Offshore Assets: From Corrosion Engineering to Corrosion Management

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Corrosion is one of the primary threats to the integrity of the topside process pressure systems (TPPS) of any offshore asset. Corrosion engineering and corrosion management disciplines are required to mitigate this threat. This article provides a detailed account of the above concepts and their interactions throughout the operations phase of the asset.

The integrity of the topside process pressure systems (TPPS) of any offshore asset is threatened by many factors, among which corrosion is primary. To mitigate such a threat, an integrity management system (IMS) or an asset integrity management system (AIMS) is required, two of whose components are:

- Corrosion engineering (CE).
- Corrosion management (CM).

CE and CM can be regarded as two discrete components within any IMS; nevertheless, they are very closely interrelated and interact elaborately with each other throughout the asset life cycle, especially post-commissioning and during the operations phase.

The integrity of TPPS is ideally ensured and maintained through:

- Sound application of CE know-how, beginning at and mainly during the design phase.
- Proper implementation of CM principles post-commissioning and during the operation phase.

The interactions between the two throughout the asset life cycle and their blurred boundary cause confusion for the responsible corrosion engineer, leading to poor CE and inconsistent CM. This situation is often the main reason behind some of the recurring corrosion issues onboard the TPPS of offshore assets.

The CE/CM interactions throughout the operations phase influence many asset attributes; the following four factors are discussed in this article:

- Personnel safety and environmental protection.
- Repair and maintenance costs.
- Frequency of unplanned shutdowns.
- Inspection cost.

The recurring corrosion issues encountered post-commissioning can be rectified or mitigated through an understanding of the following factors:

- Both CE and CM concepts and their components and structures.
- Their timely implementation.
- Their delicate interactions post-commissioning and during the operations phase.

This article defines both CE and CM, explains and clarifies their interactions post-commissioning and during the asset operations phase, and shows how the shortcomings of one can affect the other one or the IMS in general. It also recommends ways to handle each situation and improve the IMS during the operations phase.

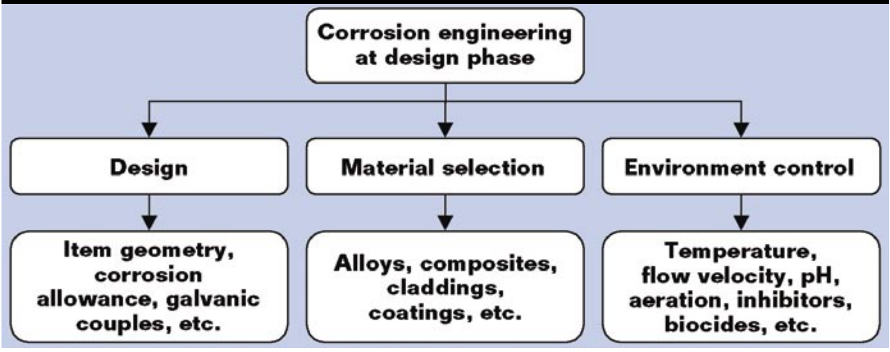
Corrosion Engineering

CE may be defined as "the design and application of methods to prevent corrosion."[1] CE's contribution to the overall IMS of the TPPS should begin ideally at the design phase. The CE structure and its contribution to the IMS can be based on the following three components:[2]

- Design.
- Material selection.
- Environmental control.

Figure 1 illustrates the three components and the corrosion parameters within each.

FIGURE 1

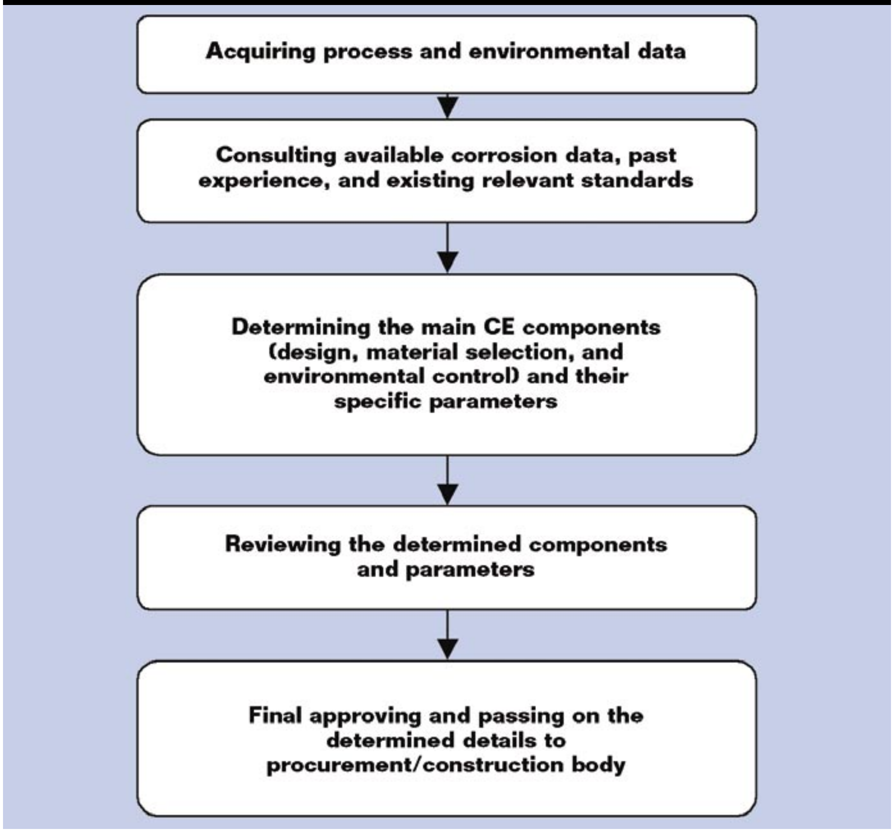


CE components and their specific parameters at the design phase.

At the design phase, CE is largely dependent on the use of the available corrosion data, existing standards, and past experience. Proper use of the existing corrosion data, along with process and environmental data such as seawater quality and its corrosive characteristics, is the first step in determining corrosion issues and possibly designing them out.

Further CE inputs might be necessary post-commissioning and throughout the operations phase because of poor CE input at the design phase or changes in process or operations. Figure 2 depicts the overall CE process to be followed at the design phase.

FIGURE 2



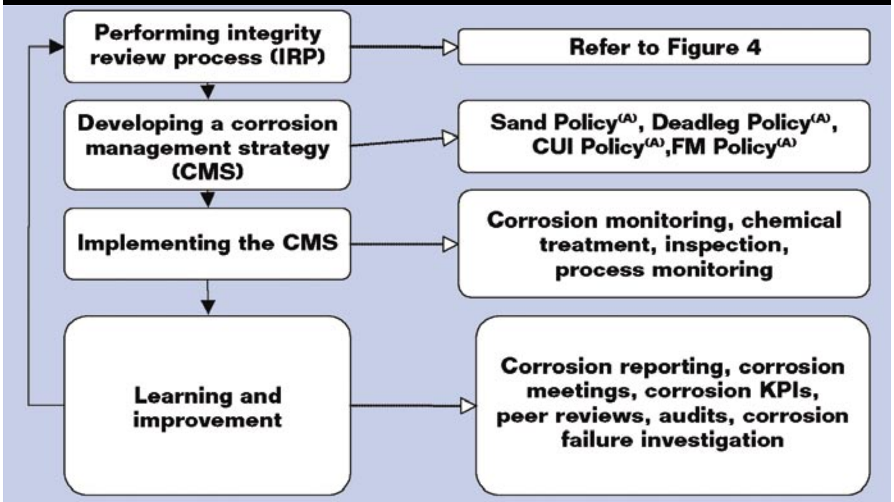
CE process at the design phase.

The corrosion engineer involved at this stage should know the following:

- Corrosion properties and characteristics of the alloying systems to be recommended, based on the available process and environmental data.
- Corrosive characteristics of the process and environment(s) to be encountered.
- All the probable deterioration mechanisms (including corrosion, erosion, and cracking) to be encountered along with the estimated deterioration rates.

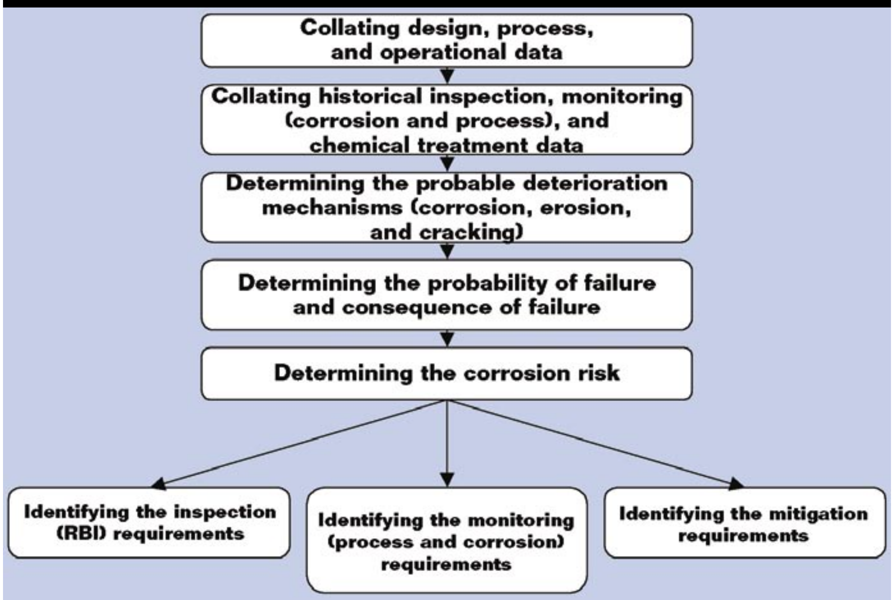
The efficiency and size of any asset CM post-commissioning will depend on the quality and correctness of the initial CE input at the design phase. A poor CE input necessitates a bigger, more

FIGURE 3



CM structure and components (left) and their parameters (right).
(A)If applicable.

FIGURE 4



The six stages of an integrity review process.

comprehensive and more complicated CM post-commissioning.

The interrelations and delicate interactions between CE and CM post-commissioning and during the operations phase are discussed below.

Corrosion Management

CM may be defined as controlling corrosion by keeping the corrosion rate within acceptable limits throughout the operations phase. CM begins immediately post-commissioning and is closely associated with the operations phase. CM is strongly influenced and affected by both the extent and the quality of the initial CE input during the design phase. The better the quality of the CE input, the more straightforward and simple the CM can be. On the contrary, any shortcomings in the initial CE input can further complicate the ensuing CM.

For any offshore TPPS, CM is achieved through a corrosion management strategy (CMS). A CMS is a suite of procedures, strategies, and systems to maintain asset integrity through preventing or mitigating corrosion throughout the operations phase. CM and CMS terms are often used interchangeably and synonymously, even though they are two distinct concepts.

Any CMS comprises four components with specific parameters belonging to each component (Figure 3).

The success, applicability, and thoroughness of any asset CMS depends significantly on the asset integrity review process (IRP). During an IRP, the responsible corrosion engineer collates various useful data to carry out failure risk assessment (FRA) and determine the corrosion risk on a system-by-system basis for the asset. Figure 4 illustrates consecutive stages of an IRP and its main three products, which ultimately constitute the asset CMS. The responsible corrosion engineer should perform an IRP immediately post-commissioning and thereafter on a regular basis to maintain an up-to-date asset CMS.

An efficient CM always begins with an IRP to identify the inspection, monitoring (corrosion rate and process), and mitigation requirements. Lack of appreciation of any of these three requirements will lead to recurring corrosion problems of increasing number and intensity.

From Corrosion Engineering to Corrosion Management

The foregoing discussions have indicated that:

- CE is closely associated with the asset design phase, while CM begins at and continues throughout the asset operation phase.
- CM is strongly influenced by the initial CE input, but the opposite does not hold true (i.e., CE is not in any way affected by CM).

Ideally, an initial, sound CE input at the design phase is followed by a consistent

TABLE 1

Integrity condition of an offshore asset TPPS with regard to various CE and CM levels/inputs and their interactions post-commissioning

Corrosion Engineering	Corrosion Management: Poor	Corrosion Management: Excellent
Excellent	**Symptoms:** No immediate corrosion issues encountered post-commissioning, but the number and severity of such issues increase as the asset ages. Other symptoms include: • Decreasing personnel safety and environmental protection due to continuous increase in the corrosion risk. • Increasing repair and maintenance costs. • Increasing number of unplanned shutdowns. • Increasing inspection costs (and the inspection carried out is not RBI). 2	**Symptoms:** Simply best in class. Low number of corrosion issues post-commissioning. Other symptoms include: • Excellent personnel safety and environment protection. • Low repair and maintenance costs. • No unplanned shutdowns due to unforeseen corrosion issues. • Low inspection cost since the inspection carried out is RBI. 4
Poor	**Symptoms:** Encountering immediate corrosion problems post-commissioning. Such problems will increase in number and severity throughout the operation phase of the asset. Other symptoms include: • Decreasing personnel safety and environmental protection due to continuous increase in the corrosion risk. • Increasing repair and maintenance costs. • Frequent unplanned shutdowns. • Increasing inspection costs (and the inspection carried out is not RBI). 1	**Symptoms:** Encountering immediate corrosion problems post-commissioning, but the number of such issues would start to decline as most of them would be predicted, tracked, rectified, and/or at least mitigated by successive IRPs as the asset ages. Other symptoms include: • Improving personnel safety and environment protection. • Decreasing repair and maintenance costs. • Decreasing unplanned shutdowns. • Decreasing inspection costs (and the inspection carried out is RBI). 3

and efficient CM post-commissioning. The responsible corrosion engineer is well conversant with both concepts and their applications and interactions, and is assisted and well supported by the operator to fully implement the CMS. In many instances, however, this is not the scenario; poor CE input is often followed by inconsistent or lack of any CM.

The situation is often made worse by the corrosion engineer's lack or inadequate understanding of the CMS, its components, and their appropriate and timely implementation. The overall situation is manifested by recurring corrosion issues with increasing intensity onboard the TPPS during the operations phase. While there are many courses available to train students in corrosion engineering, there are not many offering training on CM as the latter is often viewed as a subset of the former.

The situation is further exacerbated by the reluctance of some operators toward adopting an appropriate CMS post-commissioning. They believe the initial CE input at the design phase has eliminated the requirement to have a CMS in place. This reluctance often continues throughout the operations phase until the first corrosion issues appear, causing equipment failures, incidents, and shutdowns. The root cause of such corrosion issues can either be poor CE input or inconsistent or lack of CM.

Corrosion Engineering and Corrosion Management Interactions Post-Commissioning

CE and CM interactions post-commissioning can sometimes be complicated and confusing, hence misleading the responsible corrosion engineer. To better recognize and deal with circumstances arising from CE/CM interactions and their ultimate influence on the general integrity of the TPPS, two distinct quality/efficiency levels have been considered. Both CE and CM are designated either excellent or poor depending on their input quality and performance. Consequently, there will be four possible permutations describing CE/CM interactions post-commissioning. These permutations are illustrated in the form of the following colored areas/zones in Table 1:

- Red area: poor CE vs poor CM (Zone 1).
- Yellow area: excellent CE vs poor CM (Zone 2).
- Green area: poor CE vs excellent CM (Zone 3).
- Blue area: excellent CE vs excellent CM (Zone 4).

TABLE 2

Recommended solutions with regard to the discussed CE/CM interactions post-commissioning

Corrosion Engineering	Corrosion Management: Poor	Corrosion Management: Excellent
Excellent	**Solution:** Immediately carry out an IRP identifying the inspection, monitoring, and mitigation requirements. Thereafter implement measures to fulfill those requirements. **2**	**Solution:** Maintain current CMS in place and carry out an IRP when necessary. **4**
Poor	**Solution:** Carry out the following actions: 1. Immediately carry out an IRP identifying the inspection, monitoring, and mitigation requirements. 2. Carry out an RBI to identify the high corrosion rate areas; calculate the remaining life and consider repair/replacement if remaining life ≤2 years. 3. Try to improve the initial poor CE input by enhancing/streamlining any of the CE's three main components and their specific parameters if possible. **1**	**Solution:** Carry out regular IRP to gradually and possibly rectify corrosion-related issues created by the initial poor CE input. **3**

These CE/CM interactions affect many different aspects of the IMS, either favorably or adversely depending on the CE/CM interaction and the prevalent zone. Four important parameters are covered in Table 1 and listed below:

- Personnel safety and environmental protection.
- Repair and maintenance costs.
- Frequency of unplanned shutdowns.
- Inspection costs.

One or more of the four parameters can be selected by the responsible corrosion engineer as high-level key performance indicators (KPIs). These KPIs will reflect on the performance and efficiency of any IMS.

The following are key points to consider regarding the illustrated zones and the four parameters:

1. Zone 1 is the least safe for personnel and Zone 4 is the safest.
2. Zone 1 has the costliest CM while Zone 4 has the most economical CM.
3. Zone 1 and 2 inspections are not risk-based even if stated to be so.

Table 2 lists a number of recommendations related to the zones and colored areas already depicted in Table 1.

Conclusions and Recommendations

Many recurring corrosion problems encountered onboard TPPS of offshore assets were caused by lack or inadequate understanding of:

- CE and CM concepts.
- Their structure and components.
- Their interactions post-commissioning.

Once these are fully appreciated, such repeating corrosion issues can be handled more conveniently. Performing an IRP is considered the best solution to rectify many corrosion-related problems that occur post-commissioning. Through the IRP, crucial and sometimes missing data are collated and the inspection, monitoring, and mitigation requirements are identified. The identification of such requirements and keeping them up-to-date through a regular IRP will certainly improve the IMS.

This solution is even more applicable to old offshore assets that have been managed and owned by different operators post-commissioning. These assets mostly suffer from poor transfer processes and the loss of valuable integrity-related data during each transfer.

References

1 D.A. Jones, Principles and Prevention of Corrosion, 2nd ed. (1996), p. 5.

2 K.G. Budinski, M.K. Budinski, Engineering Materials Properties and Selection, 6th ed. (1999), p. 433.

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