Corrosion & Cathodic Protection Engineering Applied to

LNG Regasification Terminals

LNG Terminals Functioning and Process

In recent years, the LNG industry expanded rapidly and continues to do so, with a significant volume imported by Europe in excess of 75 Mt in 2021 alone[1].

This is achieved by existing or new offshore technologies including land based LNG terminals, offshore gravity based structures and more recently Floating Storage Regasification Units (FSRUs). Different assets are involved in realising these technologies, including but not limited to unloading arms, cryogenic pipelines, storage tanks, pumps, compressors /de-condensers and vaporisers.

LNG assets demand for a tailored and expert corrosion integrity management approach due to the technical complexity imposed by different corrosive environments (offshore and onshore). From conceptual stage to decommissioning, corrosion integrity management is a systematic, comprehensive and multidisciplinary approach in order to maintain and prolong a suitable state of fitness of an asset and to fulfil its design purpose.

Our firm belief is that corrosion integrity is a key contribution towards a global sustainable perspective.

[1]*Source: Statista, "LNG Market in Europe – statistics and facts".*

Fig. 1 - The durability of marine structures contributes to sustainability

Cescor Services for LNG Terminals

Some of the services that Cescor can provide during the design phase are:

- Material selection and corrosion risk assessments implementing FMECA (Failure Mode, Effects & Criticality Analysis) and FTA (Fault Tree Analysis) methodologies
- Corrosion management philosophies and manuals
- Cathodic protection design for onshore/offshore applications, incorporating finite element and boundary element methods
- Definition of metallurgical requirements as well as welding and coatings engineering support for pipelines, steel structures and critical components.

Cescor can assist with the following services during the operational phase:

- Risk Based Inspection (RBI) planning for pressure vessels and piping to API 581, DNV GL RP F116 / G101
- Integrity operating windows assessment to API RP 584
- Fitness for service assessments to ASME B31G / DNV RP F101
- Inspection supervision, corrosion data analysis and evaluation
- Integrity assessments for pipelines, steel structures and critical components
- Cathodic protection inspections for offshore or onshore steel structures
- Concrete durability assessments for Gravity Based Structures (GBS).

Material Selection, Corrosion Risk Assessments, Philosophies and Manuals

Cescor can deliver these crucial activities which allow the end user to evaluate the pertinent corrosion threats and perform a risk ranking for the assets under study with respect to the probability of a failure due to various forms of corrosion. In addition, tools such as FMECA and FTA can be used to perform the corrosion analysis, which is the main activity of the corrosion risk assessment procedure, aimed to calculate or assess the likelihood of corrosion failure.

Corrosion philosophies and manuals allow the end user to construct a set of barriers and mitigative actions which prevent or delay the development of corrosion mechanisms.

Left: Fig. 2 - Aerial view of an LNG facility

Advanced CP Design

FEM (Finite Element Method) and BEM (Boundary Element Method) are used to describe in a realistic way the geometry of intricate structures and to study the large number of influencing variables. They represent a useful tool for CP design, in order to evaluate the impact and consequences of the engineer's choices on existing systems and predict different scenarios. Amongst others, they provide significant advantages such as realistic virtual modelling, detection of under or overprotected areas, optimised anode spacing and evaluation of anode consumption. Cescor can offer advanced CP design solutions by implementing such modelling methods.

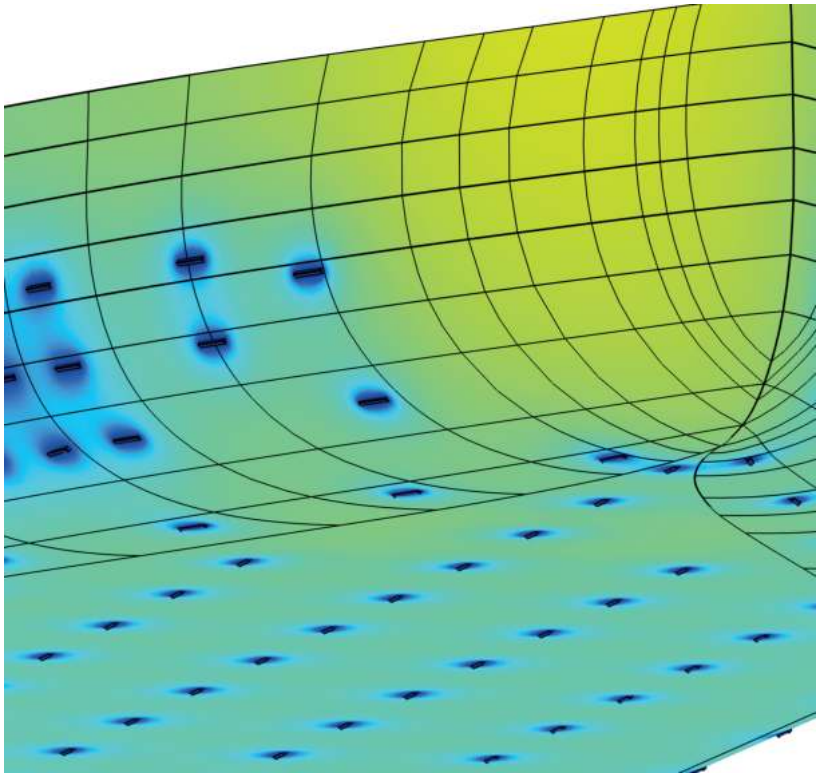


Fig. 3 - Example of an FSRU hull protected by galvanic anodes

Metallurgy, Welding, Coatings

The specialist competencies in metallurgy, welding and coatings offered by Cescor are underpinned by the in house expertise of its personnel (IWE/EWE, PCN, CSWIP for welding and ICorr, Frosio, BGAS/CSWIP for coatings). Cescor can therefore aid engineering activities at different project stages including preparation and review of relevant project documentation, specification and procedures, technical bid evaluations as well as support during qualification, pre-production and production fabrication activities.

Fig. 4 - Close view of a weld profile

Risk Based Inspection Cycle Management

Risk Based Inspection (RBI) is a decision making technique for inspection planning based on risk. Risk Based Inspection is applied to the LNG regasification plants to optimize and reduce the cost of inspection activities of pressure piping and equipment reducing the overall equipment downtimes and ensuring asset integrity.

Cescor manages the whole RBI cycle for pressure piping and equipment as follows:

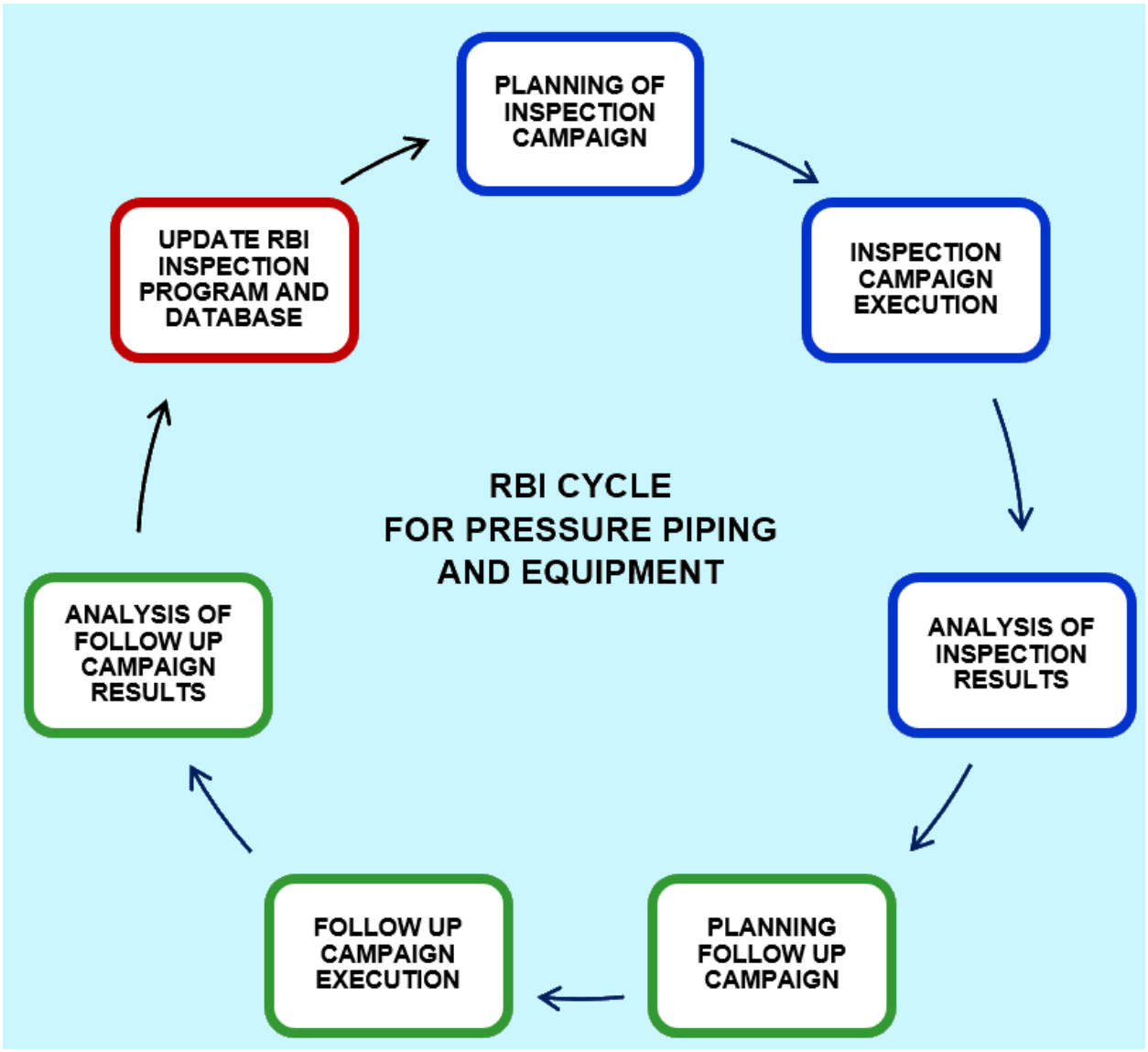


Fig. 5 - RBI yearly activity cycle

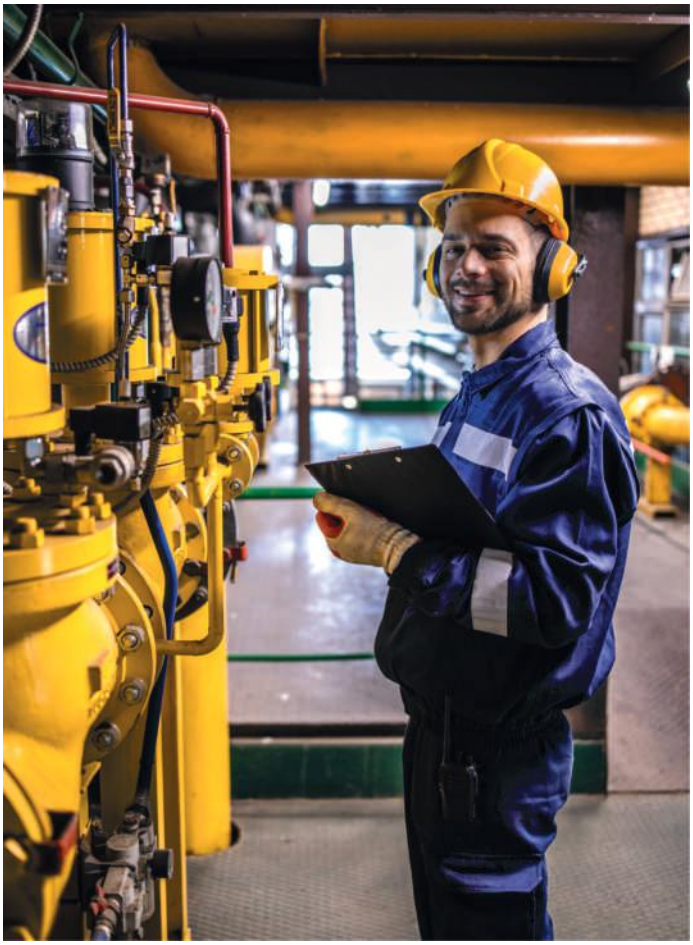
Integrity Operating Windows

The analysis of Integrity Operating Windows (IOWs) incorporates multiple aspects and requires the collaboration of a multi-disciplinary IOW team. Cescor can join such teams as a corrosion and integrity specialist, able to propose tailored and pragmatic solutions suiting the client's requests. IOW shall provide the bridge between the design and operational phases to ensure the integrity of the facilities involved and maintain safe operations.

Fitness for Service Assessments

ASME B31G and DNV-RP-F101 Parts A and B allow to conduct Fitness for Service (FFS) assessments for corroded pipelines. Defect features measured during the ILI (In line Inspection) are used to determine whether each defect feature is critical or not at the time of the inspection. Internal and external defects related to corrosion may develop and it is important to assess the time frame in which they will become critical. Therefore, predictive models are used to assess corrosion rates and simulate defect growth.

Inspection Supervision, Corrosion Data Analysis and Evaluation



The corrosion engineering expertise assists in supervising the execution of the inspections.
The company representative helps to:

- Ensure the accomplishment of the objectives and targets of the campaign
- Check the compliance of the executed activities with those recommended in the inspection plan.

Collected inspection data need to be properly managed and assessed to determine the status of the component in respect of the investigated corrosion mechanisms.
Inspection data interpretation requires engineering capabilities and specialist expertise: all data analysis and expert judgements regarding the integrity of a component are in charge of qualified corrosion and materials engineers.
Dedicated smart databases can be created to store and manage all inspection data.

Cescor is entrusted by several clients to receive, examine and process their data related to corrosion, and to manage and interpret these data safely.
Thus, our services in data collection, management and analysis ensure clients can make the most appropriate choices when defining the actions needed to mitigate and monitor corrosion as part of an established life cycle assessment.

Left: Fig. 6 - Supervising inspections at an LNG regasification plant

Integrity Assessments for Pipelines, Steel Structures and Critical Components

The integrity of the steel structures is assessed through a dedicated analysis of all possible degradation mechanisms affecting the structural metals in the atmospheric zone, splash zone and immersed zone.

The evaluation of the corrosion rate for the most common engineering metals for structural applications is performed on the basis of the applicable engineering tools and international standards.

CP Inspections of Offshore Structures

The main metallic offshore structures of LNG Terminals that are cathodically protected are:

- Jacket or floating structure
- Risers and offshore pipelines
- Mechanical outfitting like breasting structures, boat landing, riser protector
- Metallic reinforcement bars and plates embedded in the concrete structures.

Cescor services for offshore CP protected structures are:

- Job specifications for CP underwater inspections
- Execution of CP inspection
- Execution of CP profile for subsea pipelines
- Supervision of offshore inspection campaigns to check and ensure compliance with the requirements of the job specification
- Analysis and interpretation of CP inspection data.

CP Inspections of Onshore Pipelines from/to LNG Terminals

The corrosion engineering expertise helps supervise the execution of the inspections.
The company qualified representative can be responsible for the following activities:

- Periodical interventions and/or ordinary maintenance:
  - On/off potential measurements
  - 24 hours interference registrations at rail crossings
  - Checks and regulations on T/R operating parameters
  - Verification of efficiency of insulating joints
- Close Interval Potential Survey (CIPS) and Transverse Gradient Method (TGM) in order to obtain the cathodic protection profile
- Verification of the interference with high-voltage aerial cables crossing or parallel to the pipeline.

Concrete Durability for Gravity Based Structures

Localized corrosion of steel reinforcements starts when the chloride ion concentration in the concrete around the reinforcements reaches a critical threshold.
The estimation of the durability of the concrete structures is performed through the:

- Dedicated Assessment of degradation mechanisms for concrete structures for the atmospheric zone, splash zone and immersed zone
- Preparation of job specification for concrete coring
- Supervision of the execution of concrete coring
- Analysis of the concrete laboratory results.

Safety

Historically, LNG has the best safety record of all common fuel types and is completely nontoxic.
However, if released into the open and not contained, the gas would be highly flammable and pose a risk of fire or explosion.
To prevent the probability of a failure and consequent leakage, Cescor can provide its expertise to ensure the integrity of the asset in all project phases from design to construction and operation.

Through its specialized expertise, Cescor supports its clients in achieving their environmental goals, maintaining their safety standards and building a globally sustainable strategy.

Fig. 7 - Activities on concrete walls of a Gravity Based Structure

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