An Introduction to Asset Corrosion Management in Industry

BY **Ali Morshed**

NACE INTERNATIONAL

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Preface

It all began in 2010. Back then I was based in Aberdeen (Scotland) and was working as a corrosion engineer on several projects for the oil and gas industry in the United Kingdom's North Sea and elsewhere. I had published a few papers through NACE International on corrosion management and given several U.K. and international training workshops on the same subject. I was still two years away from publishing my first book on corrosion management for the oil and gas industry, which shortly after its publication became a NACE bestseller.

One day I received a telephone call from a fellow corrosion engineer, who at the time was working for the construction industry. He was wondering if I could help him by transferring corrosion management knowledge that had been gained in the hydrocarbon industry to the construction industry and by tailoring the former industry's corrosion management lessons, know-how, and applications in a way that the latter industry could also benefit from.

That call back in 2010 was the first such request, but since then I have received similar enquiries and requests from various industries, such as

- Water and wastewater management.
- Petrochemicals.
- Military.
- Nuclear.
- Marine and ship building.

Such requests have made me look into and study corrosion problems associated with the above industries. Through these studies and growing interactions with fellow corrosion engineers working for such industries, it became evident that in many cases the root causes and the solutions were very similar (if not identical) to those in the oil and gas industry.

Such observations and similarities encouraged me to share oil and gas industry corrosion management experience, knowledge, and expertise in a more organized and comprehensive fashion. Hence this book!

It is true that different industries use different alloy systems and that the corrosive environments vary. Hence, the associated deterioration mechanisms are also different. Nevertheless, rectification measures, whether they are corrosion engineering based or non–corrosion engineering based are very similar to (if not exactly the same as) their counterparts in the oil and gas industry.

Failure investigations carried out in other industries have demonstrated—just like in the hydrocarbon industry—that lack of, poor, or inadequate design, materials selection, communication, documentation, and competency are the main culprits behind corrosion failures.

The successful application of the corrosion management process in various oil and gas projects has convinced the author that because of the aforementioned similarities, such corrosion management applications could also be successfully implemented in other industries.

It has been more than seven years since I submitted my first book's manuscript to NACE for publication. Since then I have had numerous opportunities—either as an engineer, trainer, consultant, or university lecturer—to get involved in various corrosion management projects, agendas, forums, and training courses.

I have had the chance to do the above in many different countries and regions, including the United Kingdom, North Africa, the Persian Gulf region, and South Asia. Interestingly, the outcomes and conclusions of most of the above involvements have been the same: corrosion engineering by itself cannot adequately, efficiently, and satisfactorily mitigate our corrosion problems, but corrosion management applications are indispensable in doing so.

I have witnessed numerous times how proper corrosion management applications have resulted in cost optimizations, enhanced chemical treatments, "real" risk-based inspections, and improved corrosion engineering and corrosion management awareness and competency.

This personal and first-hand experience and involvement has kept me excited about corrosion management applications and provided me with the driving force and motivation to press on with publishing a second book on corrosion management applications; hence this book, which shares oil and gas industry corrosion management expertise with other industries.

Akin to my previous book, which was solely written for the hydrocarbon industry, this book has been compiled in a simple and straightforward manner, with very little use of jargon.

My main aim throughout this book is to keep it plain and easy to understand, with practicality and clarity given the highest priorities. These qualities ensure that this book can be used in many different industries and by various individuals, practicing various disciplines, without any particular prerequisites or special subject matter knowledge.

I hope that the study of the book's contents and the implementation of its various guidelines and recommendations will help any enthusiastic reader to better and more efficiently mitigate corrosion while enjoying the various benefits that a timely and proper corrosion management application can offer.

Acknowledgments

It was back in 2007 when I initially approached NACE and submitted my first paper proposal on corrosion management in the oil and gas industry. That proposal was accepted, and my first *Materials Performance* (*MP*) paper was published a few months later. The publication of that paper was the first stage in a close relationship with NACE that has continued until the present day.

Therefore, first, I would like to thank NACE for this long, fruitful, and close relationship that has enabled me to share my ideas and disseminate my experience for the past 10 years with my dear fellow corrosion and integrity engineers and other individuals around the world. NACE support has been both indispensable and instrumental in enabling me to publish papers on a regular basis through *MP* and to publish my first ever book and then its second edition, all on asset corrosion management.

If it was not for such impeccable support, I would not have been able to press on with the current book and finish it several months early, mostly because of the prompt actions and encouraging support of Jonnie Fuller (NACE's product development manager).

Thus, I would like to express my deepest gratitude to the following mostly NACE personnel (past and current) for their very professional, prompt, thorough, yet friendly service, help, and support throughout all these years with both my paper and book publications. They include (in no particular order)

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Ms. Gretchen Jacobson: Managing Editor in Chief, *MP*
Mr. Robert Chalker: CEO, NACE International
Mr. John H. Fitzgerald III: Technical Director Emeritus, *MP*
Mr. Norm Moriber: Technical Director, *MP*
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Ms. Suzanne Moreno: NII Contractor Accreditation Program Administrator
Ms. Brenda Nitz: Advertising Coordinator, *MP*
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Thereafter, I would like to thank Dr. Bijan Kermani, who initially introduced me to the subject of corrosion in the oil and gas industry at Imperial College London more than 20 years ago. Since then, Dr. Kermani has been a kind and constant source of fatherly advice regarding career moves, technical issues, project work, and almost anything else. From our first meeting at Imperial College classrooms in early 1997, he has been my idol, and I owe him a great deal for all my professional successes as a corrosion engineer, author, and trainer.

I would like to thank many fellow corrosion engineers and engineers in other disciplines and other industries, such as petrochemicals, water and wastewater, nuclear, and military, who have kindly

provided me with various opportunities to get involved in their corrosion projects, to learn from them, and to share my oil and gas corrosion management experience and expertise. Such practical and useful interactions with those individuals have enabled me to compile the current book.

Over the years, I have also had the chance to work with some of the brightest and greatest minds and nicest personalities in the field of asset integrity management. Such cooperation has provided me with invaluable opportunities to learn new useful lessons and improve my technical knowledge. Accordingly, I greatly owe the following dear individuals:

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Introduction

1.1 Corrosion in Various Industries

Asset integrity and its management are indispensable parts of almost all industries. Corrosion is a major integrity threat for numerous industries, and it adds various (sometimes very significant) costs to an asset's life cycle, from design to decommissioning. Such costs include

- Design and materials selection.
- Chemical treatment.
- Inspection.
- Corrosion monitoring and fluid sampling.

In addition to the above cost categories, a corrosion incident, failure, or leak could inflict more costs, such as

- Wasted product.
- Asset shutdown (or deferred production).
- Repair and replacement.
- Labor and logistics.
- Safety and environmental mitigation.

Perhaps nothing could better highlight and demonstrate the effect of corrosion on various industrial sectors than the below excerpts from a study carried out by the U.S. Federal Highway Administration:[1]

- The annual direct cost of metallic corrosion in the United States was $276 billion.
- This figure represented 3.1% of the U.S. gross domestic product and was equal to a direct corrosion cost of just under $1,000 per person per year.
- The total direct and indirect corrosion costs were $552 billon or 6% of the gross domestic product.

This study pertained to metallic corrosion in almost every industrial sector in the United States. The study looked into the cost of corrosion control methods and activities and determined the impact of corrosion on particular sectors. Table 1.1 is a summary of the annual cost of corrosion in different industries according to this study.[1]

Table 1.1 Annual Cost of Corrosion in Different Industries[1]

Industry	Annual Cost ($ billion)
Waterways and ports	0.3
Highway bridges	8.3
Gas and liquid transmission pipelines	7.0
Gas distribution	5.0
Drinking water and sewer systems	36.0
Petroleum refining	3.7
Chemical, petrochemical, and pharmaceutical	1.7

To combat and control corrosion and its consequences in various industries and to reduce the associated costs, corrosion engineering has been used as the main tool and discipline. For many, corrosion engineering–orientated asset integrity management systems (AIMSs) are created to facilitate and promote effective corrosion prevention and mitigation.

Appropriate corrosion engineering input during an asset's design stage could significantly improve the overall asset integrity management after commissioning. Once an asset has been commissioned, such input and applications should be reviewed as required to ascertain that they remain relevant, adequate, and effective. However, as the asset ages, the likely operational and process changes may render the existing corrosion engineering applications less relevant, up to date, or efficient. In such a situation, the asset may begin to suffer from corrosion-related problems of increasing number and severity if such changes, and their potential effects on the asset's integrity, are not addressed in a timely and proper manner.

However, working with and studying various integrity management projects associated with the oil and gas industry has demonstrated that corrosion engineering by itself could not effectively and efficiently mitigate postcommissioning corrosion. Numerous observations revealed that many corrosion-related failures, leaks, and near misses were not at all due to obsolete, inadequate, or erroneous corrosion engineering designs or applications but were promoted, accelerated, and bolstered by other shortcomings. Such observations have also shown that other factors or parameters by absence or inadequate presence and application—either due to negligence, ignorance, complacency, incompetence, or a combination of these factors—can adversely influence the overall integrity management of an asset. Interactions with other industries, outside the oil and gas industry, demonstrated the same patterns, issues, and causes.

The following list describes some of the observed cases in which non–corrosion engineering parameters or factors were believed to be the main culprits in loss of integrity:

- The most prevalent deterioration mechanisms behind most of the observed regular equipment leaks and failures—in an asset or within a particular system—were not identified over long periods after commissioning. The failure to identify them often led to an inability to devise and implement the required remedial, corrective, or rectifying activity (or activities).
- No integrity reviews were carried out after commissioning, and changes in the operations and process parameters had increased the corrosion threat levels or even created new ones. This

situation often led to higher deterioration rates and more frequent leaks, equipment failures, and near misses.
- Lack of appropriate and much-needed databases, registers, procedures, strategies, meeting minutes, and other forms of documentation whose data, information, guidelines, and instructions could have significantly improved an existing AIMS.
- Lack of adequate communication between various individuals or companies who contributed to the overall asset integrity management.
- Lack of adequate training associated not only with corrosion engineering but also with corrosion management.
- Reliance on out-of-date, inaccurate, or irrelevant data and information, which often led to erroneous technical judgments and decisions with seemingly higher cost implications.
- A non–risk-based approach to inspection and overall asset integrity management.

With the benefit of hindsight, many of the above issues and shortcomings (which led to various corrosion failures) could have been easily and conveniently prevented and mitigated if a simple but well-defined and multistaged process had been in place. This process would have comprised the following three stages:

1. Reviewing the required integrity management measures.
2. Regularly monitoring their performance.
3. Assessing their effectiveness.

Assets on which this process had been implemented benefited greatly from significantly better asset integrity management, associated with optimized costs.

This book is all about this process, which is hereafter referred to as the "asset corrosion management process." The book is almost entirely dedicated to this process and its products, applications, and benefits.

1.2 From the Oil Industry to Industry as a Whole

When it comes to corrosion, there are some differences and some similarities between various industries. The combination of alloy systems and corrosive fluids or environments differs in different industries. Thus, the associated deterioration or corrosion mechanisms could be different.

However, the required integrity management measures (corrosion engineering based, non–corrosion engineering based, or both) are either identical or markedly similar. It is such similarities—or in other words, such resemblances—between various industries (in terms of activities, principles, or requirements to mitigate and control asset corrosion) that are covered in this book. As both types of the required integrity management measures—corrosion engineering based and non–corrosion engineering based—are included or incorporated into the corrosion management process, the corrosion management expertise, experience, and know-how originating from and associated with the oil and gas industry can be shared and disseminated with any other industry in which corrosion is a major integrity threat.

The corrosion management concepts or processes described in this book that were originally associated with the oil and gas industry can be easily and conveniently applied to other industries. Many components or products of the corrosion management process are readily applicable to other industries. Examples include

- Integrity review process (IRP).
- Regular performance monitoring and assessment of effectiveness.
- Failure risk assessment (FRA).
- Corrosion control matrices (CCM) and corrosion key performance indicators (KPIs).
- Asset corrosion management strategy (CMS) document.

This flexibility and versatility associated with corrosion management applications has been the main motivation and driver in compiling the current book. The author is confident that once the corrosion management process has been applied across other industries, the benefits gained will be similar and as significant as those being gained in the oil and gas industry.

1.3 Rationale

The perceived lack of appreciation of the corrosion management concept, processes, applications, and benefits in industry was one of the main drivers to compile this book. The other reason was the observed improvements in the overall asset integrity management for those oil and gas assets when the corrosion management process had been introduced and applied, particularly for the more mature assets. Such benefits (i.e., improvements in asset integrity management) were often associated with enhancements in personnel safety, environmental protection, corrosion failure preemption, and cost optimization.

The author strongly believes that many similar improvements and benefits could be accomplished if such corrosion management know-how, experience, and expertise were shared with other industries as well.

There are already some positive signs, such as the increasing move by many operators and contractors toward risk-based inspection (RBI), maintenance, and integrity management systems. This momentum illustrates that the corrosion management process and its useful applications (e.g., RBI) have been gaining more acceptance and recognition among operators and integrity contractors in other industries.

Nevertheless, many operators and integrity contractors are still totally oblivious to the corrosion management concept and its applications. This lack of awareness is evident in the many integrity management shortcomings and failures due to a lack or inadequate application of the corrosion management process observed by the author during various trip or site/asset studies.

This book has been written for both of the above groups, with the main aim being to produce a useful and practical tool and a source of guidelines in the field of corrosion management in any industry in which corrosion is considered a major integrity threat.

The author first started teaching and provided training on this topic in 2005. Later, and as he got involved with more international integrity management projects, he started to write articles on this topic in the NACE International *Materials Performance* (*MP*) journal from 2007 onward. He published his first book on asset corrosion management in the oil and gas industry in 2012, followed by its second edition in 2016. The positive and encouraging feedback he received after the publication of each *MP* article and the above books was one of the main reasons and incentives for authoring this book for industries other than oil and gas.

1.4 Scope of the Book

The author has written this book mainly using his experience in the oil and gas industry. However, the discussions, guidelines, and principles presented are simple, clear, commonplace, and general. As such, they could be used or applied with minimal changes or modifications, if necessary, to all other industries, such as

- Water and wastewater.
- Petrochemicals.
- Petroleum refining.
- Nuclear.
- Construction.
- Military.

The author, sometimes personally and sometimes in collaboration with fellow corrosion engineers from other industries, has successfully used, applied, or implemented the corrosion management principles described in this book to enhance existing AIMSs in non–oil and gas industries and optimize corrosion costs while improving other aspects of integrity management, such as failure preemption and personnel competency or training.

The author has trained many individuals internationally who were eager to learn what corrosion management applications could do for their respective industries. This book is regarded as the continuation of such training for all individuals working in any industry in which corrosion is a major integrity threat.

1.5 Corrosion Management Misconceptions and Abuses

The author has observed a gradual increase in corrosion management awareness and applications among academics and industry professionals over the past few years. However, there is still a long way ahead of us, since a considerable number of individuals still regard the term “corrosion management” to be a mere synonym for “corrosion engineering.” Such an approach by these people, either when it comes to the provision of corrosion management training or the provision of corrosion management services and consultancy, is misleading and detrimental.

In taking this approach, such people mislead and confuse their students (if they are allegedly providing corrosion management training). Furthermore, these people fail not only to offer the best