The Paint Inspector's Field Guide2

For protective coating inspection and engineering

An inspection aid and guide produced for the inspector by an inspector

By **Lee Wilson**

Painting & Coating Specialist.

Edited by **Brian Goldie**

Introduction

Welcome to the Paint Inspector's Field Guide 2, the long awaited follow up to the hugely successful Paint Inspectors Field Guide. With updated information and several new chapters, this is the perfect guide for Inspectors in the field.

The use of protective coating systems is the most common method of corrosion control in the industry today and is often considered as the first line of defence in the never-ending battle against corrosion. The ultimate success of protective coating systems however is dependent upon numerous factors, coating inspection being one of the most important.

The painting and coating industry recognises and acknowledges that the lifespan of any protective coating system is greatly improved by good quality control and inspection before, during and after, the surface preparation and application stages of a painting project.

This field guide was developed by an inspector, to offer significant guidance, experience and assistance to protective coating Inspectors, Specifiers, Owners, Painting Contractors, or individuals interested in the inspection of protective coatings application.

It is intended as an inspection aid for the Inspector whilst in the field - providing vital information on inspection methods, general good painting practice, and experience points, from a well qualified and experienced coating and painting inspector, and with contributions from well recognised inspection professionals. The guide provides information which could prove vital to the success of protective coating projects.

The information in this handbook concerns the general duties and responsibilities of painting and coating inspectors and is intended to enhance their performance. It is not intended as a substitute for formal inspection training and certification

Although corrosion is not just applicable to steel this handbook focuses mainly on the corrosion of steel due to the general use of this material in the industry.

Please note that standards referenced in this book are readily available from standard bodies such as NACE, SSPC, ASTM and ISO. This book is not a substitute for any standards referenced however serves only as a field guide to general requirements of the standards used in the industry. The author strongly recommends that any standards the reader, or users; of this book are working to, are the current versions and are purchased from the applicable standards body owning the standard.

About the author:

Lee Wilson

Lee has a wide range of experience with coating inspection techniques and methods. His vast experience within the field of corrosion control begun as a surface preparator and coating applicator prior to entering Supervision and Inspection. Lee is NACE CIP Level 3 Certified (Peer Review) in Coating Inspection and is recognised as an Instructor of the NACE CIP Programme subsequently teaching the NACE Coating Inspection Programme throughout the UK. He is approved by the

Institute of Corrosion (ICorr) Level 3 Senior Painting Inspection approval and possesses Level 2 Insulation Inspection approval from ICorr and SSPC. Lee is also a fully certified NACE Senior Corrosion Technologist, NACE Corrosion Specialist and NACE Protective Coating Specialist and a fellow of the institute of corrosion having "FICorr" professional status.

He is recognised by his peers as a leading figure within the corrosion control industry today through his work with the development and improvement of corrosion control via protective coatings. Lee is a highly qualified professional individual with vast knowledge and a wealth of experience within Corrosion Control & Coating and Painting projects worldwide. Lee is also a fully chartered corrosion engineer, CEng.

He provides first class Supervision, Engineering Management and Inspection services to the Marine, Construction and Oil/Gas sectors.

Lee is also recognized as an expert on Fabric Maintenance and Corrosion under Insulation and provides cost effective Solutions to the oil and gas majors. He is currently a director and consultant of Corrtech ltd, a coating inspection and consultancy company. Wilsonlee78@outlook.com

About the Editor:

Brian Goldie

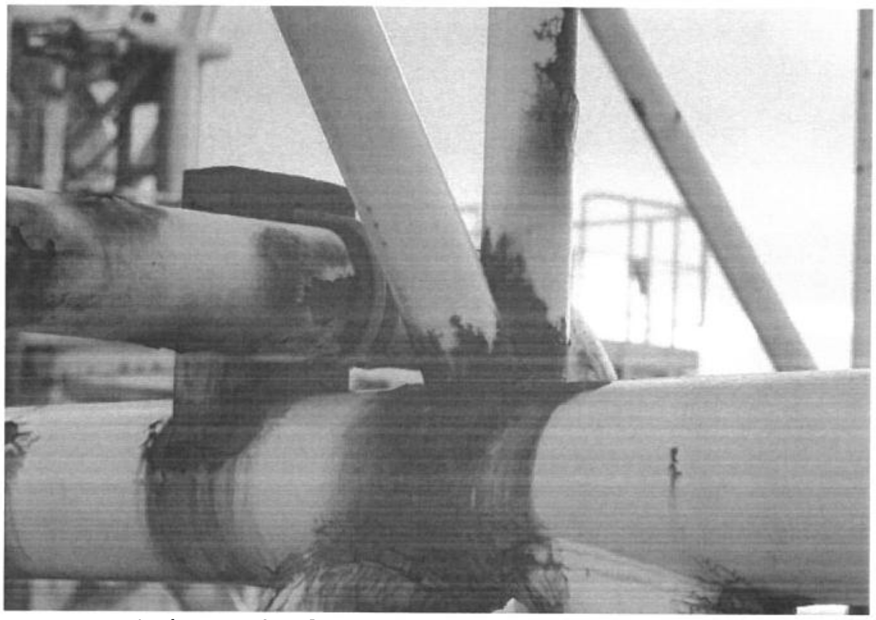
Brian has been in the surface coatings industry for more than 40 years. Initially as a research chemist involved in the development of novel marine anti-fouling coatings and then novel non-toxic anti-corrosion pigments, which he then commercialised. He then led a laboratory involved in paint R & D and testing of commercial products, and plant troubleshooting for the BP Group worldwide. He was involved in the early days of the North Sea oil and gas production, including development systems to protect against corrosion in this harsh environment.

For the past 25 years, he has been involved as a Consultant to the coatings industry, carrying out failure analyses, expert witness investigations and carrying out technical and market studies. Currently he is the technical editor of *The Journal of Protective Coatings & Linings* in the USA.

Brian is also the editor of the original PIFG which became the industry standard for inspectors globally and bestselling guide.

1. Corrosion

Dealing with the effects of corrosion, or the deterioration of steel, is a multi-trillion-dollar industry. The NACE IMPACT survey in 2016 estimated that the annual cost of corrosion globally as $2.5 Trillion USD per year across all industries. As stated by NACE this represents approximately 3.4 % of US GDP. The effects of corrosion in industry impacts upon a number of critical factors such as: safety, integrity, cost and appearance.



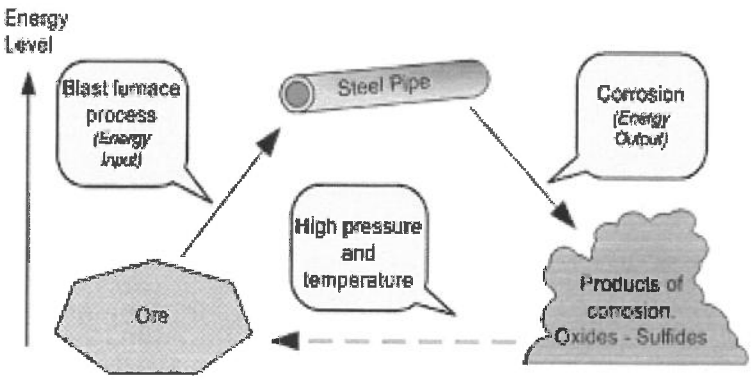
A typical example of corrosion taken on a North Sea platform

<u>So what is corrosion?</u>

A basic understanding of the fundamentals of the corrosion process will give inspectors a better view and general understanding of the concept and importance of protective coatings.

NACE defines corrosion as "the deterioration of a material, usually a metal or its properties, because of a reaction with its environment."

The atmospheric corrosion of steel results from an electrochemical reaction between steel and elements present within the natural environment, primarily oxygen and mositure. Simply, steel is produced from iron ore, which when extracted from the earth is in a (natural) inert state. During the smelting process to produce iron metal from the ore large volumes of heat and energy are needed altering this natural state and chemical balance. Subsequently, and upon reaction with the natural environment, the steel (iron) releases this energy in an attempt to revert back to a more stable state i.e. iron ore (oxide). This appears as rust, but also results in metal loss at the surface. The Inspector needs to be aware that a structure can lose its integrity when it corrodes.



The above statement encapsulates the very basic fundamentals of the corrosion process, offering a simple explanation to the inspector of the electrochemical reactions involved.

Inspection Note: The Inspector is not required nor expected to know the full dynamics of corrosion. "We are not corrosion engineers" however the protective coating inspector should be aware of the basic fundamentals of the corrosion process, as it is this process which we are ultimately trying to control.

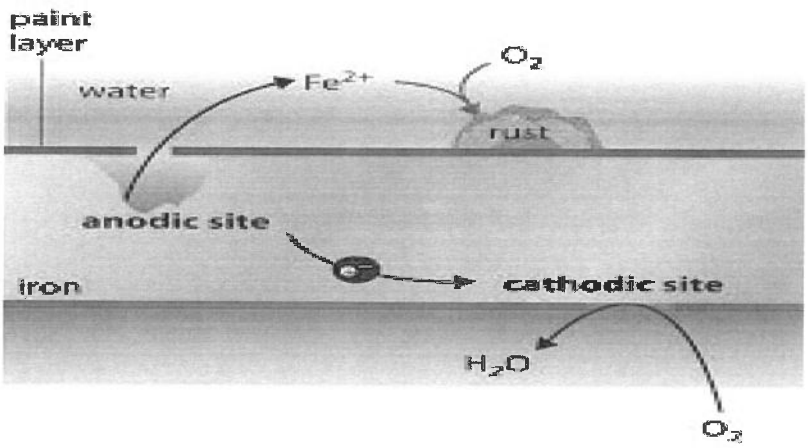
Experience Note: I find that a general understanding of the above is always of benefit to the inspector as he or she is often consulted and questioned about the corrosion process on projects, and let's face it, in order to ultimately protect against corrosion, some fundamental knowledge of the process is certainly required.

Elements required for corrosion

The Coating Inspector should understand that four elements are required for corrosion to take place these elements together form what is collectively a corrosion cell. If we eliminate or remove any of the four elements the corrosion process will cease due to the corrosion cell being incomplete. This forms the very basis of corrosion control.

Requirements of a corrosion cell in steel are (see diagram below):

- Anode
- Cathode
- Metallic Pathway
- Electrolyte



We should remember that corrosion always takes place at the anode. The anode is the area in a corrosion cell where metal loss is encountered. It is the area which dissolves into the electrolyte. Corrosion product, i.e. ferrous oxide or rust build-up due to reactions at the cathode.

The metallic pathway is the actual steel which is conductive; it is how the electrons flow during the corrosion process i.e. a direct conductive line between the anode and the cathode.

The electrolyte can be defined as any medium which conducts electricity. Electrons essentially flow through this from cathode to anode, thus completing the electrical circuit (the corrosion cell). In the corrosion control industry water is the most commonly encountered electrolyte however the inspector should be aware that this does not rule out other mediums such as soil and concrete.

Types of corrosion

Uniform Corrosion

Uniform corrosion is considered an even attack across the surface of a material and is the most common type of corrosion. It is also the most benign as the extent of the attack is relatively easily judged, and the resulting impact on material performance is fairly easily evaluated due to the ability to consistently reproduce and test the phenomenon. This type of corrosion typically occurs over relatively large areas of a material's surface.

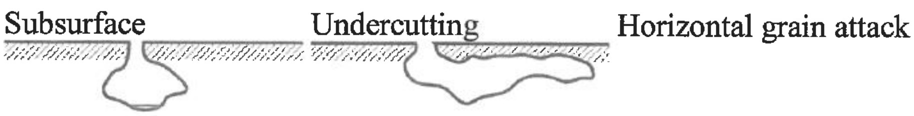
Pitting Corrosion

Pitting is one of the most destructive types of corrosion, as it can be hard to predict, detect and characterise. Pitting is a localised form of corrosion, in which a very small area of the surface becomes anodic and is surrounded by a very large cathodic region. This produces a large driving force for corrosion, which is concentrated on the small anodic area. Once a pit has initiated, it grows into a "hole" or "cavity" that takes on one of a variety of different shapes. Pits typically penetrate from the surface downward in a vertical direction. Pitting corrosion can be caused by a local break or damage to the protective oxide film or a protective coating; it can also be caused by non-uniformities in the metal structure itself. Pitting is dangerous because it can lead to failure of the structure with a relatively low overall loss of metal.

Types of Pitting Corrosion:

Trough Pits

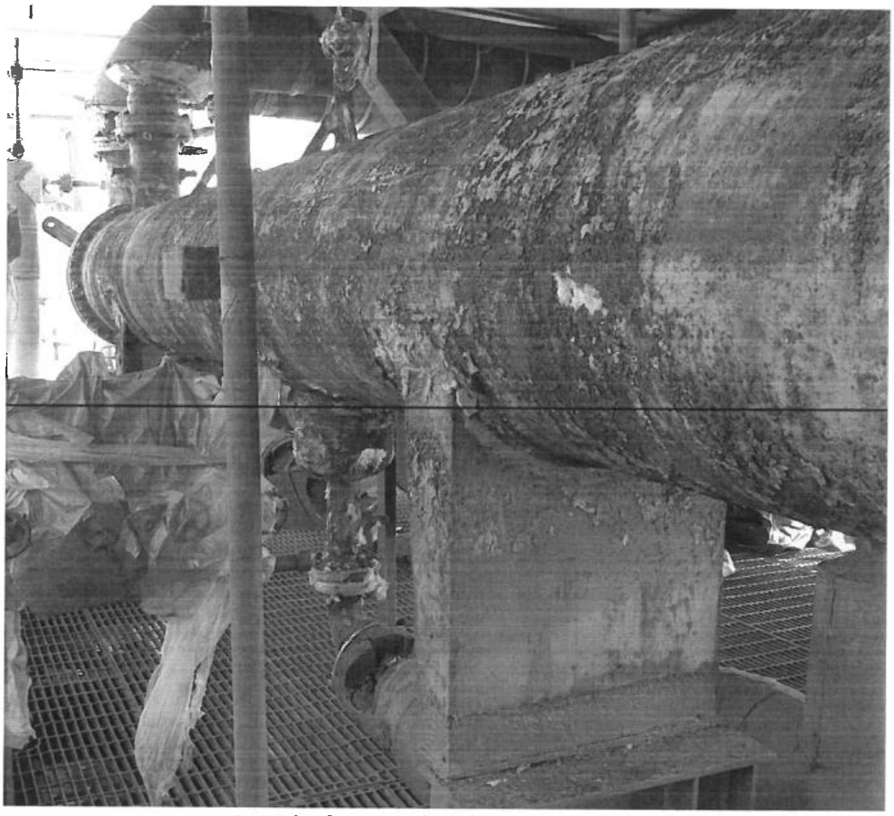
Sideway Pits



Crevice Corrosion

Crevice corrosion is also a localised form of corrosion and usually results from a stagnant microenvironment in which there is a difference in the concentration of ions between two areas of a metal. Crevice corrosion occurs in shielded areas such as those under washers, bolt heads, gaskets, etc. where oxygen is restricted. These smaller areas allow for a corrosive agent to enter but do not allow enough circulation within, depleting the oxygen content, which prevents re-passivation. As a stagnant solution builds, pH shifts away from neutral. This growing imbalance between the crevice (microenvironment) and the external surface (bulk environment) contributes to higher rates of corrosion. Crevice corrosion can often occur at lower temperatures than pitting. Proper joint design helps to minimize crevice corrosion.

Corrosion under Insulation (CUI)
CUI is a particularly severe form of localised corrosion – see section 2 for a detailed description of this type of corrosion.



A typical example of severe CUI

Intergranular Corrosion of Stainless Steels
An examination of the microstructure of a metal reveals the grains that form during solidification of the alloy, as well as the grain boundaries between them. Intergranular corrosion can be caused by impurities present at these grain boundaries or by the depletion or enrichment of an alloying element at the grain boundaries. Intergranular corrosion occurs along or adjacent to these grains, seriously affecting the mechanical properties of the metal while the bulk of the metal remain intact. An example of intergranular corrosion is carbide precipitation, a chemical reaction that can occur when a metal is subjected to very high temperatures (e.g., 426°C - 898°C) and/or localized hot work such as welding. In stainless steels, during these reactions, carbon "consumes" the chromium, forming carbides and causing the level of chromium remaining in the alloy to drop below the 11% needed to sustain the spontaneously-forming passive oxide layer. 304L and 316L are enhanced chemistries of 304 and 316 stainless that contain lower levels of carbon, and would provide the best corrosion resistance to carbide precipitation.

Stress Corrosion Cracking
Stress corrosion cracking (SCC) is a result of the combination of tensile stress and a corrosive environment, often at elevated temperatures. Stress corrosion may result from external stress such

as actual tensile loads on the metal or expansion/contraction due to rapid temperature changes. It may also result from residual stress imparted during the manufacturing process such as from cold forming, welding, machining, grinding, etc. In stress corrosion, the majority of the surface usually remains intact; however, fine cracks appear in the microstructure, making the corrosion hard to detect. The cracks typically have a brittle appearance and form and spread in a direction perpendicular to the location of the stress. Selecting proper materials for a given environment (including temperature and management of external loads) can mitigate the potential for catastrophic failure due to SCC.

Galvanic Corrosion

Galvanic corrosion is the degradation of one metal which occurs when two electrochemically dissimilar metals are in electrical contact in an electrolytic environment; for example, when copper is in contact with steel in a saltwater environment. However, even when these three conditions are satisfied, there are many other factors that affect the potential for, and the amount of, corrosion, such as temperature and surface finish of the metals. Large engineered systems employing many types of metal in their construction, including various fastener types and materials, are susceptible to galvanic corrosion if care is not exercised during the design phase. Choosing metals that are as close together as practicable on the galvanic series helps reduce the risk of galvanic corrosion.

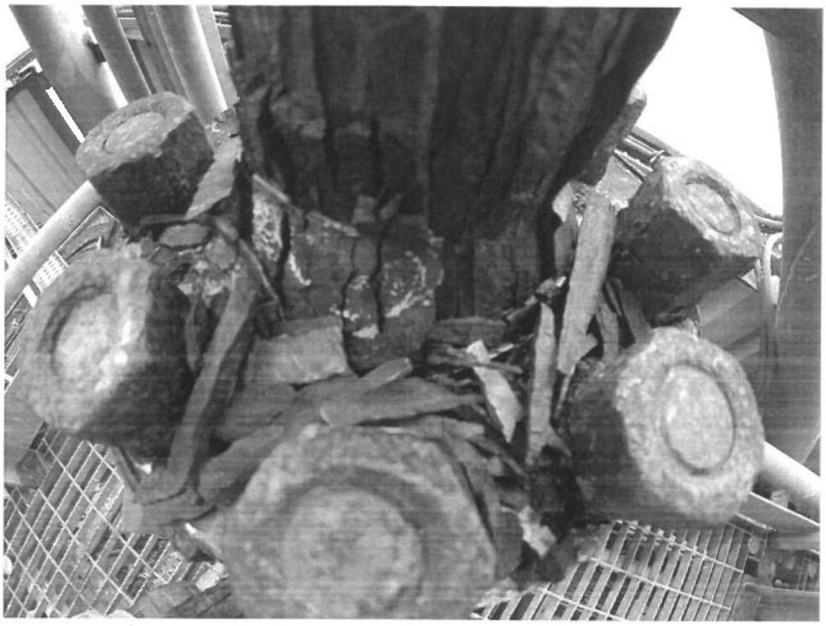
2. CUI

CUI is a particularly severe form of localized corrosion that has been plaguing chemical process and Oil & Gas industries since the energy crisis of the 1960s which subsequently forced plant designers to include far greater insulation and corrosion control into their designs.
Corrosion Under Insulation (CUI): is one of the most well-known phenomena in the petrochemical industries, and yet it still makes up an inordinately large percentage of global maintenance expenditures it is the costliest form of corrosion to mitigate with major maintenance budgets allocated specifically for CUI.

CUI is a subject that is well-researched and understood; extensive studies have been commissioned to determine the causes, effects, prevention, and mitigation of CUI.

(1) In the simplest terms, CUI is any type of corrosion that occurs due to moisture present on the external surface of insulated equipment. The damage/attack can be caused by one of the multiple factors, and can occur in equipment operating at ambient, low, and heated/elevated services, depending upon conditions. Moreover, CUI can occur in equipment that is in service, out of service, or in cyclic service.

The corrosion itself is most commonly galvanic, chloride, acidic, or alkaline based corrosion. If undetected, the results of CUI can lead to localised corrosion resulting in subsequent leaks and the shutdown of a process unit or an entire facility. This has happened on numerous occasions and costs owners and operators billions in lost revenue this is without the environmental impacts caused by leaks of process commodities.



Extensive Atmospheric Corrosion typical for nuts and bolts and hard to access areas

Intruding water is the key problem in CUI. Special care must be taken during design not to promote corrosion by permitting water to enter a system either directly or indirectly by capillary action. Moisture may be external or may be present or formed during the process for example. On average, 60% of all insulation in service for more than >10 years, will have corrosion under insulation._There are two primary water sources involved in CUI of carbon steel. First, breaks in the weatherproofing cladding or shielding can lead to infiltration of water to the metal surface from external sources such as rainfall, drift from cooling towers, condensate falling from cold service equipment, steam discharge, process liquid spillage, spray from fire sprinklers, deluge systems, washrooms, and from condensation on cold surfaces after vapour-barrier damage. Secondly, a major corrosion problem develops in situations where there are cycling temperatures that vary from below the dew point to above-ambient temperatures. In this case, the classic wet/dry cycle occurs when the cold metal develops water condensation that is then baked off during the hot/dry cycle. The transition from cold/wet to hot/dry includes an interim period of damp/warm conditions with attendant high corrosion rates.