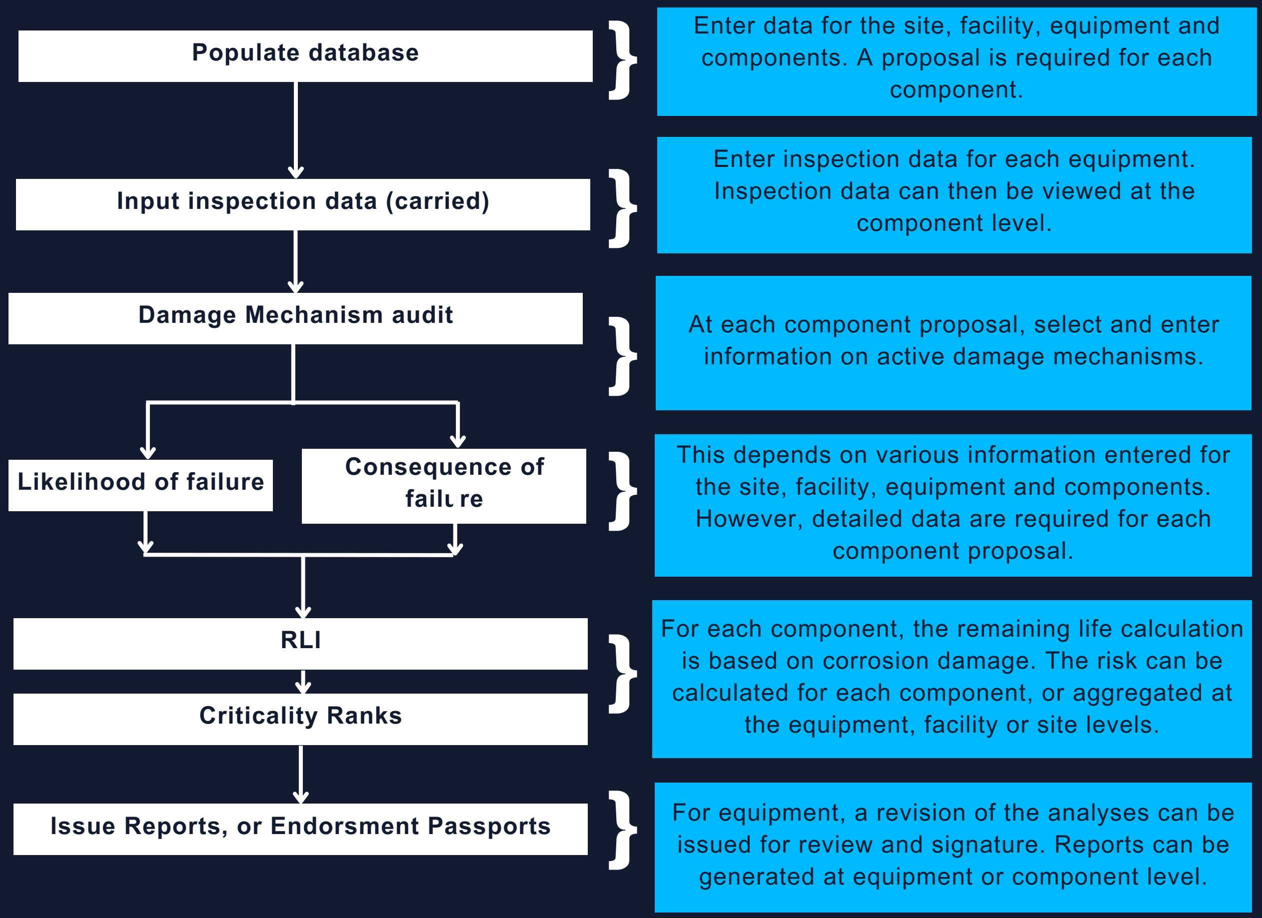


Figure 2: Flowchart for RBI Assessment on Web-Based RBI Software

Benefits of using Risk Based Inspection (RBI)

A properly performed RBI process results in findings such as:

- Identification of the potentially available damage
- Location of the damage
- The rate at which the damage may evolve
- Identification of the danger of catastrophic failure
- Reducing revenue loss by minimising the turnaround times
- Extend inspection intervals and reduce scope

05

Simulations for Structural Integrity Assessment

Simulations for Structural Integrity Assessment

TWI identifies and applies the most appropriate technology to support our client's decisions regarding the safe operation of a structure. Our activities span across the aerospace, automotive, oil and gas, and power generation sectors, and include the structural integrity assessments for:

- FEA for an FFS on crack-like flaws on a power boiler reheater header
- Creep analysis using FEA for an FFS on the main steam pipeline found susceptible to creep damage
- Creep-relaxed stress analysis using FEA for an FFS on high-energy piping of a power boiler
- Fracture and fatigue of petroleum road fuel tankers with the results presented to UK Parliament
- Corrosion of well conductors, incorporating in-line inspection (ILI) data directly in the models
- Dents and gouges of subsea pipelines that were identified by remotely operated vehicles
- Tubular joints in offshore jacket structures, using constraint-based fracture mechanics
- Fracture and strength of radioactive waste disposal canisters
- Hydrogen-induced stress cracking (HISC) of duplex stainless steel joints for subsea service

Finite Element Analysis at TWI

TWI's modelling team are world-leading experts in applications of FEA for structural integrity assessments. The Numerical Modelling and Optimisation section at TWI is made up of Chartered Engineers, Chartered Mathematicians, and NAFEMS-certified Professional Simulation Engineers.

TWI offers a variety of computational engineering capabilities including FEA, computational fluid dynamics (CFD), and data analysis. Our team sit as members of the British Standard 7910 committee, the UK nuclear structural integrity code R6, and are highly cited researchers in fracture, fatigue and damage mechanics, having recently received an award from the International Conference on Ocean, Offshore and Artic Engineering (OMAE)

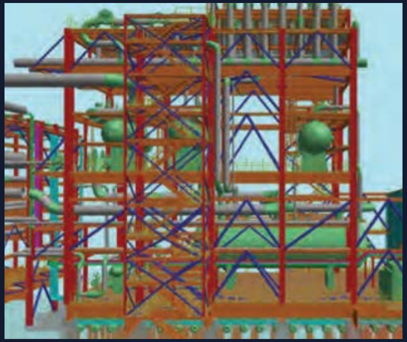
Joining and Welding

Joining and Welding

Our team of welding and material engineers provide support to a range of global pipeline operators and fabricators. With unequalled experience in material manufacture and fabrication standards, we can support all types of projects.

With a focus on quality and repeatability, our engineers can provide advice and assistance from the pre-FEED stage right through to commissioning and acceptance.

Since 2013 we performed ECDA for over 2,000 km of onshore natural gas pipelines for a number of pipeline operators in Central Asia.



Over the last few years, we have completed a number of laser scanning and 3D modelling projects for a number of operators with ageing facilities in Central Asia.

Materials and welding support services include:

- Welding procedures
- Manufacturer and supplier capability assessment and audit
- Weldability and in-service welded repairs
- Construction audits
- Technical concessions/deviations by way of ECA
- Codes, standards and specifications
- Trouble-shooting and failure investigations
- Training

07

Corrosion Management

Corrosion Management

Our understanding of the complex challenges that are associated with corrosion issues on ageing assets, particularly in offshore environments, has provided a cost-effective platform for many operators to form corrosion management strategies. We can offer solutions that maximise production uptime while maintaining the highest possible safety standards.

Corrosion management services include:

- Corrosion management systems audit and gap analysis
- Development of corporate corrosion management policies
- Corrosion control strategies (CCS)
- Corrosion risk assessment (CRA) for assets (plant, vessels, pipework and pipeline)
- Pipeline risk assessment (PRA) for subsea pipeline and risers
- Internal and external pipeline direct assessment
- Review and monitoring of cathodic protection (CP) system including CIPS, DCVG, ACVG, etc

Since 2012, a number of South East Asian offshore operators such as Pertamina Hulu Energi have engaged TWI for RBI studies. Facilities covered included offshore steel structures, flow stations, floating storage and offloading (FSO) units, onshore receiving facilities, and subsea pipelines.

08

NDT
and Inspection Services

NDT and Inspection Services

TWI's non-destructive testing services leverage all available NDT technologies, and our team is adept at identifying the optimum solution for any practical industrial application.

We are able to offer third party oversight in all NDT inspection areas, relying on our expert personnel qualified up to ISO 9712 NDT Level 3 and ASNT NDT Level III in the full range of methods including:

NDT and inspection support services include:

- Guided wave (LRUT)
- Acoustic emission
- Alternating current field measurement
- Digital radiography
- Eddy current testing
- Array ultrasonic imaging techniques (FMC/TFM)
- Manual ultrasonic testing
- Phased array ultrasonic testing
- Radiography testing
- Thermography
- 3D X-ray microscopy
- Time of flight diffraction
- Modelling of ultrasound

In 2019, TWI conducted a three-phase project aimed at determining the feasibility of using alternating-current field measurement (ACFM) testing, a non-destructive testing (NDT) technique, to inspect train bogies without the need to remove the surface coating.
Conventionally, train bogies are inspected using visual and magnetic particle inspection (MPI) where paint coatings have to be removed prior to inspection. Otherwise, probability of detection (POD) will be low, or the indication of defects might be inaccurate

Under this project, the client asked TWI to firstly explore the feasibility of using ACFM testing on the train bogie without coating removal. Secondly, if proven feasible, TWI was asked to produce the defect specimens and perform the ACFM testing blind trial test on the train bogie.

TWI demonstrated that it was possible to detect defects, through surface coatings, with a high POD of 91% over MPI, without coating removal. The variety of ACFM testing probes with differently angled/lengthened heads also further expedites the inspection on weld joints and areas previously difficult to access using MPI. This reduces the overall downtime and the extra cost for production that is associated with removing coatings.

09

Plant Integrity Management Software
CorrosionWISE

Plant Integrity Management Software

TWI has been developing software products to support customers in welding, engineering and training for over 30 years.
The software saves time, improves the quality of documentation and decision-making, and helps to ensure the safety and integrity of welded joints.
TWI's combination of extensive expertise in both latest software development techniques and all aspects of welding and joining technology makes it ideally positioned to develop this kind of software.

TWI Software products include:

- RiskWISE® for process plants
- Power-RBI and integrity solution for boilers
- CrackWISE®
- RiskWISE® for pipelines

CorrosionWISE

Corrosion is a significant concern for industries, especially in the offshore sector where maintenance and inspections can be challenging. Traditional methods of predicting corrosion rates on inaccessible piping systems have often been time-consuming and costly. However, with the advent of artificial intelligence (AI) and machine learning (ML), a groundbreaking solution has emerged: CorrosionWISE. This innovative model leverages AI-powered approaches to provide accurate and efficient corrosion rate predictions for topside facilities and offshore platforms.

How CorrosionWISE developed

1. Data collection and Preprocessing: To develop CorrosionWISE, data was collected from various sources, including historical records, sensor readings, and environmental data. The collected data is then preprocessed to remove noise and inconsistencies, ensuring a clean and reliable dataset

2. Training and model development: The preprocessed data is used to train the ML model underlying CorrosionWISE. Advanced algorithms learn the complex relationships between corrosion indicators and factors affecting corrosion rates, such as temperature, pressure, material fluid composition, and component types. The model is fine-tuned to optimise its predictive accuracy

3. Predictive insights and reporting: The trained and validated model which is called CorrosionWISE, generates predictions for corrosion rates on inaccessible piping systems. These predictions are presented through a user-friendly interface, allowing operators to visualise and interpret the results easily

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RiskWISE for Process Plants

RiskWISE for Pipelines

RiskWISE
for Process Plants

RiskWISE® is a code-compliant risk-based inspection and maintenance software system that makes safe and confident management of risk and economic operations of plants and equipment.

Programme features:

- User-friendly software designed for use by plant personnel
- Fully quantitative RBI assessment as per API RP 581: 2016
- Regularly updated database with all relevant damage mechanisms, as well as guidance on formulating the probability and the consequence of failure
- Targets inspection by identifying the most likely locations for damage
- Sensitivity analysis capabilities ideal for situations where data is unavailable
- Fully auditable output acceptable to insurers and regulators

RiskWISE
for Pipelines

RiskWISE® for pipelines is a risk and life management software developed for pipeline integrity management based on formal risk-based inspection practices. RiskWISE® for pipelines software works by targeting and scheduling inspection and maintenance activities. The software is developed by TWI experts in accordance with globally recognised codes and standards such as ASME, API 581 and API RP 580.

Programme features:

- User-friendly Inspection management software developed in accordance with the new API RP 580
- Accurate assessment, measuring the likelihood and consequence of failure in pipeline segments
- Inspection frequency, based on formal reliability rules remaining life interval (RLI) module
- Translation of inspection data, converting the data into pipeline risk and remaining life profiles for ‘direct assessment’
- Identification of the high risk locations, proper targeting of each pipeline or pipeline network inspection
- Facilitation of optimum selection of risk mitigation measures

11

CrackWISE Fitness-for-Service (FFS)
Power-RBI and Integrity Solution for Boilers

CrackWISE Fitness-for-Service

Designed to assist you with the evaluation of the integrity of pipelines, pressure equipment and structures containing flaws in line with BS 7910. CrackWISE ensures that you continue to operate safely, while reducing the potential cost of outages and other unforeseen problems.

Programme features:

- Automation of BS7910 the widely-accepted flaw assessment procedure
- Fully compatible and traceable to the fracture and fatigue clauses of BS 7910
- Extensively validated software developed under TickITplus
- Latest advances in fracture assessment techniques incorporated
- Includes a PDF of the current edition of BS 7910
- User-friendly interface intuitive to existing and new users.

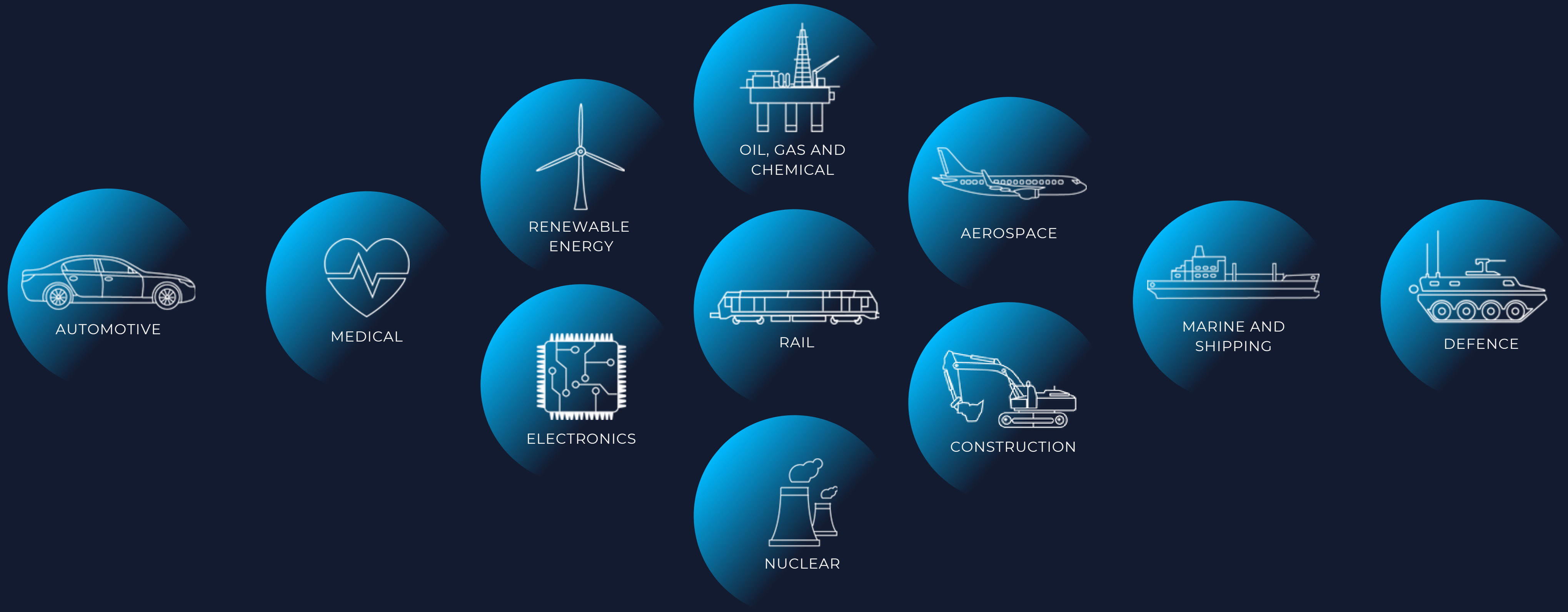
Power-RBI an Integrity Solution for Boilers

An advanced risk and life management software developed for boilers integrity management based on TWI's In-house developed RBI methodology. Power-RBI software works by targeting and scheduling of inspection and maintenance activities.

Programme features:

- User-friendly software fully transparent risk based maintenance software. Compliance with API 580, 581, ASME PCC-3, API 579 and EPRI
- True maintenance planning tool rather than only a risk analysis tool. Fully integrated AIMs tool quipped with IDMS (Inspection and Document Management System)
- 2D/3D visualisation of the assets and TML
- Determination of the risk of failure with time in service
- Regularly updated database with relevant damage mechanisms, and guidance on formulating probability and the consequence of failure
- Quantitative and qualitative assessments
- Unit-wide risk audit enables repair and maintenance resources to be risk-focused

Industry Sectors



Case Studies

TWI | Global Technical Solutions

CorrosionWISE
Revolutionising Corrosion Prediction with AI and ML

INTRODUCTION

Corrosion is a significant concern for a variety of industries, but especially in the offshore sector where maintenance and inspection can be challenging. Traditional methods of predicting corrosion rates on inaccessible piping systems have often been expensive and time-consuming. However, artificial intelligence (AI) and machine learning (ML) have helped with the creation of our groundbreaking CorrosionWISE software solution. This innovative system leverages AI-powered approaches to provide accurate and efficient corrosion rate predictions for topside facilities and offshore platforms.

HOW CorrosionWISE developed

Data Collection and Preprocessing: Collecting data from various sources, including historical records, sensor readings, and environmental data, CorrosionWISE then preprocesses the information to remove noise and inconsistencies, ensuring a clean and reliable dataset.

Training and Model Development: This preprocessed data trains the ML model underlying CorrosionWISE, with advanced algorithms learning the complex relationships between corrosion indicators and factors affecting corrosion rates, such as temperature, pressure, material fluid composition, and component types. The model is fine-tuned to optimise its predictive accuracy.

Predictive Insights and Reporting: Once the model is trained, CorrosionWISE generates predictions for corrosion rates on inaccessible piping systems. The predictions are presented through a user-friendly interface, so operators can visualise and interpret the results easily.

CorosionWISE
Revolutionising Corrosion Prediction with AI and ML

HOW AI AND ML BENEFIT INDUSTRIES

Enhanced Predictive Capabilities
AI and ML algorithms analyse vast amounts of historical data, including environmental factors, material properties, and corrosion indicators, to identify patterns and correlations. By learning from this data, these algorithms can make highly accurate predictions about corrosion rates, helping industries plan maintenance schedules and resource allocation effectively.

Reduced Downtime and Costs
Traditional inspection and maintenance methods often require shutdowns or partial shutdowns followed by access to the surface area, resulting in significant downtime and financial losses. CorrosionWISE eliminates the need for such frequent inspections by providing remote monitoring and real-time predictions.
This approach helps prevent costly inspection techniques and reduce the uncertainty about the inaccessible locations.

Optimal Resource Allocation
With limited resources available, industries must allocate them efficiently. CorrosionWISE provides insights into corrosion rates on inaccessible piping systems, allowing operators to prioritise maintenance activities based on the severity of predicted corrosion. This targeted approach optimises resource allocation and extends the lifespan of assets.

Data-Driven Decision Making
AI and ML models like CorrosionWISE empower industries with valuable data-driven insights. By leveraging historical and real-time data, operators can make informed decisions regarding maintenance strategies, equipment upgrades, and material selection. This data-driven approach enhances efficiency and ensures optimal asset performance.

CorosionWISE
Revolutionising Corrosion Prediction with AI and ML

Improved Safety and Risk Mitigation

Corrosion can compromise the structural integrity of offshore platforms, posing risks to personnel and the environment. By accurately predicting corrosion rates, CorrosionWISE helps identify high-risk areas and enables proactive measures to mitigate those risks. This promotes a safer working environment and reduces the potential for accidents or leaks.

CONCLUSION

CorrosionWISE represents a significant leap forward in corrosion prediction for topside facilities and offshore platforms. By harnessing the power of AI and ML, this innovative solution enables industries to accurately forecast corrosion rates, reduce downtime and costs, optimise resource allocation, enhance safety, and make data-driven decisions. Embrace the future of corrosion management with CorrosionWISE and unlock the potential for improved asset integrity and operational efficiency.

Crane
Weld Repair

BACKGROUND / OVERVIEW

A drilling company contacted TWI to discuss on their current weld crack indication observed at pedestal crane column. Weld toe crack indications were observed between the full penetration weld crane column and the retaining ring. The crack was then removed by grinding. However, less than a week after the crane resumed its operation (approximately 2t-3t maximum lift) the crack was then regenerated. The cracks run circumferentially at the toe of the full penetration fillet weld toe.

The crack depth was later examined using two non-destructive test (NDT) sizing techniques, phased array ultrasonic testing (PAUT) and alternative current potential drop (ACPD). Following the investigations, the client requested TWI help ensure best practice for any further investigation(s) and repair.

APPROACH

Task 1
Review existing WPSs and provide repair procedures

Task 2
Provide a technical expert to witness the development and qualification of crack removal procedure and WPSs, pedestal crane mock-up test and laboratory testing

Task3
Provide a technical expert to witness and oversee the crack removal and weld repair process offshore, and on-site investigation

Crane
Weld Repair

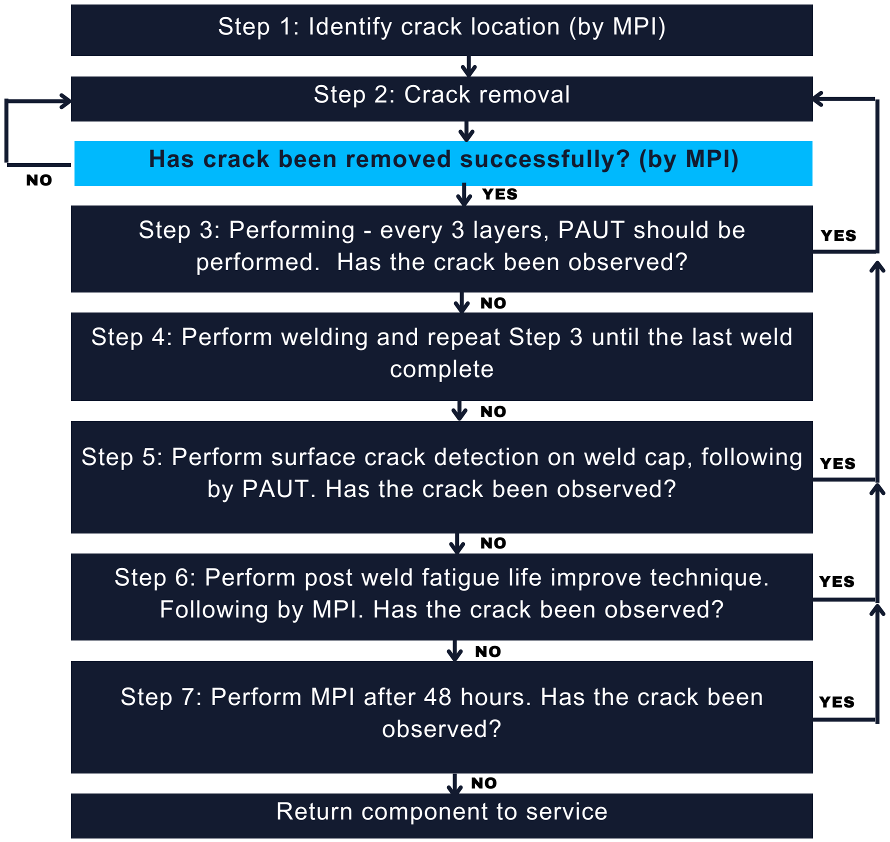


Figure 3: Crack removal and welding solution diagram

CONCLUSION

It was found that the applicable WPS can be used as a guideline for pedestal crane repair works. The welding parameters and its selected consumables are applicable. However, all welding parameters should be closely monitored, e.g. preheat and interpass temperature and extra control of welding electrodes. Without postweld heat treatment stress concertation and amount of distortion should be taken into account. The proposed WPS also meets with client specification.

Welding repair works including non-destructive test (NDT) was carried out and witnessed in the presence of all representatives. The results obtained from repair activities e.g. WVI, MPI, PAUT, and load test met the required acceptance criteria, as no indications were observed.

It should be noted that if the pedestal crane column had passed all minimum required NDTs then the fitness for purpose of the repair works would not have been questioned, as they had survived load test. The pedestal east-crane complied with all the required construction code requirements. However, the crane should be under monitoring with a time based inspection approach to be considered.

Failure Investigation

INTRODUCTION

Our client in South East Asia had experienced a perforation on their flowline resulting in loss of containment (LoC). The flowline is the second spool of the flowline downstream of the choke valve and has been in operation for more than 10 years. The material of construction was carbon steel.

The perforation occurred approximately one year after an inspection indicated no damage, i.e. no metal loss measured. TWI was asked by the client to perform an investigation to determine the root cause and provide recommendation solutions for the LoC.

OBJECTIVES

- To conduct a metallurgical failure investigation of the perforated pipe to determine the applicable cause damage mechanism
- To conduct root cause analysis of the loss of containment (LoC)
- To provide recommendations and improvement to prevent future similar LoC, i.e. lessons learned

Failure Investigation

RESULTS / ACHIEVEMENTS

The RCA concludes that preferential weldment corrosion (PWC) was found to be the damage mechanism associated with the perforation due to an increase in production rates (e.g. temperature, flow and pressure) resulting in the current risk assessment and inspection frequency being in question.

Preferential weld corrosion (PWC) is the preferential attack of the weld or HAZ that is exposed to a corrosive environment (e.g. seawater or CO2-containing environments). In this case, the weld corroded faster than the parent metal, see Figure 4. PWC is influenced by three main factors such as oxidants, electrolytes and susceptibility of the material (carbon steel). The severe metal loss originates internally and locally affects the weldment root. Over time, the metal loss increases through the weldment wall until perforation. There was no final overloading of a ligament, i.e. leak before break.

These phenomena are increasingly a critical concern in ageing facilities as they can lead to safety, reliability and structural integrity issues in the facilities. We provided short-term and long-term recommendation solutions including and inspection approach for PWC.

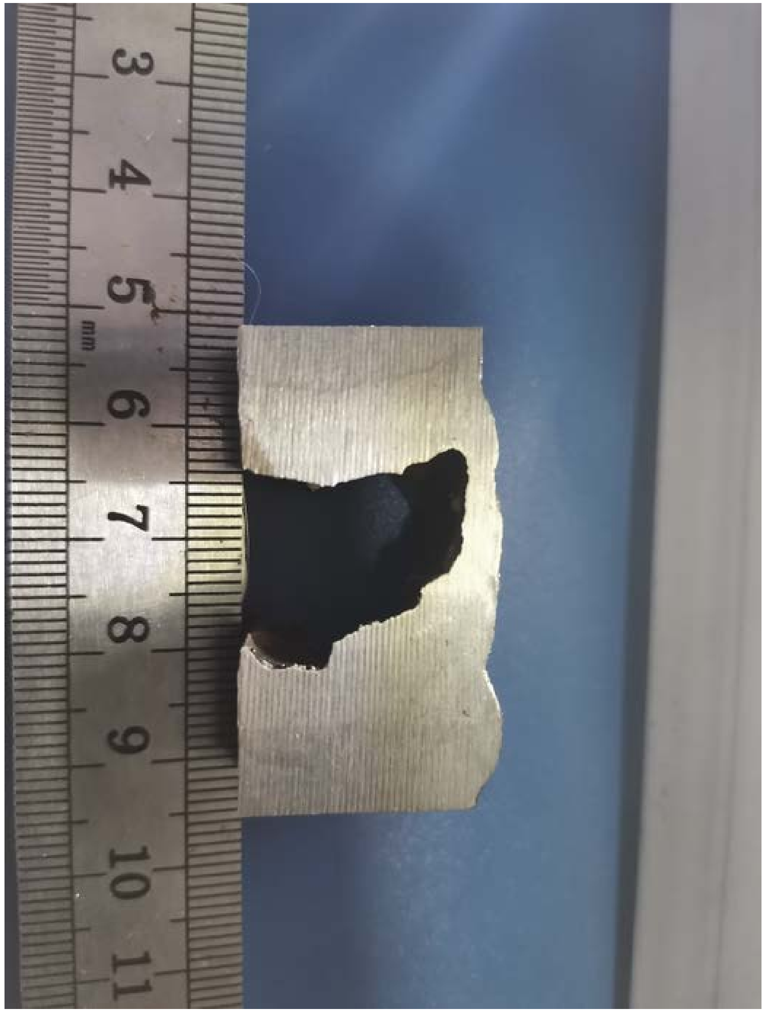


Figure 4: PWC at the weldment

Feasibility Study of Alternating Current Field Measurement (ACFM) for Train Bogie

BACKGROUND / OVERVIEW

TWI conducted a three-phase project aimed at determining the feasibility of using alternating-current field measurement (ACFM) testing, a non-destructive testing (NDT) technique, to inspect train bogies without the need to remove the surface coating. Conventionally, train bogies are inspected using visual and magnetic particle inspection (MPI) where paint coatings have to be removed prior to inspection. Otherwise, probability of detection (POD) will be low, or the indication of defects might be inaccurate.

Under this project, the client asked TWI to firstly explore the feasibility of using ACFM testing on the train bogie without coating removal. Secondly, if proven feasible, TWI was asked to produce the defect specimens and perform the ACFM testing blind trial test on the train bogie.

OBJECTIVES

- To perform a literature search study to assess the suitability of the ACFM method to replace MPI for the train bogie
- Fabrication of crack-like defects on the ACFM test specimens
- Provide a technical consultant to witness and oversee the feasibility study

RESULTS

TWI demonstrated that it was possible to detect defects, through surface coatings, with a high POD of 91% over MPI, without coating removal. The variety of ACFM testing probes with differently angled/lengthened heads also further expedites the inspection on weld joints and areas previously difficult to access using MPI. This reduces the overall downtime and the extra cost for production that is associated with removing coatings.

Simulations for Structural Integrity Assessment at TWI

What is Structural Integrity? Why is it Important?

New and aging assets may not live up to their intended design life. For that reason, structural integrity assessment is an engineering field that plays a fundamental role in ensuring that structures are fit to do what they are designed to under normal operating conditions and are safe when conditions exceed the original design intent. Integrity is not just a case of good design; it needs to be maintained and periodically assessed throughout the life of a structure.

The most common damage mechanisms to structural integrity are:

- Corrosion (local metal loss)
- Fatigue (due to cyclic loading)
- Crack-like flaws (due to fatigue or welding defects)
- Creep damage (high temperature applications)

Established fitness-for-service (FFS) and engineering critical assessment (ECA) standards such as API 579/ASME FFS-1 and BS 7910 provide the approaches and calculation methods to assess the susceptibility and acceptability of the above damages on simple structural configurations.

However, when structure configurations and loadings are more complex, the damage is near a structural discontinuity, or there is a desire to reduce the conservatism in the assessment, Finite element analysis (FEA) can be used to provide a more accurate result.

Simulations for Structural Integrity Assessment at TWI

Assessing Structural Integrity with FEA

TWI identifies and applies the most appropriate technology to support our clients' decisions regarding the safe operation of a structure. Our activities span across the aerospace, automotive, oil and gas, and power generation sectors, and include the structural integrity assessments for:

- FEA for an FFS on crack-like flaws on a power boiler reheater header
- Creep analysis using FEA for an FFS on a main steam pipeline found susceptible to creep damage
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- Fracture and strength of radioactive waste disposal canisters
- Hydrogen induced stress cracking (HISC) of duplex stainless steel joints for subsea service

TWI has internationally-recognised laboratories for materials characterisation, fracture and fatigue testing, environmental testing, and full-scale performance qualification. The modelling techniques that TWI applies for structural integrity assessments have been validated experimentally with decades of evidence to give confidence to our clients.

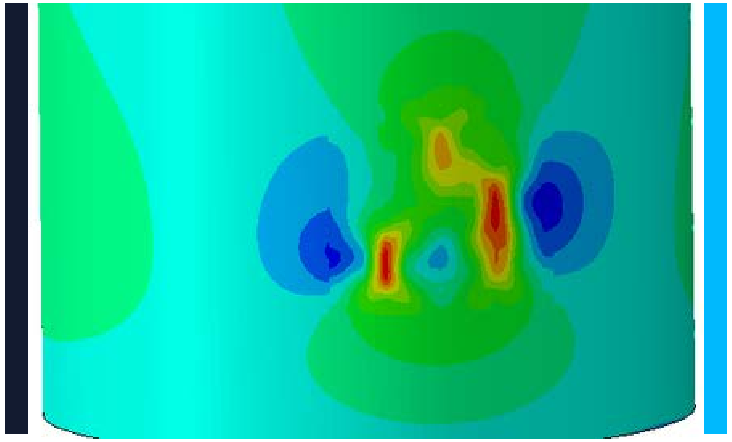

Figure 5: Level 3 FFS for metal loss on an aboveground storage tank

Pipeline Loss of Containment Root Cause Analysis

BACKGROUND / OVERVIEW

During a recent inspection, a loss of containment (LoC) incident was found at a failed welded joint. The pipeline, commissioned in 1999, has a diameter of 33 inches and a wall thickness of 10mm. It was constructed using API 5L X70 and adhered to the guidelines specified in ASME B31.8.

To delve deeper into the LoC incident, a comprehensive geotechnical investigation was conducted at the LoC location. The investigation findings indicated that the excavated pipeline exhibited plastic deformation in the lateral direction, suggesting that the pipeline experienced stress levels exceeding its yield point. TWI was contracted to identify the root cause of the LoC. TWI employed advanced techniques such as finite element analysis (FEA), engineering critical assessment (ECA), and fault tree analysis (FTA) to conduct a thorough analysis and determine the underlying factors contributing to the incident.

OBJECTIVE

To determine the root cause of the pipeline LoC based on known information using advanced techniques such as FEA, ECA and FTA

FEA, ECA AND FTA TECHNIQUES

To obtain stress values for ECA, an FEA was performed to simulate the deformation of the bent pipeline, by taking into account the findings from the geotechnical investigation. Subsequently, an ECA assessment was carried out, incorporating data from the failure investigation, operational records, and the results of the FEA. TWI's CrackWISE 6, which adheres to BS7910 standards, was utilised for the ECA analysis. Sensitivity analyses were also conducted to assess the significance of the parameters employed in the assessment. The FTA systematically traces the potential causes of a loss of containment (LoC) in a pipeline, starting from the top event and progressively examining intermediate and basic events

Pipeline Loss of Containment
Root Cause Analysis

RESULTS

By using the ECA and FEA techniques, the following results were derived:

- The measured external circumferential crack would have experienced failure based on the material properties and stress levels obtained from finite element analysis (FEA)
- The stress levels applied to the crack during the loss of containment (LoC) surpassed the material's yield strength and approached the ultimate tensile stress
- A thorough engineering critical assessment (ECA) determined that the measured crack size would have failed through ductile fracture

The FTA results concluded:

- Increased bending load occurred due to gradual ground movement, leading to localised deflection
- The possibility of external environment leaks existed due to the potential shearing of joint wraps
- The combination of high tensile stress and susceptible materials initiated stress corrosion cracking (SCC)
- The undetected propagation of SCC resulted in the welded joint and LoC rupture at a critical crack size

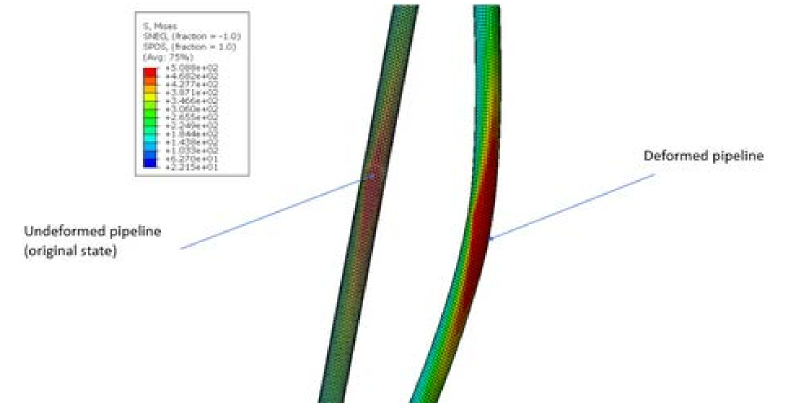

Figure 6: Failure assessment diagram at LoC location

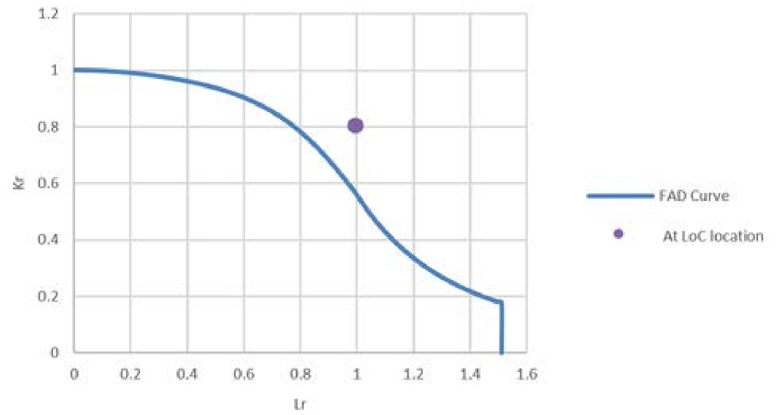

Figure 7: Undeformed and deformed presentation of the FEA model at the LoC

On Type IV Creep in Welded Grade 91 Steel and Non-Invasive Approach for Early Stage Detection

BACKGROUND

Welding is the most common joining process involving several metallurgical processes such as phase transformation, solidification, compositional changes, stress distribution, and heat treatment. These processes not only affect the weld volume but also the microstructure of the adjacent base material. The distribution of heat energy into the base material during welding results in the formation of different heat-affected zones (HAZ). These zones, based on the microstructure appearance and heat exposure, are broadly characterised as coarse grain zone (CGHAZ), fine grain zone (FGHAZ), and inter-critically heated zone (ICHAZ). Due to the presence of these inhomogeneous microstructure bands resulting from the welding process, the performance of each zone may be reduced under elevated operating conditions. This reduction in service performance depends on several factors, including stress, temperature, and time.
Type IV creep damage in low alloy and creep strength-enhanced ferritic steels is an ideal example of the poor performance of the HAZ.

Type IV creep damage incubates at the subsurface in the form of micro-voids in FGHAZ/ICHAZ and subsequently coalesces to form microcracks (Figure 8), finally resulting in sudden premature failure of the component.

It is perhaps this complex nature of incubation and the location/extent of the susceptible zone, that poses a challenge to the effectiveness of otherwise well-established methods for creep assessment such as hardness, strain measurement, replication, etc.

The danger of Type IV damage is that it can evolve rapidly during operation. So, early-stage damage which remains undetected during an outage inspection can develop into cracks that may lead to failure before the next outage. Therefore, there is a need to have reliable non-invasive volumetric techniques for the detection of such degradation at an early stage.

On Type IV Creep in Welded Grade 91 Steel and Non-Invasive Approach for Early Stage Detection

OBJECTIVES

The primary objectives of this research work, supported by the Core Research Programme at TWI, were:

- to conduct a review to understand the efficacy and efficiency of commercially available NDT techniques
- to identify a suitable (field deployable) approach for further development enabling early-stage detection of Type IV creep

RESULTS

Based on literature review the ultrasound method was found to be a likely candidate for providing information on early-stage localised damage below the surface of components.

Ultrasonic testing is a well-established method for the volumetric examination of welds to detect macro-scale weld flaws at the fabrication stage. The emergence of PAUT and array ultrasonic imaging techniques have significantly improved the detection and sizing capability of flaws at a macro-scale. However, the outcome of trials performed within this framework on creep-exposed samples was not encouraging.

To further explore the potential of the ultrasonic method to detect micro-scale subsurface creep damage, a bespoke solution was developed that shows promise for providing information on early-stage localised sub-surface damage (Figure 9).

The results of this investigation provide a good basis for moving forward with industrial validation of this ultrasonic technique.

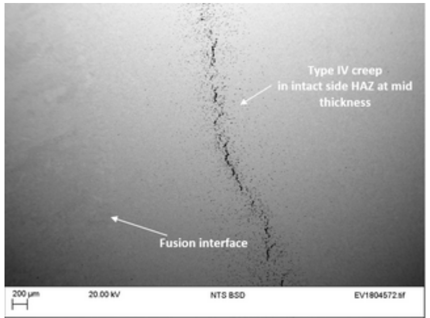

Figure 8: Scanning electron microscope image from the intact heat-affected zone of a cross weld creep-failed Gr 91 specimen showing advanced Type IV creep damage with a high density of voids.

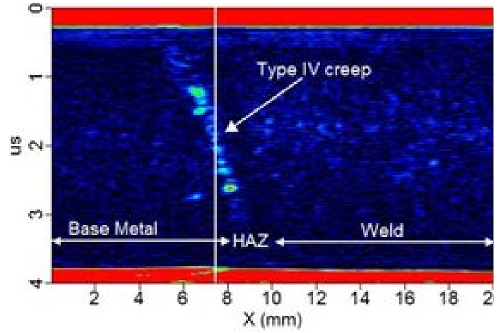

Figure 9: Ultrasonic data acquired using a tailored technique from the intact side of creep exposed specimen showing Type IV creep.

Engineering Studies for Replacement Oil Flowlines

Hydraulic/ Corrosion Assessment and Cycle Cost (LCC) Analysis

BACKGROUND

A major onshore company identified oil flowlines requiring replacement and would like to implement "Fit for Purpose (FFP)" strategy for all replacement flowlines.

TWI was engaged to conduct the following engineering studies to select the proper size and construction material per the FFP strategy.

- Conduct a hydraulic study to determine optimal flowline size
- Conduct the corrosion assessment study for the carbon steel flowline
- Select flow line material of construction in line with life cycle cost (LCC) analysis

The existing oil flow lines are designed to ASME B 31.8/31.4 and installed as surface laid bare carbon steel above ground lines in normal terrain (sand dunes area).

OBJECTIVES

- To assure implementation of industry best practices for oil flow line design, in line with the client's FFP strategy
- To select optimal flow line size and material of construction (MoC) in line with the LCC approach

Engineering Studies for Replacement Oil Flowlines
Hydraulic/ Corrosion Assessment and Cycle Cost (LCC) Analysis

DATA ANALYSIS AND RESULTS

Assessment of External Corrosion Rate

The steps required to determine the corrosion rate are shown in the figure to the right. The corrosion rate was determined using the basic data provided by the client, in conjunction with the equation:

CR=CRB*FSR*FT*FCP*FCE

In this equation, the base corrosion rate, CRB, is adjusted for soil resistivity, FSR, temperature, FT, cathodic protection, FCP, coating effectiveness, and FCE. Determination of the base corrosion rate and each of these factors is discussed in the following paragraphs.

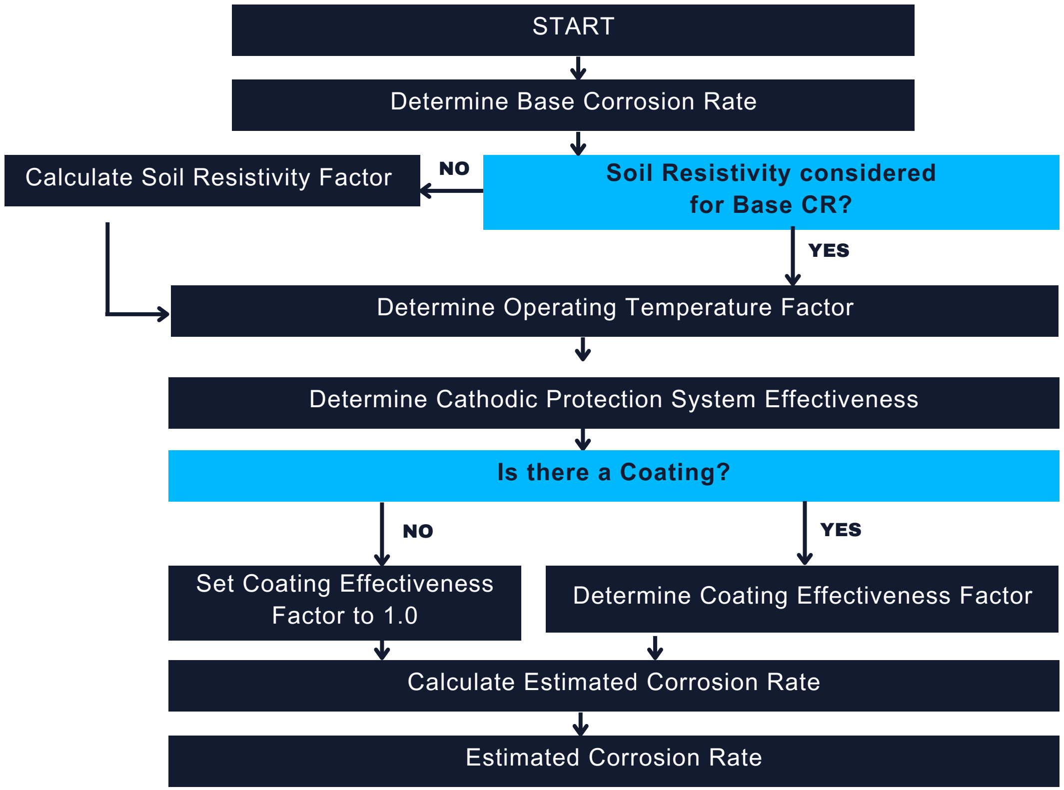

Figure 10: Determine the corrosion rate

Engineering Studies for Replacement Oil Flowlines
Hydraulic/ Corrosion Assessment and Cycle Cost (LCC) Analysis

LIFE CYCLE COST ANALYSIS

The life cycle cost (LCC) approach was adopted for the selection of specific construction materials for oil flow lines. TWI adopted LCC assessment methodology applicable to oil flow lines.
TWI/client established the current materials costs, installation, operation, and capital cost of materials for all the pipeline sizes that were used for the calculation that was based upon the best available data from suppliers/client.
The cost of construction was estimated by TWI/client including welding costs for carbon steel and the cost of bonding lengths of polymeric materials.
Life cycle cost analysis was completed by TWI, taking into account the costs of corrosion inhibitor injection over the life of carbon steel pipelines.

LIFE CYCLE COSTING (LCC)

Engineering Studies for Replacement Oil Flowlines
Hydraulic/ Corrosion Assessment and Cycle Cost (LCC) Analysis

ASSESSMENT OF LIFE CYCLE COSTING

Adopted Approach

- Identified the service condition of each line
- Selected the most practical material for the pipeline construction
- Identified operational and mechanical constraint of each selected material
- Provided the most available costing within the market, taking into consideration a 15% to 20% escalation in cost due to unstable market prices
- Conducted corrosion assessment to furnish pipeline life expectancy
- Assess the applicability of each pipeline against service conditions
- Conduct LCC for two scenarios, (with/without production deference due to loss of pipeline during repair duration)
- The estimate is direct material, operation and construction cost and is for comparison purposes only. The other costs such as the home office, construction preliminaries, and contingencies are not part of the above comparison
- A provision has been added to cover crossings
- Some special costs such as prequalification tests are not included above for this comparison exercise
- Items such as pig valves, and chemical injection skids are fixed cost and only considered once for the life cycle of the asset

Engineering Studies for Replacement Oil Flowlines
Hydraulic/ Corrosion Assessment and Cycle Cost (LCC) Analysis

Data Analysis

In this assessment, two scenarios were considered: -

1. LCC assessment considering deferred production due to pipeline failure and repair or/and replacement duration
2. LCC was excluded since production is either retained within the facilities or/and diverted to other flowlines
3. HSE impact

Obviously, based on the outcome of the LCC, HSE, and material environmental suitability the recommendation of selection is done.

The data utilised to select the most suitable material for the pipeline construction takes into consideration the limitation (temperature, pressure, CO_2, and H_2S) of each material under evaluation.

The following points were considered when conducting the LCC assessment:

- MIF + Internal coating option was excluded based on past experience on internal coated failures
- Liner option in the existing CS flowline is excluded as the flowline is already corroded
- The cost estimate is +/- 20% accurate as of now and should be verified and corrected (if required) at the time of implementation
- The bare CS with an acceptable leak option is included for reference only as leaks are not acceptable as per the FFP strategy
- GRE material of construction is acceptable only up to 65 deg C and hence to be considered for below 65 deg C design temperature service
- Techno-economic material selection shall be applicable per current/future operating temperature and as well as the controlling integrity (Int /Ext.) issue
- The LCC study table shall prevail when the condition within the table is met

Engineering Studies for Replacement Oil Flowlines
Hydraulic/ Corrosion Assessment and Cycle Cost (LCC) Analysis

ASSESSMENT OF LIFE CYCLE COSTING

S.N.	CORROSION CASE	PRIMARY MOC	ALTERNATE 2ND OPTION
1	Internal corrosion governing case	RTP flowline	Non-metallic, CRA liner
2	External corrosion governing case	Ext coating + CP	RTP flowline
3	Internal, both int and ext corrosion governing case corrosion governing case	RTP flowline	Int liner + ext coating+CP

Fit for Purpose (FFP) Study

The current and future operation data was provided for the flowlines included in the scope in TWI template format. TWI conducted a hydraulic study using PipeSIM (2021.1) model, a corrosion study using the Larkton CM model and TWI LCC-based material selection model.

Result of Fit-for-Purpose (FFP) Study

The table below furnishes the optimum recommended flowline size, assessed internal and external corrosion rate and recommended “LCC-based material selection” for the oil flowlines included in the scope.

Engineering Studies for Replacement Oil Flowlines
Hydraulic/ Corrosion Assessment and Cycle Cost (LCC) Analysis

SUMMARY OF FFP STUDY OUTCOME FOR THE OIL FLOWLINES

Well / Line #	Existing FL size (inch)	Hydraulic FL size (inch)	Assessed Corrosion Rate (mm/yr)		PL Length (Km)	Recommendation LCC based Material of Construction
			INT	EXT		
002	6	6	0.44	0.8	7.0	RTP flowline (up to 82 deg C)
196	6	6	0.68	0.3	0.9	RTP flowline (80 to 110 deg C)
442	6	6	1.12	0.5	2.7	RTP flowline (up to 82 deg C)
393	6	6	0.56	0.3	4.03	RTP flowline (up to 82 deg C)
403	6	6	1.52	0.3	2.52	RTP flowline (80 to 110 deg C)
410	6	6	1.29	0.3	5.13	RTP flowline (80 to 110 deg C)
012	6	6	1.09	0.3	2.9	RTP flowline (80 to 110 deg C)
629	6	6	0.95	0.3	2.9	RTP flowline (80 to 110 deg C)
363	6	6	1.25	0.3	1.6	RTP flowline (up to 82 deg C)
106	6	6	0.9	0.3	1.4	RTP flowline (80 to 110 deg C)

The above table furnishes the initial recommendation for the type of material to be utilised per line. An alternative second material option is also identified and addressed in the report.

Identifying Corrosive Bacteria Contaminated Equipment Across Various Assets and Developing Bio-Mapping for Each Field

BACKGROUND

The number of loss of prime containment (LOPC) incidents due to microbial induced corrosion (MIC) is increasing across predominant oil and gas company assets. The source of corrosive bacteria is either produced fluids or re-injection fluids or supply/injection/wash water.

The samples to be tested are mainly water samples and/or debris samples collected from the following locations.:

- Producing oil well heads, oil flowlines, oil pipelines, main oil lines, storage tanks
- Supply, injection water clusters
- Produced water re-injection (PWRI) lines
- Service water/firewater

In this respect, TWI Gulf was engaged to identify the corrosive bacteria contaminated equipment across various assets and develop bio-mapping for each field including recommendations for mitigating microbial induced corrosion issues.

OBJECTIVES

- To identify bacteria (SRA/Methanogens/SRB/IRB/APB) contaminated equipment by conducting bacteria testing followed by bio-mapping of corrosive bacteria-contaminated areas
- To develop mitigation measures for bacteria corrosion
- This testing is planned to be conducted at all assets using external microbiology laboratory services

Identifying Corrosive Bacteria Contaminated Equipment Across Various Assets and Developing Bio-Mapping for Each Field

RESULTS / ACHIEVEMENTS

Quick Bacteria Testing

The quick corrosive bacteria testing was done using 2nd generation ATP monitoring technologies for detection of all actively growing organisms in the system, using portable units “LuminUltra” ATP monitoring kits at each asset.
TWI conducted the quick testing technology (ATP technique) by counter-testing the same samples using the qPCR technique for one sample each from the oil system and water system prior to proceeding with bulk testing at each asset.

Bacteria DNA (qPCR) Testing

The quantitative polymerase chain reaction (qPCR) testing was collected at various fields and tested using LuminUltra gene count machine targeting microbes such as SRB/SRA/Methonogens/IRB/APB etc... (in line with NACE TM 0212 standard).

Data Analysis and Root Cause Analysis

TWI analysed the bacteria test data, identified the source of corrosive bacteria, type of major bacteria (Planktonic or Sessile), bacteria family species and its related impact on different metallic/non-metallic material of construction, root cause/s, analysed the severity in terms of microbial induced corrosion (MIC), and recommended remedial measures to control the MIC issues at each asset.

Identifying Corrosive Bacteria Contaminated Equipment Across Various Assets and Developing Bio-Mapping for Each Field

RESULTS / ACHIEVEMENTS

- Highly complex microbial/chemical process
- Key role for sulfate reducing prokaryotes, but also others:
- Methanogens
- Iron reducing/oxidising bacteria
- Acid-producing bacteria
- Enhanced pitted corrosion rates at spots with biofilms and elemental sulphur
- Pitted corrosion difficult to predict
- Biofilm communities more biocide resistant

Mitigate by:

- Biofilm development mitigation by biocide
- Cathodic protection
- Regular pigging
- Inert lining and SS-piping

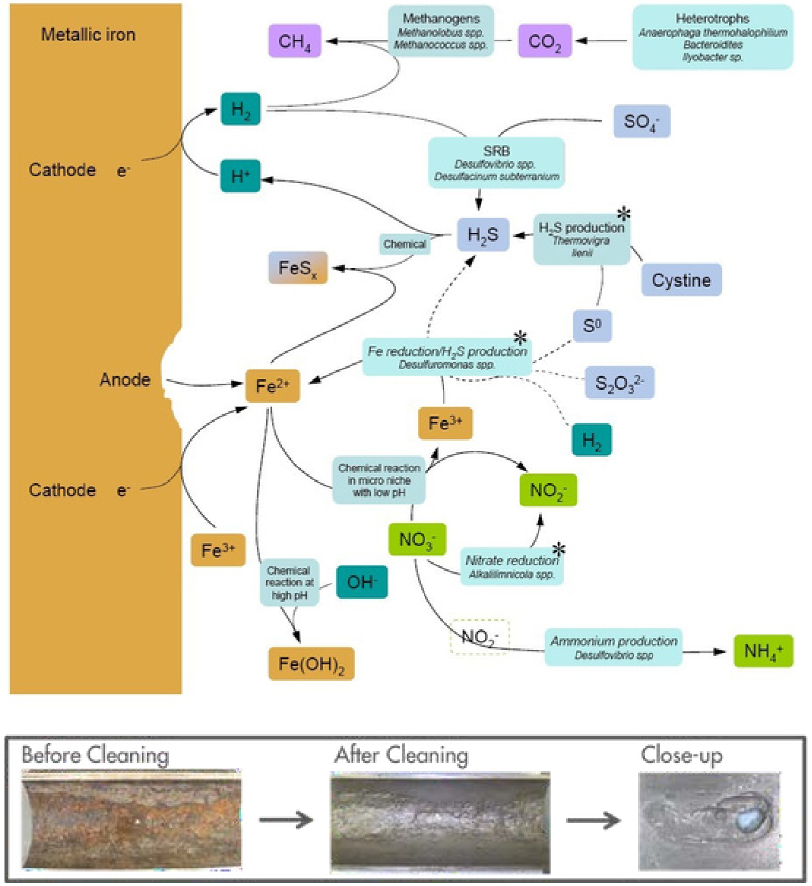

Figure 11

Integrity, Inspection and Assesment Work on a Pipeline

BACKGROUND

TWI Services Sdn. Bhd. (TWI) was contracted to perform the integrity, on-site inspection, and assessment work on a 20-year-old nationwide long gas pipeline system in peninsular Malaysia, buried and above-ground. The work was carried out primarily in accordance with the ASME B31.8S, and NACE RP0502-2010 external corrosion direct assessment (ECDA) requirements.

The ECDA approach consists of four major phases; pre-assessment, indirect inspection, direct examination, and post assessment. Mainly for the buried sections, under the indirect inspection phase, a combination of two or more inspection techniques were carried out to verify the pipeline locations, identify coating failures, anomalies, and/or corrosion, which include:

- Pipeline current mapper (PCM) together with the geographic information system (GIS) surveys
- Close interval potential surveys (CIPS) to determine the existing cathodic protection (CP) system's effectiveness
- Alternating current voltage gradient (ACVG) to determine the location and size of coating defects/holidays and characterise corrosion activity

Locations for bell-hole excavations were then identified based on the results from PCM, CIPS, and ACVG with the selection criteria as follow:

- very low pipe-to-soil potential (due to under-protection)
- very high pipe-to-soil potential (due to overprotection)
- moderate to severe coating breakdown from ACVG readings

Direct pipe surface evaluations were carried out at these locations via through close visual inspection (CVI), base metal and coating thickness measurement, pit depth measurement, and others. Direct pipe surface evaluation was also carried out on the above-ground sections in accordance with the API 570 requirements

Integrity, Inspection and Assesment Work on a Pipeline

OBJECTIVES

To conduct ECDA with the purpose of determining the pipeline integrity status.

RESULTS / ACHIEVEMENTS

Based on the CIPS and PCM results, majority (>50%) of the buried pipelines sections had 70%-99% protected length, in compliance with the client protection criteria with no significant indications of coating breakdown. Excavations with CVI supplemented by thickness measurement showed no significant metal loss for some of the severely under-protected pipelines. Where a leak was found, CIPS results had confirmed that the pipeline was severely under-protected with signs of coating failure observed from CVI.

Excavations at over-protected areas showed evidence of coating breakdown, and flaking or disbondment. Adhesion was poor where the paint can be easily scraped off to the bare metal. Remaining life assessment based on ASME B31.8, ASME B31.G & API 570 showed that the pipeline has in excess of more than 10 years of safe operation
It was also concluded that the existing CP system either reaching the end of its operating life, or current distribution is not uniform.

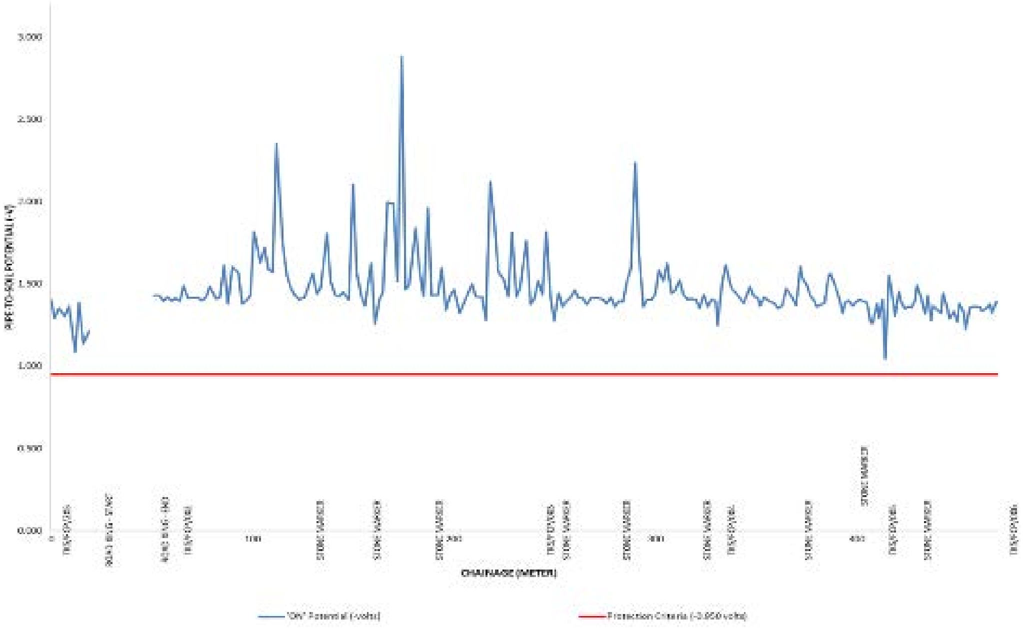

Figure 12

Replacement of sacrificial anodes were recommended with CIPS to be conducted within 6 to 12 months from installation.
On top of the integrity assessment, TWI also helped client to establish a database for the pipelines. The pipelines were systematically tagged and ID'd based on the zones and locations, and all relevant information of the pipelines were organised under the ID including the construction drawings, design and operating information, GIS data, inspection reports, and the final integrity assessment reports.

Pipeline Loss of Containment Root Cause Analysis

BACKGROUND / OVERVIEW

During a recent inspection, a loss of containment (LoC) incident was found at a failed welded joint. The pipeline, commissioned in 1999, has a diameter of 33 inches and a wall thickness of 10mm. It was constructed using API 5L X70 and adhered to the guidelines specified in ASME B31.8.

To delve deeper into the LoC incident, a comprehensive geotechnical investigation was conducted at the LoC location. The investigation findings indicated that the excavated pipeline exhibited plastic deformation in the lateral direction, suggesting that the pipeline experienced stress levels exceeding its yield point. TWI was contracted to identify the root cause of the LoC. TWI employed advanced techniques such as finite element analysis (FEA), engineering critical assessment (ECA), and fault tree analysis (FTA) to conduct a thorough analysis and determine the underlying factors contributing to the incident.

OBJECTIVE

- To determine the root cause of the pipeline LoC based on known information using advanced techniques such as FEA, ECA and FTA

FEA, ECA AND FTA TECHNIQUES

To obtain stress values for ECA, a FEA was performed to simulate the deformation of the bent pipeline, by taking into account the findings from the geotechnical investigation. Subsequently, an ECA assessment was carried out, incorporating data from the failure investigation, operational records, and the results of the FEA. TWI's CrackWISE 6, which adheres to BS7910 standards, was utilised for the ECA analysis. Sensitivity analyses were also conducted to assess the significance of the parameters employed in the assessment. The FTA systematically traces the potential causes of a loss of containment (LoC) in a pipeline, starting from the top event and progressively examining intermediate and basic events

Pipeline Loss of Containment Root Cause Analysis

RESULTS

By using the ECA and FEA techniques, the following results were derived:

- The measured external circumferential crack would have experienced failure based on the material properties and stress levels obtained from finite element analysis (FEA)
- The stress levels applied to the crack during the loss of containment (LoC) surpassed the material's yield strength and approached the ultimate tensile stress
- A thorough engineering critical assessment (ECA) determined that the measured crack size would have failed through ductile fracture

The FTA results concluded:

- Increased bending load occurred due to gradual ground movement, leading to localised deflection
- The possibility of external environment leaks existed due to the potential shearing of joint wraps
- The combination of high tensile stress and susceptible materials initiated stress corrosion cracking (SCC)
- The undetected propagation of SCC resulted in the welded joint and LoC rupture at a critical crack size

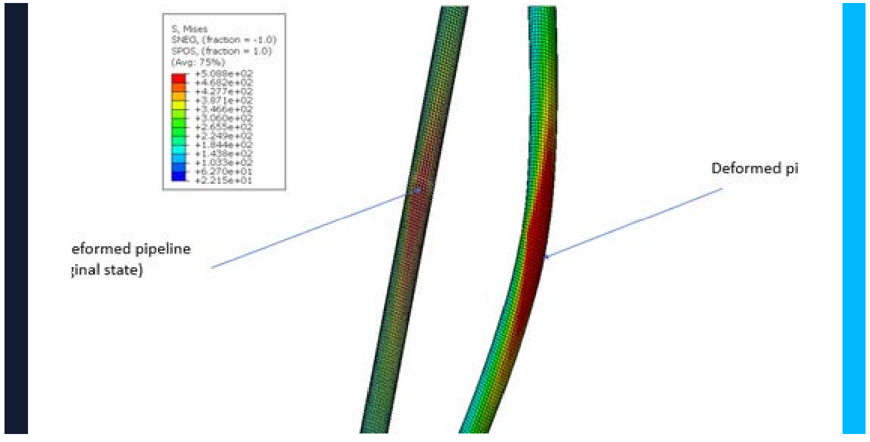

Figure 13: Undeformed and deformed presentation of the FEA model at the LoC

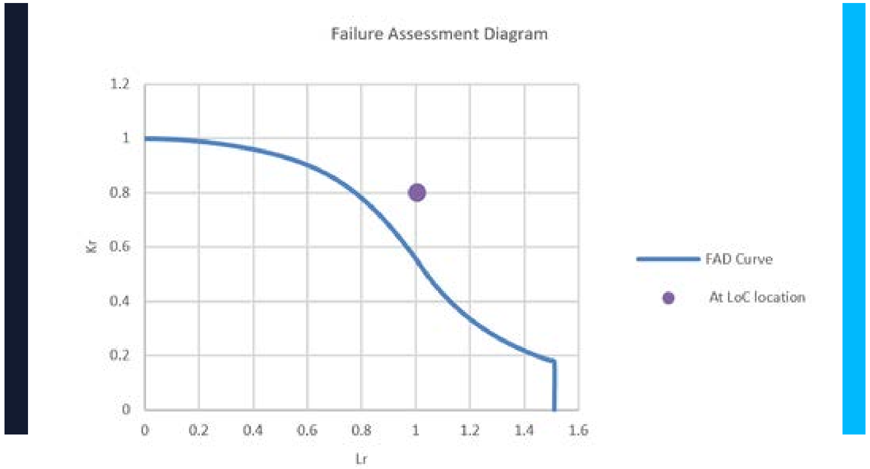

Figure 14: Failure assessment diagram at LoC location

RBI Assessment of Pressurised Equipment

BACKGROUND / OVERVIEW

Risk based inspection (RBI) represents the next generation of inspection approaches and interval setting, recognising that the ultimate goal of inspection is the safety and reliability of operating facilities. RBI focuses attention specifically on the equipment and associated deterioration mechanisms representing the most risk to the facility. In focusing on risks and their mitigation, RBI provides a better linkage between the mechanisms that lead to equipment failure and the inspection approaches that will effectively reduce the associated risks.

The types of pressurised item and associated components and internals covered by API RP 580 include:

- Pressure vessels – all pressure containing components
- Process piping – pipe and piping components
- Storage tanks – atmospheric and pressurised
- Rotating equipment – pressure containing components
- Boilers and heaters – pressurised components
- Heat exchangers (shells, heads, channels and bundles)
- Pressure relief devices

OBJECTIVE

TWI provide engineering services by conducting RBI assessment of pressurised components. The RBI assessments are conducted using RiskWISE software.

RESULTS

The process of RBI consists of a logical and systematic approach to manage the plant's asset integrity by focusing the management action in prioritising resources on critical equipment, i.e. assessed to be high risk. It requires a wide range of data to reliably assess the equipment's probability and consequence of failure and subsequently develop an inspection plan to manage that risk. Figure 15 (on next page) shows a generic approach of RBI assessment.

RBI Assessment
of Pressurised Equipment

The first step in conducting RBI assessment using RiskWISE is data input. Data input on RiskWISE software is based on design data, operation data, corrosion monitoring data, inspection data, maintenance history data and others. Based on the data input, RiskWISE will automatically determine the active potential damage mechanism (DM) such as external corrosion, internal thinning, etc as shown in Figure 16 (on next page). Based on the active DM, the damage factor (DF) value will be automatically calculated. From the DF value, component type and factor management system (FMS), the probability of failure (PoF) value will be obtained. The consequence of failure (CoF) value will be calculated automatically based on input data on RiskWISE.

From the PoF and CoF values, risk of each equipment can be obtained. Based on the risk ranking, inspection intervals for each equipment can be scheduled. The results of risk and inspection intervals are displayed on RiskWISE as shown in Figure 17 (on the next page).

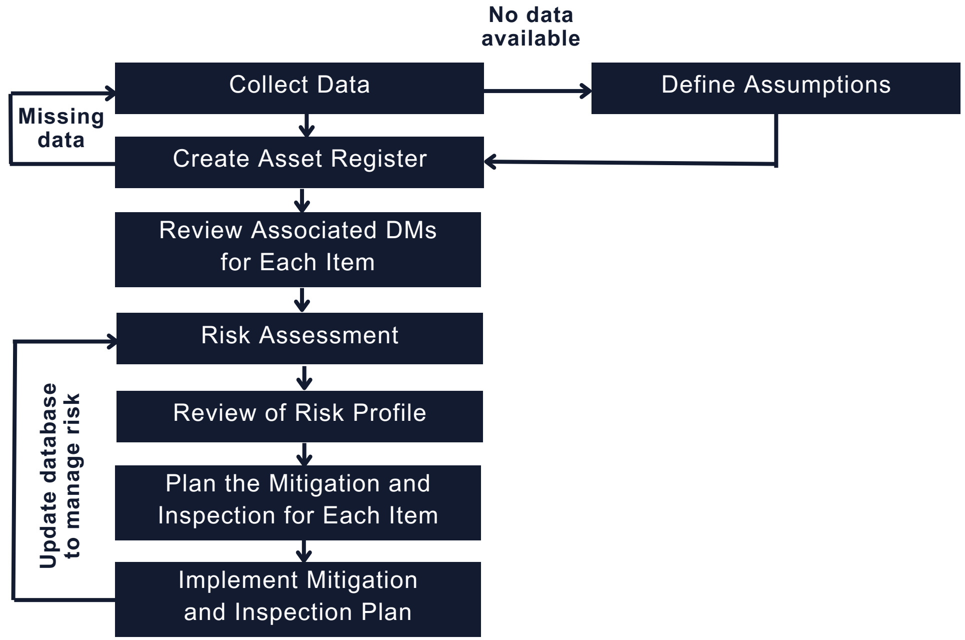

Figure 15: Generic approach of RBI assessment using RiskWISE

RBI Assessment
of Pressurised Equipment

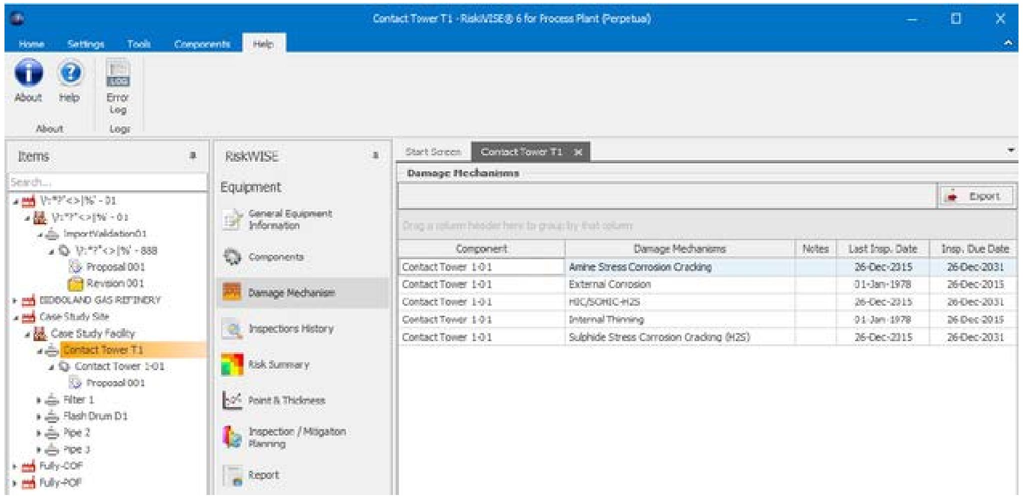

Figure 16: Damage Mechanism Module on RiskWISE

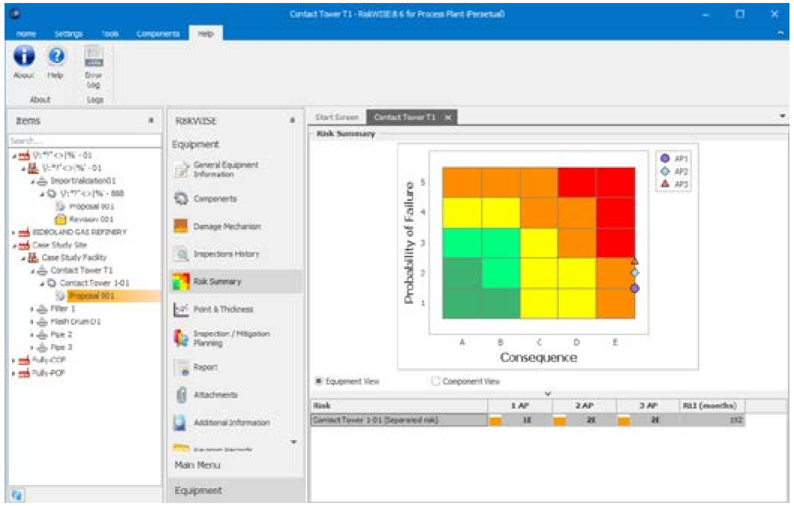

Figure 17: Equipment Risk on RiskWISE

Structural Integrity Assessment of Well Conductors

BACKGROUND / OVERVIEW

It is now more crucial than ever to guarantee the structural integrity of well conductors to prevent unforeseen failures as life extension projects result in many oil wells being used beyond their design life.

TWI provided a comprehensive structural integrity assessment for a major offshore oil and gas operator, providing peace of mind that around 150 oil well conductors were safe to continue service. As well as carrying out the assessment according to a custom fitness-for-service (FFS) methodology, TWI also provided the operator with an inspection strategy for the future, to ensure the most efficient use of resources and reduced inspection costs going forward.

Offshore wellbores consist of several tubes. The outermost well casing - the conductor - protects the inside casings from aggressive corrosion. The conductor should not leak, buckle, or collapse under axial load and bending moment.

The broad scope of work includes a design basis and review of the integrity of the existing wells to estimate the minimum required thickness (MRT) of offshore well conductor pipes for specific well designs, considering all uncertain parameters.

Depending on their functionality (oil producer wells, gas producers, water injector wells, etc.), depth, and other factors, well conductors can be evaluated individually or by grouping them into distinct categories. Axial loads and bending moments for each well within each category group were examined.

Based on this review, the most critical well in each group was nominated as the representative well (most onerous) in that group for further analysis.

The strength and stability assessments were performed for the representative well in each group by using finite element software. The finite element model:

- Includes the conductor, inner casings, surface equipment, jacket lateral supports, and soil support (p-y soil springs/soil fixity)
- Calculates axial well loads (considering casing eccentricity) in the conductor and casings at the wellhead for each critical drilling stage
- Perform a strength and stability assessment of the well conductor, connectors, and surface equipment flanges, as required following the IP guidelines and the relevant AISC and API codes, with modifications for the stability of concentric pipes in accordance with Stahl and Baur 1983, and Imm and Stahl 1990

Structural Integrity Assessment of Well Conductors

- Consider environmental loads including a 100-year return period wave
- Extract bending moments at key surface equipment elevations and along the conductor and then compare against allowable capacities for bending, axial, and lateral/environmental loads (as appropriate)
- Assesses wave and current induced fatigue
- Check vortex shedding

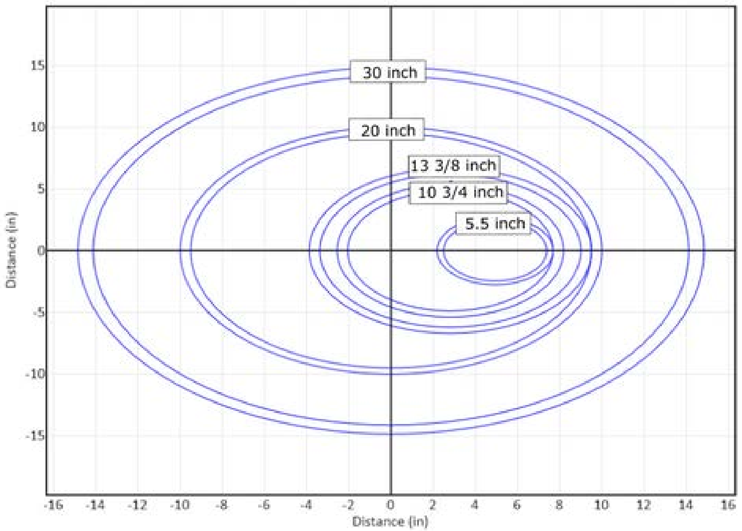

Figure 18: Casing Eccentricities Example

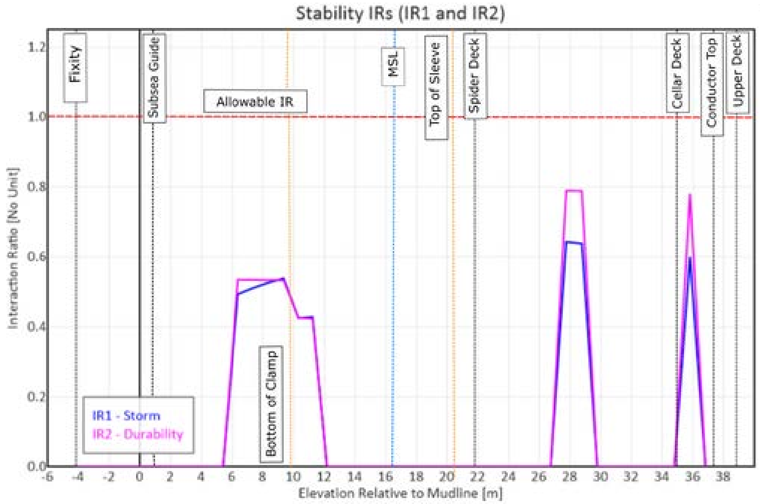

Figure 19: Stability Chart Example

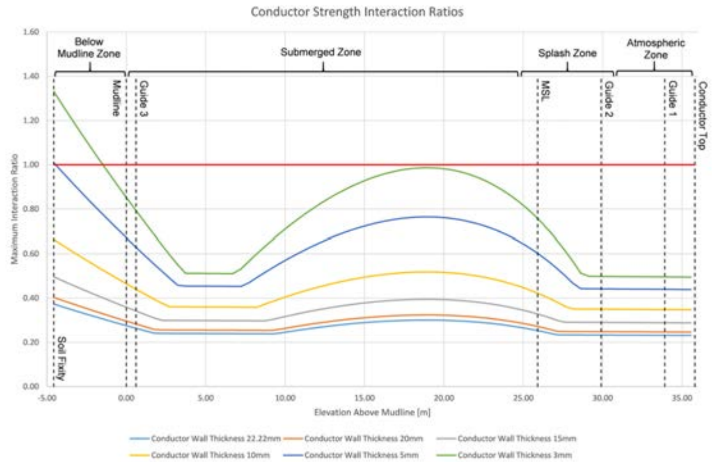

Figure 20: Maximum Conductor Strength Interaction Ratios

Structural Integrity Assessment of Well Conductors

Based on the developed finite element (FE) model, the minimum required thickness (MRT) for each well type was provided. MRT is the thickness below which the required cross-sectional area is not achieved and failure may occur.

Calculation of Probability of Failure

Different parameters contribute to the estimation of the MRT of a conductor well, such as:

- Axial weight
- Bending moment
- Conductor yield stress
- Modulus of elasticity
- Bucking length

In general, FE softwares use deterministic values for the above-mentioned parameters to perform the stress analysis and, consequently, for obtaining the MRT values. However, there are many uncertainties in the applied loads on the conductors (e.g. axial load and bending moment) and in the resistance of the conductors.

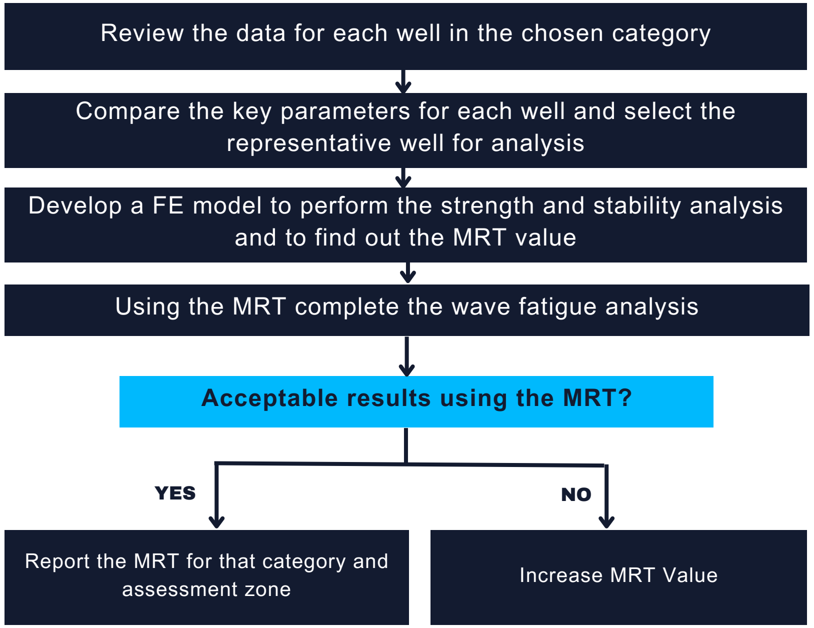

Figure 21: MRT Calculation Flow Chart

Structural Integrity Assessment of Well Conductors

The scope of work includes providing the failure probability of the conductor wells.

Since the exact value of the above parameters is uncertain, instead of a deterministic value, a distribution is assigned to each parameter. Based on the previous studies, log-normal distributions with a COV (Coefficient of Variation) of 0.1 were considered for the above-mentioned parameters. The mean values of the parameters are those values that used in the FE model.

Having assigned distributions for the input parameters, a normal distribution can be assigned to the MRT value. After obtaining the MRT distribution, the remaining life (RL) for the conductors is estimated as:

$$RL = \frac{t_{avg} - MRT}{CR}$$

Where tavg is the averaged measured thickness from the UT results and CR is the corrosion rate for each conductor based on UT thickness measurements.
Due to assigning a distribution for MRT, a distribution can be assigned to the remaining life. After assigning a distribution to the remaining life, the probability of failure (POF) for different conductor thickness (ti) is obtained as the probability of remaining life is less than zero, i.e.:

$$POF = P(RL \leq 0) = P\left(\frac{t_i - MRT}{CR} < 0\right)$$

In each group of conductors, based on the calculated MRT and the estimated CR, the remaining life of the conductor was estimated and some recommendations and mitigation actions were provided.

The final step was to develop a bespoke risk assessment model. This informed an inspection and mitigation plan which highlighted any particularly high-risk conductors and defined target dates for proposed inspection or mitigation.

Structural Integrity Assessment of Well Conductors

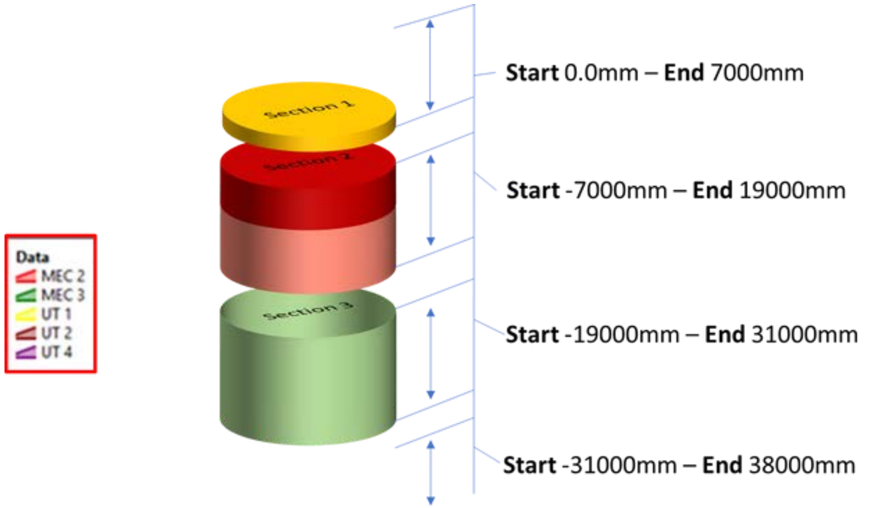

Figure 22: Data Analytics: Section Graphs

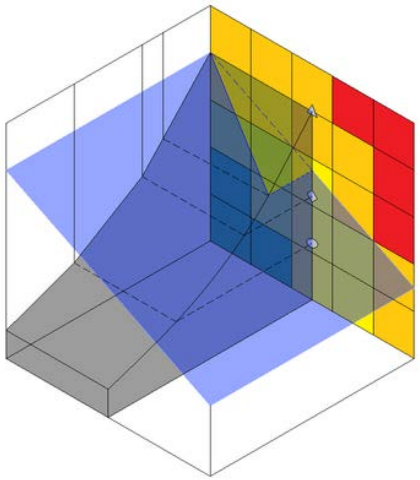

Figure 23: Risk Target Achievement

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