



GUIDANCE NOTES ON

THE APPLICATION AND INSPECTION OF MARINE COATING SYSTEMS

JANUARY 2017

**American Bureau of Shipping
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Foreword (1 January 2017)

The steel structure of a vessel is prone to corrosion throughout its service life. Due allowance should be made at the new building stage and by periodic maintenance to provide effective corrosion protection that contributes to the continued structural integrity of the vessel.

Given the emphasis on protective coatings in the various mandated Rules and Regulations and the unprecedented acceleration of coating technology, personnel involved with coatings should have factual knowledge of coating systems and the applicable standards. It is the intent of these Guidance Notes to meet this need in a straight-forward and practical manner.

The Performance Standards for Protective Coatings (PSPC) from IMO are intended to standardize the requirements for protective coatings for ballast tanks, cargo oil tanks and void spaces for a target of 15 years of useful life. A good quality protective coating can delay the onset of corrosion of the structure. The mandated standards represent the latest in the line of many regulatory actions taken to enhance vessel longevity and thereby enhance safety.

There has been an increased industry focus placed on the consequences of corrosion and an increased demand for better coating performance as primary corrosion control. This has led to adoption of ballast tanks' PSPC for SOLAS Chapter II Part A-1 Regulation 3-2 on December 8, 2006, and adoption of PSPC for cargo oil tanks of all crude oil tankers per SOLAS Chapter II Part A-1 Regulation 3-11 on May 21, 2010. Those mandated PSPC standards specify requirements for coating application processes during various stages of new construction.

To help industry to understand the major elements of PSPC requirements, ABS has produced and maintained this publication since 2007. As a direct response to the needs of industry personnel involved with the PSPC implementation, a complete revision has addressed the fundamentals of coating technology as applied to ship structures for the regulatory requirements for coatings in ballast tanks, void spaces, cargo tanks, cargo holds and outer hull anti-fouling systems. Figure 1 gives a brief timeline of requirements or recommendations from IMO and IACS.

These Guidance Notes start with the basics of the chemistry, and mechanics of corrosion to understand protective coatings as a barrier to corrosion. The coating application process technology and coating inspection for surface preparation, environmental controls, film thickness measurements and the methods of coating application are included. Once a vessel is in-service, the coatings are subject to various conditions. To aid in the assessment of the coatings in service, coating assessment methods and typical failures are illustrated as guidance.

For ballast tank's PSPC of ABS classed vessels only, ABS provides the *Guide for the Class Notation Coating Performance Standard (CPS)* and a detailed procedure to obtain the ABS CPS notation. ABS also provides the optional notations Environmental Protection (ENVIRO) or Environmental Protection Plus (ENVIRO+) for vessels and antifouling systems as part of the ENVIRO or ENVIRO+ Notation requirement.

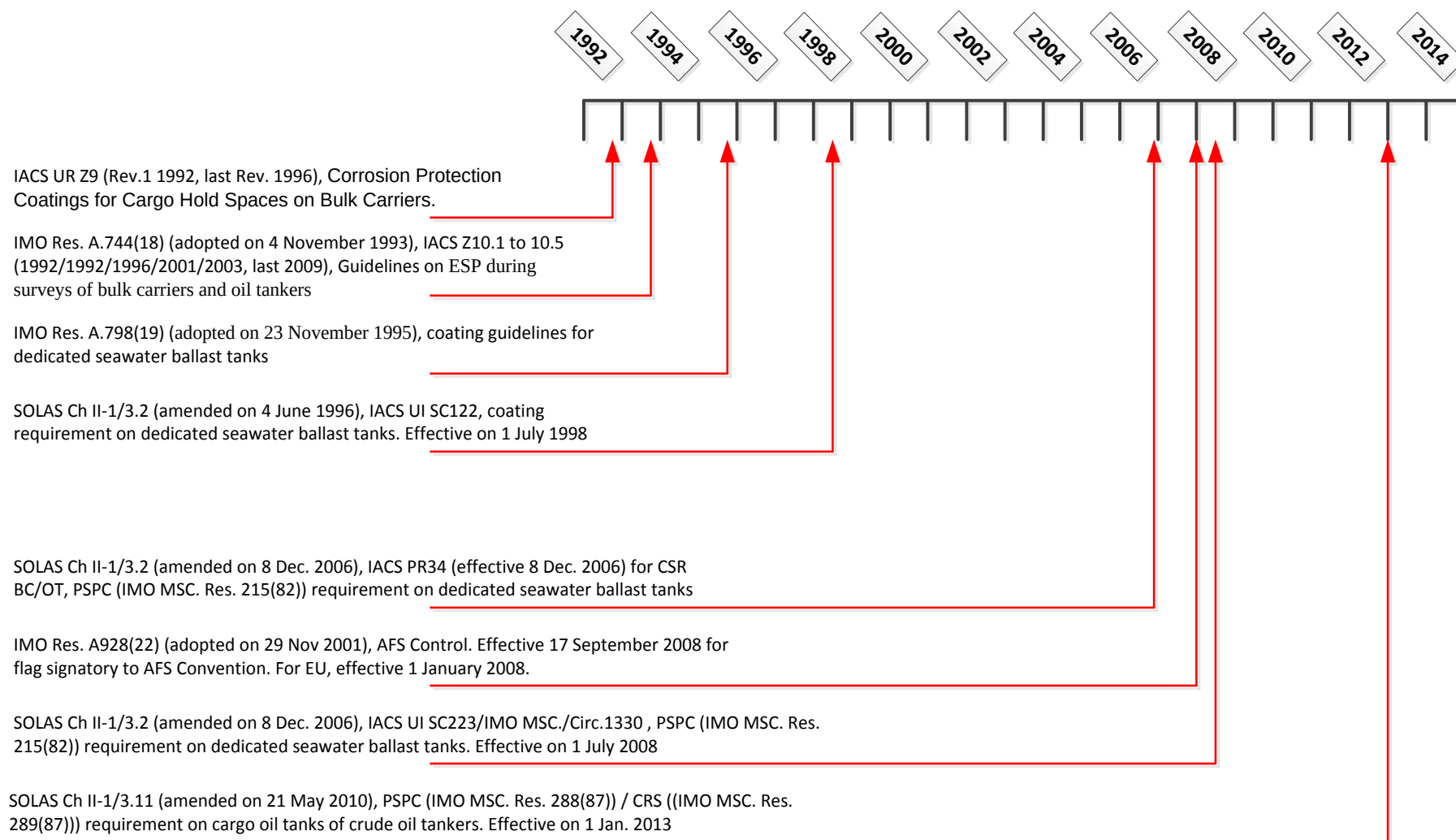
Please note that the adoption of ballast water exchange practices (as per IMO Resolution A.868(20)) may potentially have a negative effect on the longevity of the coatings. NACE has developed a test standard (NACE TM0112-2012) to determine the potential corrosion effects of Ballast Water Treatment Systems on Ballast Tanks.

These Guidance Notes become effective on the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of these Guidance Notes is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.

FIGURE 1
Timeline of Development



Note: See applicable regulations for details of the above dates



GUIDANCE NOTES ON

THE APPLICATION AND INSPECTION OF MARINE COATING SYSTEMS

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SECTION 1 Corrosion

1 General (1 January 2017)

The ability of coatings to resist corrosion over extended periods is an important contributor in safeguarding the capital investment in the structure of a vessel. Protective coatings are the **primary barrier** to the corrosive marine environment. Coatings **can** minimize the rate of corrosion, thereby potentially **reducing designed** corrosion margins included in a vessel's structural scantlings.

Understanding how coatings reduce corrosion rates, how they must be maintained and how coatings eventually break down are important elements of safe vessel operation. This **Section** deals with the basic theory of corrosion and sets out the various factors controlling breakdown rates.

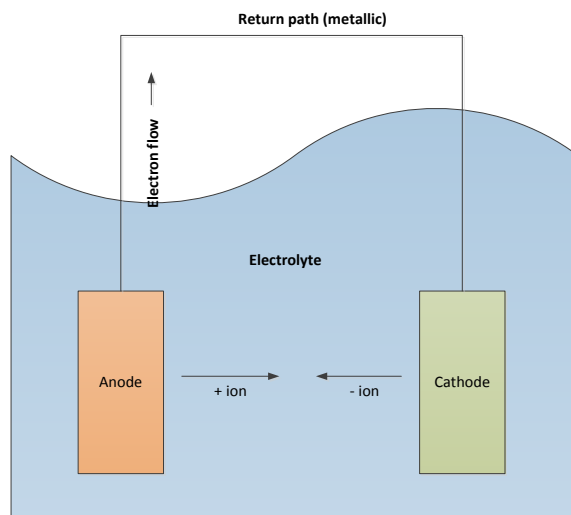
Corrosion is defined as the deterioration of a material that results from a reaction with its environment. Corrosion of steel in ballast and cargo tanks is mainly an electrochemical process in which the steel reacts with its environment to form an oxide or other compound. The electrochemical process involves the transfer of ions and electrons across a surface and forms corrosion products. The oxides of metal such as iron oxides do not provide strength to structural components. In such a case, the metal or steel structural member is deteriorated.

In order for corrosion to occur, certain conditions and elements must exist. Those are collectively referred to as the corrosion cell, as depicted in Section 1, Figure 1. Four essential elements for corrosion are anode, cathode, metallic pathway and electrolyte.

- i) *Anode:* The less noble part of the metal that corrodes. It is the negatively charged portion of the cell where metallic iron forms its ion and dissolves in the electrolyte. Generated electrons pass the anode and metallic conductor to the cathode. Oxidation occurs at the anode.**
- ii) *Cathode:* The more noble part of the metal where electrons are consumed. Reduction occurs at the cathode. Both oxidation and reduction always occur together.**
- iii) *Metallic Path:* A return path for connecting anode and cathode and allowing electrons generated at the anode to pass to the cathode.**
- iv) *Electrolyte:* Ion conductor which is pathway to transport the ions between the anode and cathode.**

All the above components must be present and form a closed circuit for corrosion to occur. Removing one or more of these components prevents corrosion from occurring. This is the principle of corrosion controls. When an organic protective coating is applied on steel surface, which acts as a barrier and prohibits direct contact between the electrolyte and metal surface, one of these components from the corrosion cell is eliminated and corrosion on the steel surface is prevented.

FIGURE 1
Corrosion Cell (1 January 2017)

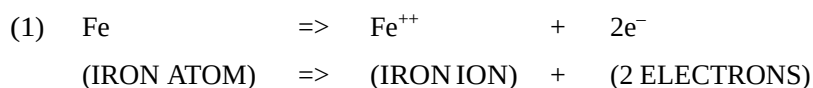


2 Uncoated Steel and the Corrosion Reaction (1 January 2017)

During the corrosion process, steel **loses** iron atoms into the environment in the form of ions. In return, some of the metal ions from the environment plate out and return to the metallic state. This is known as a reversible reaction. When the rates of the forward and reverse reactions are the same, then the process is in equilibrium and the steel takes up its equilibrium potential.

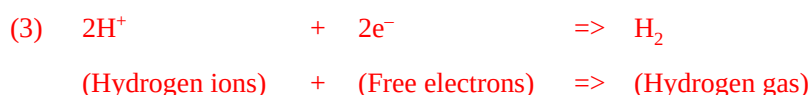
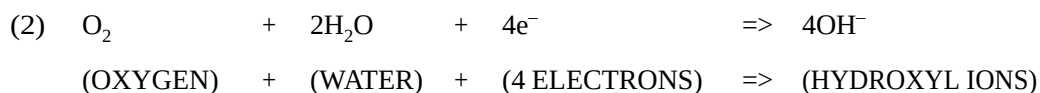
Metal atoms leave the metal and go into a solution as positively charged metal ions, leaving behind negatively-charged electrons. Consequently, the metal becomes more negatively charged. This makes it increasingly difficult or impossible for the remaining metal atoms to escape as positively charged ions as they are being held by the negative charge of the metal. For the process to continue, the excess of electrons in the metal must be consumed elsewhere in another reaction. The manner and speed with which these excess electrons can be removed is one of the factors that determine the rate of corrosion.

One important step in the corrosion of steel is the transformation of an iron atom to an iron ion by the loss of two electrons **at anode sites**. This is called the anodic reaction (**oxidation reaction**):



The free electrons created at the anode pass within the metal to another site on the metal surface, which is the cathode where the electrons are consumed by the cathodic reaction (reduction reaction) at cathode sites.

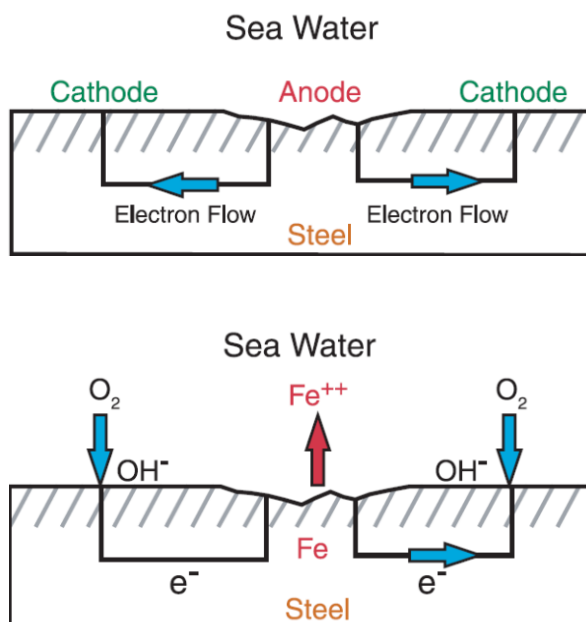
At the cathode, two following possible reactions occur in the electrolyte such as seawater. Electron consumption occurs at cathode site by reduction reaction through oxygen concentration cell or acid. Oxygen concentration cell reduction reaction can generate hydroxyl ions and acid concentration cell reduction reaction can generate hydrogen gas. See equations (2) and (3).



Freshwater or seawater contains dissolved atmospheric oxygen. The **dissolved** oxygen is electrochemically reduced to hydroxyl ions in the cathodic reaction. **The formed hydroxyl ions react with the ferrous ions resulting in iron oxides (rust).**

The heterogeneous character of the metal surface allows some areas for anodic sites and other areas for cathodic sites. The whole surface of the metal is therefore divided up into large numbers of anodic sites and cathodic sites. Section 1, Figure 2 shows anodic and cathodic sites and also shows the progress of corrosion where metal is lost from the anode, accompanied by a flow of electrons from the anode to the cathode within the metal. The electrons in turn react with both oxygen and water from the environment to form hydroxyl ions.

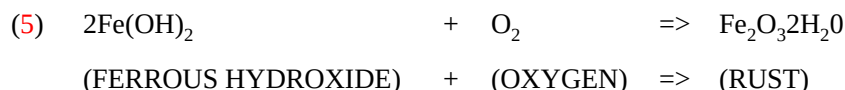
FIGURE 2
Anodic and Cathodic Areas Form on the
Uncoated Steel Surface (1 January 2017)



Both the iron ions and the hydroxyl ions diffuse in the solution and then react together to produce ferrous hydroxide as shown in reaction (4):



Ferrous hydroxide in the presence of an abundant supply of oxygen is oxidized to form the familiar reddish brown rust.



Reactions (1) through (5) are basic reactions which occur when iron or steel is in an electrolyte such as seawater or an acidic solution. However, in practical situations, the process is complex.

In given environments, certain metals, such as aluminum, copper and stainless steel, can form a thin and dense oxide film as a protective layer, which retards further corrosion. Such a protective layer acts as a natural barrier to corrosion. However, the oxide film formed on iron steel cannot act as a protective layer since it is porous and brittle and permeable to oxygen and electrolyte.

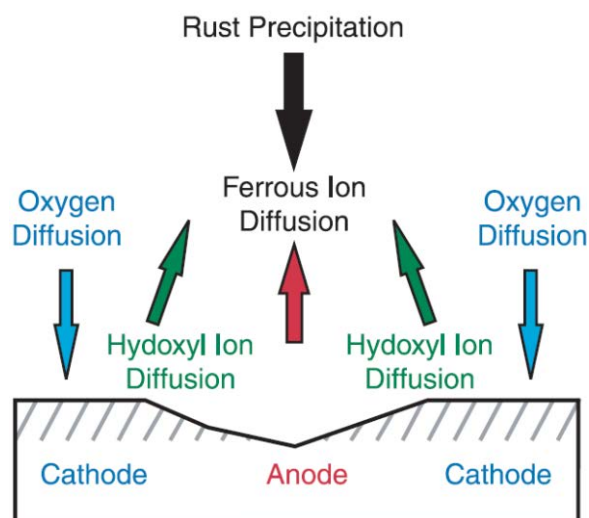
3 Factors Influencing Corrosion Rates

3.1 Oxygen (1 January 2017)

In most cases, the corrosion rates of metals are controlled by the availability of reactants at the metal surface and removal of the products. The diffusion rates of reactants can affect the availability of the reactants. Freshly exposed bare steel surfaces corrode at a greater rate than those covered with a compact layer of rust.

The corrosion rate is heavily controlled by the oxygen level in the water at the steel surface. In areas where oxygen is prevalent, corrosion occurs at faster rates. High flow areas, such as in the vicinity of bell mouths, tend to exhibit higher corrosion rates because of the increased oxygen levels, although erosion is also a factor. Areas covered by a thin, conducting moisture film, such as ballast tanks after the ballast water is removed and cargo tanks after sea water washing, corrode faster than areas under immersion. Tank's underdeck, where air has been trapped, appears to have a higher corrosion rate than other areas of the tank where they are submerged and have a lower availability of oxygen. Section 1, Figure 3 shows oxygen and ion diffusion pathways near anodes and cathodes.

FIGURE 3
Diffusion Pathways near Anodes and Cathodes



3.2 Temperature (1 January 2017)

As corrosion rates are determined by the diffusion rates of reactants and products, which are controlled by temperature. Corrosion rates are higher at higher temperatures than at lower temperatures. As a result, under-deck areas and regions adjacent to the engine room or to heated cargo tanks tend to corrode faster.

One of the features of the modern double hulled tankers is that when the cargo tanks are fully loaded, the empty ballast tanks act as a vacuum flask or thermos-bottle and retain the heat in the cargo for significantly longer periods than the single hull tankers. This increase in temperature of the cargo/ballast bulkhead combined with the cooler outer shell bulkhead (in the underwater regions) produces a complex set of corrosion conditions and results in an increase in the corrosion rate of the steel in both ballast tanks and cargo tanks.

3.3 Conductivity of Electrolytes (1 January 2017)

For corrosion to occur, there must be a conductive medium (electrolyte) between the two parts of the metal surfaces. Corrosion does not occur in pure distilled water with no dissolved substances and the rate of corrosion increases as the conductivity of electrolyte increases due to the presence of more ions dissolved in the solution.

The corrosion rate of steel reaches a maximum close to the normal ionic content of sea water. Fresh water corrodes steel to a lesser extent than brackish or estuarine water, with sea water usually being the most corrosive to steel.

3.4 Type of Ions

Some types of ions present in sea water or in cargoes are more corrosive than others. Chloride ions are usually the most destructive with sulfate and other sulfur-containing ions also presenting major problems.

Chloride ions have a destructive effect on the protective properties of any rusts produced by preventing the formation of the more protective, densely packed oxides. Sulfur-containing ions become involved in additional electron generating reactions within the rust itself which in turn forms a cyclic, self-regenerating process. This can produce intensive pitting on the inner bottoms of cargo tanks in oil and product carriers. The sulfur can originate from both the inert gas system and from cargoes containing sulfur, such as sour crude oil.

3.5 Acidity and Alkalinity (pH)

pH is a measure of the acidity or alkalinity on a scale of 1 to 14. pH 7 is neutral. In neutral sea water, the pH is around 7.5 which means that the hydrogen ions (acid) and hydroxyl ions (alkali) are almost in balance. Under such circumstances, the reaction that balances the iron dissolution is the reduction of dissolved oxygen to form hydroxyl ions. If, however, the environment becomes more acidic and the pH falls closer to 1, then there is a greater quantity of hydrogen ions than hydroxyl ions present in the solution. The excess hydrogen ions can become involved in the balancing (cathodic) reaction which results in the evolution of hydrogen gas. As both the hydrogen ions and the hydrogen gas can diffuse very rapidly, the steel can corrode faster. This is a common effect when carrying cargoes such as pet-coke, sulfur and sour crude oils.

Under alkaline conditions, where there is an excess of hydroxyl ions and the pH levels tend towards 14, steel cannot corrode and remains unaffected.

Many of the blisters which are found in ballast tanks, particularly in the double bottoms, are filled with a high pH fluid. When the blister caps are removed, the steel is bright underneath. However, it begins to corrode once the cap is removed, so once one or two of a group of blisters have been checked and the liquid found to be alkaline, the remainder of the blisters should be left intact.

3.6 Electrochemical Potential (1 January 2017)

Every metal takes up a specific electrochemical potential when immersed in a conducting liquid. This potential is called the half-cell potential as it can only be measured by comparing it to another known reference potential produced by a reference electrode, which is to be explained in the following Subsection 4/4. Common reference electrodes are the Saturated Calomel Electrode (SCE), silver/silver chloride and copper/copper sulfate reference electrodes.

The potential that a metal takes up in a solution can determine if and how fast it corrodes. The potential can be changed by connecting it to another dissimilar metal or by applying an external potential.

4 Types of Corrosion

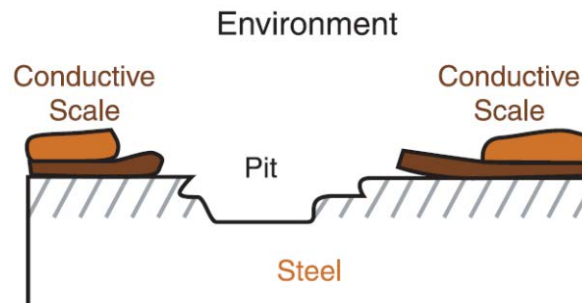
4.1 Uniform Corrosion (1 January 2017)

The most common type of corrosion is uniform corrosion in nature. The loss of metal occurs at the anode sites and there is a continual change of the anode sites in the surface over time. With progressive metal loss, areas which were initially anodic cease to be active and new anodic sites take over. There is a continuous interchange between the anodic and cathodic areas, such that over a period of time the loss of metal over the entire surface is fairly uniform. This is the easiest form of corrosion to combat or allow for because structural lifetime can be predicted.

4.2 Pitting Corrosion (1 January 2017)

The characteristic of this type of corrosion is extremely localized and the penetration is deep in relation to the surrounding area. Pitting is one of the most dangerous forms of corrosion as it often occurs in places where it cannot be readily seen. Pitting corrosion can be intense on steel surfaces not continuously covered by mill-scale, which has been left outdoors, as shown in Section 1, Figure 4.

FIGURE 4
Pitting Corrosion on Uncoated Steel, Showing Layers of Iron Oxides



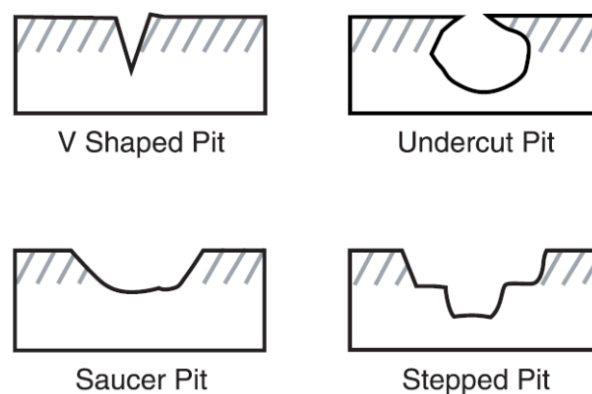
Pitting corrosion can occur whenever there are suitable localized conditions. Typically, pits form where there is a small anodic area which is supported by a large cathodic area, such as a situation of broken mill scales on steel surface. The discontinued mill scaled areas serve as small anodes and continued mill scales serve as large cathodic areas. This can also occur at isolated areas where the coating has been damaged.

Before segregated ballast tanks were introduced, cargo tanks with heating coils which were also used as ballast tanks tended to pit severely.

On uncoated stainless steel pipe work, for example, pitting can occur where the passive oxide layer becomes damaged and corrosion can initiate at individual sites. If the corrosion environment is not eliminated from the surface, corrosion continues and forms small pits. The rate of corrosion can accelerate as the pit develops.

Pits can grow in a variety of shapes, the common ones are V shaped, undercut pits, saucer pits as step sided, as shown in Section 1, Figure 5.

FIGURE 5
Different Pit Shapes



V shaped pits are a serious type of pitting as their rate of penetration through steel can be very high. Once this type of pit occurs, it becomes very difficult to clean the corrosion products from the base of the pit and the corrosion rate can increase rapidly.

Undercut pits are also a serious problem as the actual metal loss can be significantly greater than is initially apparent. If the pits are relatively shallow, then the overhang area can break under pressure and cause the pits to “open up”. Over a large area such as inner bottom plating, the effect can be the equivalent of rapid general corrosion. If the pits do not become open, then the rate of corrosion can increase as the pits contain all the constituents necessary for corrosion and the anodic and cathodic areas can separate out within the pit. As with the V shaped pits, these are extremely difficult to clean thoroughly and corrosion rates can be high. See Section 1, Photograph 1 for examples of undercut pits.

Saucer shaped and stepped pits are the least detrimental, as the rate of metal penetration is relatively low over short time periods as compared with the other types and they are easier to clean and repair.

PHOTOGRAPH 1
Undercut Pits



(a) Surface View

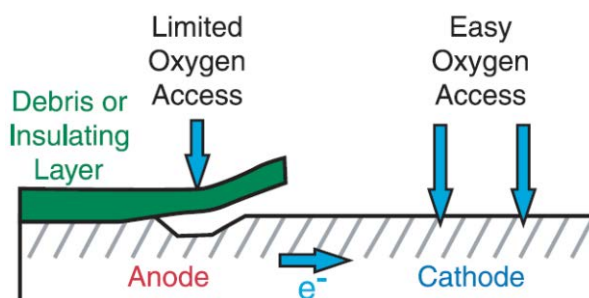


(b) Cross Section View

4.3 Crevice Corrosion (1 January 2017)

Intense localized corrosion, ranging from small pits to extensive attack over the whole surface, can occur within narrow crevices formed by the geometry of a structure, for example: riveted plates or threaded joints. Crevice corrosion is characterized by a geometrical configuration in which the cathode reactant, oxygen, can readily gain access to the metal surface outside the crevice and have less access in way of the crevice. The metal within the crevice is therefore anodic to the surrounding steel and suffers preferential corrosion, see Section 1, Figure 6.

FIGURE 6
Crevice Corrosion



When mud, poorly adherent coating, sand and other debris cover a passive surface it undergoes a similar corrosion mechanism to that occurring in crevices. Wherever loose debris collects, there is a depletion of oxygen in a crevice. Consequently, the corrosion is localized there.

Crevice corrosion and subsequent pitting can also initiate where particles of material such as soot fall on an exposed metal surface. Crevices form where two surfaces are in close contact, for example, pipes and pipe support brackets in ballast and cargo tanks can suffer from crevice corrosion where the two items touch. Another example of crevice corrosion in shipyards is from steel storage. Open air storage of stacked steel plates can cause serious pitting around overlapped out areas between plates after certain periods of weathering.

Crevice corrosion can also form between a metal structure and a nonmetallic item, such as a gasket. An example of crevice corrosion forming pits is shown in Section 1, Photograph 2.

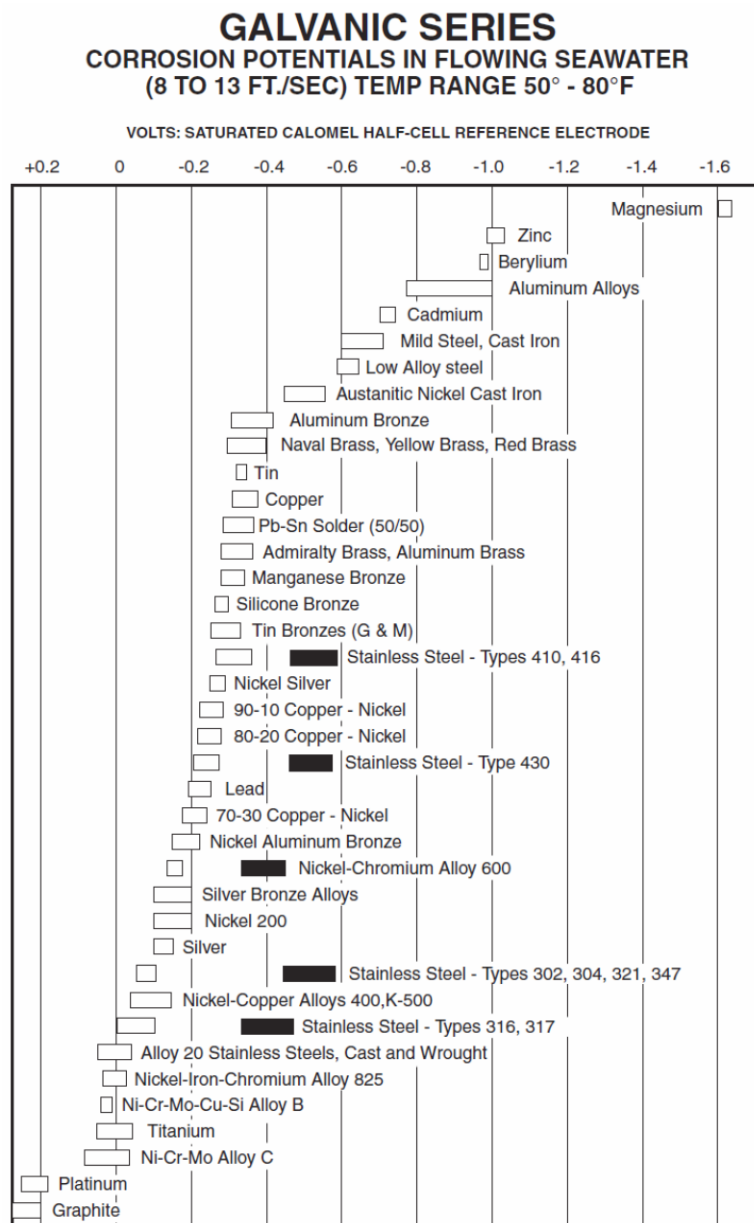
PHOTOGRAPH 2
Pits Forming as a Result of Crevice Corrosion
between the U Bolt Support and the Pipe



4.4 Galvanic Corrosion (1 January 2017)

Galvanic corrosion (also called “dissimilar metal corrosion”) refers to corrosion damage induced when two dissimilar materials are coupled in a corrosive electrolyte. When a galvanic couple forms, one of the metals becomes the anode and corrodes while the other becomes the cathode and is protected. In order to have galvanic corrosion, the dissimilar metals must contact in an electrolyte. The corrosion rate (at anodic site) is controlled by the corrosion potential, which is a potential difference between the dissimilar metals. The well-known galvanic series lists the electrochemical potentials of certain metals in sea water. In the galvanic series shown in Section 1, Figure 7, the reference potential is a Standard Calomel Electrode (SCE). This is a common reference point in chloride containing environments such as those found in the marine industry. The figure gives the ranking of a number of common engineering materials in the Galvanic Series. The most positive (noble) material is protected against corrosion at the cost of the most negative (base) material.

FIGURE 7
The Galvanic Series of Metals with the Most Noble Metals at the Bottom



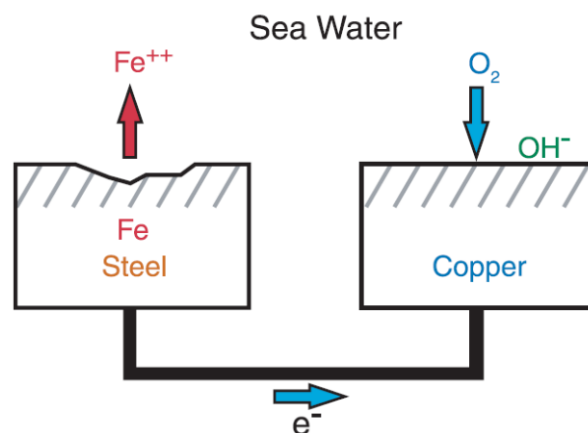
Alloys are listed in the order of the potential they exhibit in flowing seawater. Certain alloys indicated by the symbol: in low-velocity or poorly aerated water, and at shielded areas, may become active and exhibit a potential near -0.5 volts.

When two different metals in the series are electrically in contact in an electrolyte (e.g., sea water), one of them becomes the anode and the other becomes the cathode. Anodes corrode in preference to cathodes.

For instance, when steel and copper are connected as in [Section 1](#), Figure 8, steel is the less noble and therefore corrodes rapidly. Corrosion of the steel is accelerated through its contact with copper. The steel suffers galvanic corrosion while the copper is protected cathodically.

Stainless steel is also cathodic to mild steel. When the two are in direct contact, the mild steel corrodes sacrificially.

FIGURE 8
Flow of Electrons in the Iron/Copper Couple



4.5 Deposition Corrosion (1 January 2017)

Deposition corrosion is a subtle form of galvanic corrosion that occurs when the ions of a more noble metal (cathodic metal) come into contact with a less noble metal (anodic metal). This results in a local galvanic couple being formed and the less noble metal corrodes.

A common example is that of copper ions from pipe work and heating coils being deposited on exposed steel tank tops and rapid pitting corrosion can develop. See Section 1, Photograph 3.

PHOTOGRAPH 3
Deposition Corrosion



Copper ions have deposited out on an aluminum structure and caused deposition corrosion to aluminum.

4.6 Impingement Corrosion (1 January 2017)

Impingement corrosion is a form of erosion-corrosion generally associated with the local impingement of a high-velocity of flowing fluid against a solid surface.

Impingement corrosion commonly occurs in the way of tank washing and cleaning processes. Areas that are closest to the jets can suffer from a loss of coating and pitting. The force of the jet, whether it is oil or water, is sufficient to remove the protective oxide layers from the metal surface and if the protective oxides cannot reform, localized corrosion (pitting) occurs. See [Section 1](#), Photograph 4.

PHOTOGRAPH 4
Impingement Corrosion



Structures in the way of tank washing systems can lose their coating and pitting corrosion can occur.

4.7 Microbiologically Influenced Corrosion (MIC)

This type of corrosion can very occasionally occur in ballast tanks and has sometimes been blamed for the excessive pitting found on the tank tops of VLCCs. All metals, even stainless steel, can incur corrosion from microbiologically influenced corrosion (MIC). It is very difficult to clearly differentiate MIC from other forms of corrosion and opinions differ widely as to its significance. Only when mats or webs of slimy material are present in clearly de-oxygenated environments (zero oxygen) can its presence be definitively confirmed.

The two most common types of bacteria that cause corrosion are acid producing bacteria (APB) and sulfate reducing bacteria (SRB). Both live in colonies attached to the surface of the steel where they assist each other in their growth. Corrosive bacteria, such as SRB which grow in oxygen free environments, rarely thrive over large areas in the conditions on board vessels. On ships, microbes can live in the water layer at the bottom of oil cargo tanks and in the sediment in ballast tanks, but stagnant conditions are usually required for MIC to become widespread. The exact reaction of microbes and steel is not clear, but they do produce acids, create corrosive cells and produce hydrogen sulfide.

The initial detection of sulfate reducing bacteria is first achieved visually by noting a black slime deposit on the surface of the steel. Additionally, the detection of hydrogen sulfide (as a rotten egg smell) could be noted. Corrosion attributed to MIC almost always manifests as highly localized pitting and the pits are generally filled with a black ferrous product. The walls of the pit can be terraced and the metal surface below the corrosion products is often bright and active. Further confirmation can be obtained by culturing samples.

However, similar corrosion effects can also be found where MIC is not a factor. In crude oil tanks, the corrosion and pitting are driven mainly by sulfur deposits from the cargo or produced by inert gas systems.

All permitted hard coatings used in cargo and ballast tanks are known to be resistant to bacteria with the possible exception of vinyls. The latter are only rarely used in these areas. Supplementing a coating protection system with sacrificial anodes can cause the pH within the tank to increase locally. Bacteria do not usually thrive in areas where the pH level is in the alkaline range of 10 to 14.

Note that although sacrificial anodes may be present, the local pH under a bio-film or rust scale may become or remain acidic if it is shielded from the effects of the sacrificial anode. The use of biocides for treating bacterially affected areas has been tested successfully in small, enclosed tanks, but these have short-term effects and are expensive. Biocides such as chlorine, hydrogen peroxide, iodine and quaternary amine have been used.

At the new construction phase, design features should be utilized to minimize or eliminate areas for the accumulation of mud and sediment. Also, proper drainage of all liquids to a common stripping area is desirable to eliminate the possibility of stagnant water accumulating.



SECTION 2 Protective Coatings

1 General (1 January 2017)

For the reasons described in the previous [section](#), corrosion requires a **corrosive environment**. Coatings, **as barriers between a steel surface and a corrosive environment**, work first by excluding water, ions and oxygen from reaching the steel. The efficiency of the barrier determines the extent of corrosion and coating breakdown.

For a perfectly intact coating applied to a perfectly clean surface with good surface preparation, the expected lifetime (assuming that there is no mechanical damage to the coating and/or strain applied on the steel substrate due to structural behavior) would probably exceed that of the vessel. It is the deviations from perfection that compromise the coating lifetime.

2 Factors Affecting Coating Lifetime

2.1 Oxygen Permeability

Most coatings used in the marine industry are not good barriers to the diffusion of gases. Coatings allow more than sufficient oxygen through the bulk of the coating to sustain any corrosion reaction taking place at the interface with the metal.

2.2 Water Vapor Permeability

Water in its gaseous phase can generally penetrate coatings with much the same ease as oxygen. Water vapor then condenses at the metal interface back to liquid water where it can drive such phenomena as osmotic and cold wall blistering. The latter occurs when water vapor passes through the coating and then condenses on the underlying cold metal. Liquid water cannot return through the coating and so blisters are formed, usually containing neutral pH fluid.

Inward rates of water vapor diffusion are generally higher than outward diffusion rates. The corrosion process is therefore rarely limited by a lack of water availability.

2.3 Liquid Water Uptake

As well as water vapor, coatings also transmit liquid water, which is taken into the bulk of the coating and (depending on the type of coating) can cause it to swell, disbond from the metal or to leach soluble components over an extended time period. Cyclic effects can eventually compromise the barrier properties of the coating.

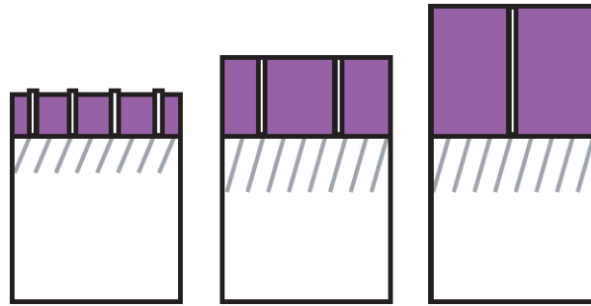
2.4 Ionic Permeability

It is usually the availability of aggressive ions such as chlorides or sulfates at the interface that determines the rate of the corrosion reaction. For cross-linked coatings such as epoxies and polyurethanes, the network structure prevents the transmission of these ions through the bulk of the coating. Ions can only reach the interface via pores and defects in the coating.

2.5 Coating Porosity (1 January 2017)

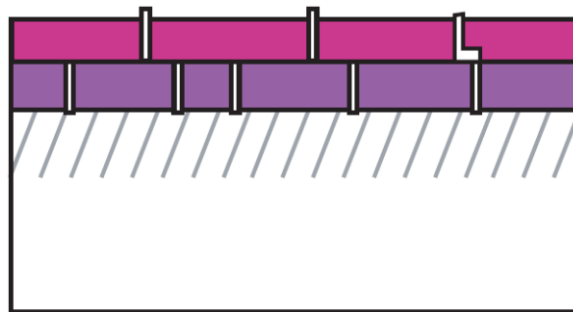
All coatings **could** contain pores and other similar defects. These are usually produced during coating application and are a result of air entrapment, solvent boiling, pigment segregation or other similar phenomena. The density and size of the defects can vary with coating thickness in the manner shown in [Section 2](#), Figure 1.

FIGURE 1
Schematic Coating Porosity in Single Coatings of Different Thickness



The thicker the coating, the lower the defect concentration and the less the likelihood of pores reaching from the surface to the steel. The chance of a pore penetrating through a single coat system is greater than through a double or multi-coat system of the same total thickness, as shown in Section 2, Figure 2. Pores can penetrate both layers as the pore in the lower layer can act as a nucleation site for the pore in the upper layer.

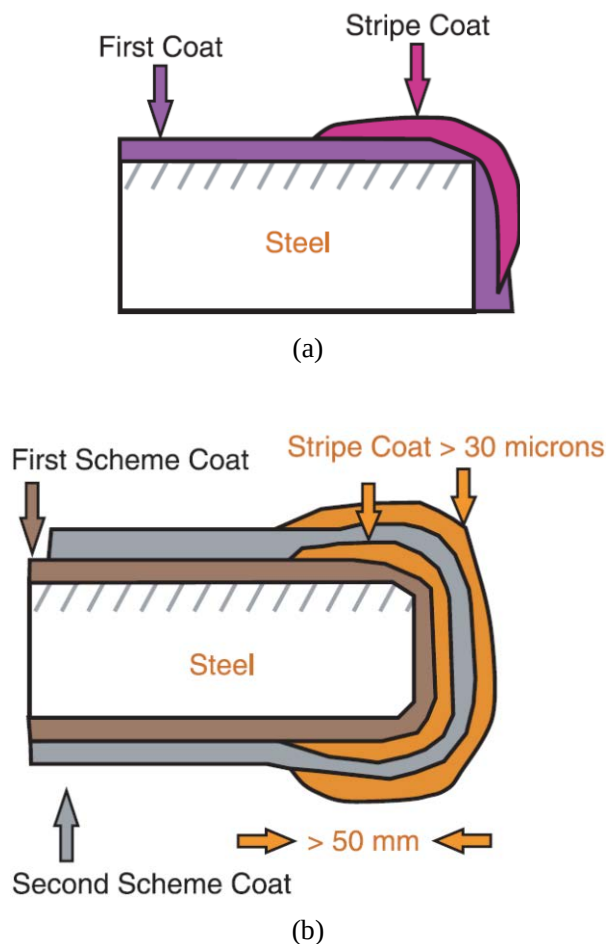
FIGURE 2
Schematic Coating Porosity in a Two Layer System



However, over thickness in a coating can lead to internal stresses being generated and cracking can occur. Therefore, a very thick coating is not necessarily better. The manufacturer's **recommendation on** dry film thicknesses (DFT) **and numbers of coats** should be achieved.

In order to achieve specified DFTs with good adhesion to substrate steel, stripe coatings are generally recommended for welds and edges before spray coating is applied. They become common practice for the new building process. They are also applied during maintenance and repair/refurbishment. Spray application processes and the inherent nature of paints in the liquid state cause the coating to pull back from sharp edges and this results in the formation of a thin film at edges, as shown in the first coat portion of Section 2, Figure 3(a). Due to the consequence from the sharp edges, sharp edge grinding (as shown in Section 2, Figure 3(b)) and irregular weld grinding are required from IMO PSPC. IMO PSPC sets out a minimum of 2 mm round edge after grinding and weld treatment to ISO 8501-3 (P2). In addition, IMO PSPC requires at least two stripe coatings, and a second stripe coat can be reduced for weld seams only if the total dry film thickness meets the requirement. The purpose of the stripe coat is to add an extra thickness (preferably about 30 μm) of coating around vulnerable areas such as cut edges, welds and drain holes. During routine maintenance on board the vessel, the application of stripe coats during repair work (particularly if the vessel was constructed without stripe coats) prolongs the life of the coating scheme.

FIGURE 3
Schematic Showing the Need for Stripe Coatings



2.6 Surface Contamination (1 January 2017)

In practice, it is almost impossible to produce a perfectly clean surface in a shipyard or dry dock. Surfaces are contaminated to a certain extent with a mixture of ions, water, oils and greases, blasting dusts, soot and other deposits. When the coating is applied to the surface, service lifetime is expected to be limited. Ionic materials cause blistering and other disbonding phenomena while the other contaminants result in various degrees of lack of adhesion.

Coating manufacturers should provide the surface cleanliness requirements for each coating in their technical data sheets. In particular, the level of ionic contamination must be less than or equal to the test qualification of the coatings certification. Ionic contamination is usually measured in micrograms of ionic material per square centimeter or milligrams per square meter. It should be noted that there is a factor of ten to convert between these two measurement systems. In addition to the coating manufacturer's requirements, the IMO PSPC_SWBT and IMO PSPC-COT set out the minimum surface cleanliness standard.

2.7 Surface Profile (1 January 2017)

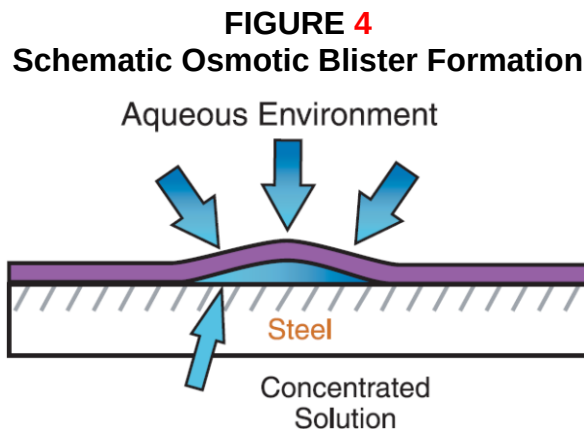
The roughness of the surface prior to coating also affects coating longevity. A good mechanical key is essential for adhesion. The term "mechanical key" describes the surface profile where the abrasive blast media has produced and allows the coating to flow in. The mechanical key helps to resist rust jacking (and calcareous deposit jacking).

3 Types of Coating Breakdown

(1 January 2017) Coating breakdown is covered here from a physical viewpoint; real life examples are shown and discussed later in Sections 10 and 11.

3.1 Blistering via Osmosis

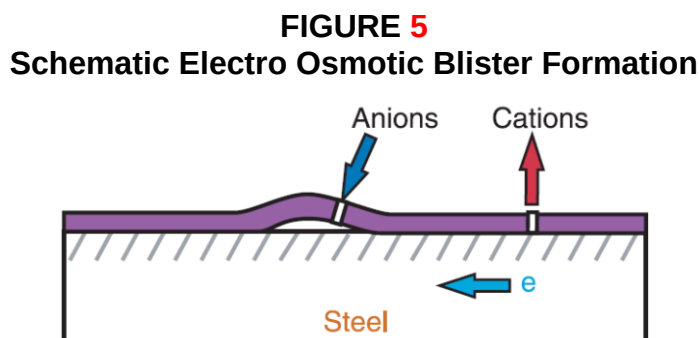
Blistering is usually caused by the presence of ionic contamination or water soluble species at the interface between the coating and the steel. Water is drawn from the environment through the coating from an area of low ionic concentration to an area of high ionic concentration by osmosis. The coating domes upwards as a result of the pressure difference, as shown in Section 2, Figure 4.



3.2 Blistering via Electro Osmosis

Osmotic blisters are usually small and relatively closely spaced. Larger blisters are the result of electro osmosis. When a normal blister grows so that it encompasses a pore in the coating, electro osmotic blistering can take place. The difference in potential between the anodic site and the local cathodic site that occurs beneath the blister drives ions into the blister. These then result in further growth of the blister via the mechanism shown in Section 2, Figure 5.

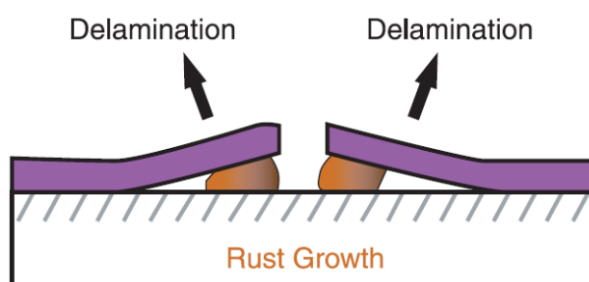
In Section 2, Figure 5 an actively corroding site or an external sacrificial anode would provide the same driving force for blistering. Osmosis and electro osmosis tend to occur early in the lifetime of a coating while it retains a degree of plasticity.



3.3 Rust Jacking

Rust jacking or rust leverage is the predominant mechanism of coating failure during the late stages of the service life of the coating. It occurs at defects in the coating, cut edges, welds and at sites of mechanical damage. It is a result of the change in volume that occurs between iron in the steel and iron in the corroded condition. Typically, **there occurs** a volume increase of between eight (8) and twelve (12) times when iron becomes rust. This volume change occurs beneath the coating and mechanically levers it from the surface in the manner shown in **Section 2**, Figure 6. Good mechanical strength in the coating and a good mechanical key to the substrate both help to resist this occurrence.

FIGURE 6
Rust Jacking



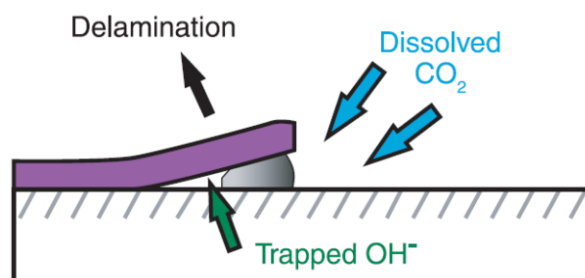
3.4 Calcareous Deposit Jacking

Calcareous deposit jacking is similar to rust jacking in that the coating is levered from the surface mechanically by a deposit growing beneath it. In this case, the white calcareous deposits grow at the interface of the steel and coating as a result of electrochemical polarization by the cathodic protection system. Hydroxyl ions are generated at the cathodic site beneath the coating. These ions change the pH of the environment, which in turn changes the solubility of components of the sea water and cause precipitation to take place in this area. Dissolved carbon dioxide can also diffuse into the gap under the coating and react with the hydroxyl ions, giving rise to chalky deposits in the manner shown in **Section 2**, Figure 7.

Calcareous deposit jacking and rust jacking usually occur together (sometimes in alternating layers) due to the cyclic conditions found in ballast tanks.

It should be noted that the calcareous deposits help to protect steel from further corrosion by the formation of a barrier layer on the steel. This is particularly of benefit in the ballast tanks of bulk carriers which suffer from impact damage from grabs, etc., on the opposite side of the plate in the cargo holds. The paint in the ballast tanks can crack or become detached and the calcareous deposits assist in the prevention of rapid corrosion at these areas until repairs to the coating can be carried out.

FIGURE 7
Calcareous Deposits



4 Protective Coatings (1 January 2017)

Protective coatings for corrosion prevention possess at least one of the following three main principles. They:

- 1) Create a barrier that keeps out charged ions and retards the penetration of water and oxygen.
- 2) **Provide** metallic contact between the steel and a less noble metal, such as zinc in the paint, which provides cathodic protection of the steel utilizing the galvanic effect.
- 3) **Cause** water on its passage through the paint coating to take on special properties or compounds inhibiting its corrosive action.

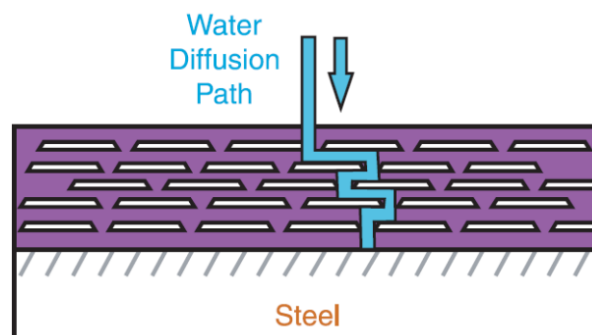
4.1 Barrier Effect

The barrier effect may be obtained by applying a thick coating, typically 200 μm to 350 μm (8 mil to 14 mil). This barrier effect is the most commonly used type of anti-corrosion mechanism. Typical paints employing this mechanism include epoxies and polyurethanes.

By adding flake pigments, such as leafing aluminum, an improved barrier effect can be achieved. The flake pigments are oriented parallel to the steel surface, and water trying to pass through encounters a more complicated and longer passage around the pigment particles, as shown in Section 2, Figure 8.

For permanently immersed steel, the first and often the only choice in coating protection is to utilize the barrier effect. However, if a barrier coating is damaged, the damaged area is open for corrosion to begin. Corrosion can then proceed into the steel substrate and outwards under the intact coating, known as rust jacking or under film rusting. Where there is a risk of mechanical damage, additional protection such as cathodic protection is sometimes provided.

FIGURE 8
Complex Pathway Produced by Lamellar Pigments



4.2 Galvanic Effect

Protection of steel through the galvanic effect (cathodic protection) can be achieved with paints containing large amounts of metallic zinc or aluminum. A condition for effective protection is that the paint is formulated to give metallic contact between the individual metal pigment particles, and between these particles, and the steel.

The very nature of these paints requires an absolutely clean steel surface and, especially for zinc silicates, a well-defined surface profile for a lasting coating system. When applied, zinc silicates are initially porous. **Over time**, the porosity is filled with corrosion products from the zinc and a barrier is formed. When damaged, the galvanic effect is re-established at the damaged area and the steel is protected effectively against rust creeping.

4.3 Inhibitor Effect

A corrosion-inhibiting effect is achieved by using primers containing inhibitors. These are soluble or basic pigments designed to suppress the corrosion process. Inhibitors work by reducing the rate of either the anodic or the cathodic process, or by depositing a high resistance film onto the corroding surface. The corrosion current flowing between the anodic area and the cathodic area is usually reduced by at least an order of magnitude. To prevent them from being washed out of the primer coats, top coats without inhibitors are applied to provide the barrier necessary for the inhibitive primer to last. However, due to the water solubility of the pigments used, inhibitive primers are not suited for prolonged immersion, as they suffer from blistering and subsequent early breakdown of the coating system can occur. When damaged, reasonable protection against rust creeping or under rusting is provided if the damaged area is not too large. When the inhibitor has been used up, corrosion occurs.

4.4 Surface Tolerant Coatings (1 January 2017)

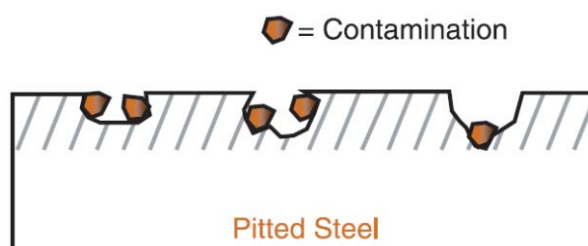
After a vessel enters service, corrosion begins to occur under coatings in tanks and holds at areas of damage or at regions where good surface preparation was not initially carried out. Maintenance of the coating is essential if its target service life is to be achieved. Any damages to the paint or any areas of rust jacking must be repaired as quickly as possible. Under service conditions, it is not always possible to achieve a very high standard of surface preparation, although some vessels have small scale abrasive blasting equipment on board.

The application of a surface tolerant paint product can be practical during coating maintenance and repairs. However, it should be remembered that no paint performs adequately if it is applied onto heavily rusted or contaminated surfaces and that steel preparation should always be carried out to the proper or highest possible standards, to avoid the necessity to repair the same area many times.

Outer hulls of vessels suffer from mechanical damage from fendering, tugs, etc., and with time, this can result in pitted steel which is difficult to clean by spot abrasive blasting. The steel looks clean visually but ionic contaminants, such as salts, can be trapped under rust scales or in pits as shown in Section 2, Figure 9.

Washing the surface with fresh water can help to reduce the residual contamination. Paint manufacturers specify the minimum surface cleanliness level allowed for their products.

FIGURE 9
Residual Contamination in Pits



5 Coating Compatibility (1 January 2017)

The compatibility between different types of coatings varies considerably. Coatings such as epoxies have very specific over-coating time intervals (sometimes called the over-coating window) and these times must be strictly followed if the individual layers are to adhere to each other.

Incompatibility between coating types, such as epoxy anti-corrosive coatings with some types of anti-fouling paints, can be overcome by the use of a tie coat, which has good adhesion to both paint types and is therefore applied onto the anti-corrosive layer before the anti-fouling layer is applied.

If paints from different manufacturers are used, advice should be sought from the manufacturer of each of the different paints. Coating compatibility is important in new building PSPC projects and its approval is specifically addressed in the PSPC standards.

Coating compatibility is also important when maintenance and repair work is carried out so that the repair coat adheres to the original paint or inter-coat adhesion failure occurs.



SECTION 3 Coating Types and Their Uses

1 General (1 January 2017)

This **Section** covers the major types of coatings that are currently available for use on vessels and includes general information on the composition of coatings. It is intended to give basic information on coatings and is not a comprehensive guide to **coating** selection. The coating manufacturer is to be consulted if information on a specific product or coatings suitable for particular areas on the vessel is required.

Coatings for ships are often divided into two broad categories:

- i) Products for application at new building and;
- ii) Products suited for maintenance and repair, which would include both major refurbishments, either at sea or in port, and On Board Maintenance (OBM). The types of **coating** used for OBM are often single pack products as this avoids the difficulties of measuring and mixing small quantities of two-pack products, although small quantities of two-pack products are sometimes available from paint manufacturers.

In general, paints are either targeted for specific vessel areas and for specific functions for best performance, or universal coatings are available for all areas with a compromise in performance. In all cases, a balance between cost, performance and difficulty of maintenance has to be achieved. For example, anti-corrosive coatings used on the outside of the accommodation area have different performance requirements from anti-corrosion paints used in sea water ballast tanks as the corrosion stress placed on the latter is far greater. Ballast tanks are also much more difficult to maintain due to access difficulties. Therefore, **to maintain the steel in good condition cost-effectively**, the use of a highly effective (and often more expensive) coating is preferred.

In contrast, the holds of bulk carriers suffer from abrasion damage due to cargo impact and grab damage, which often leads to **erosion and** corrosion. Cargo holds used as ballast tanks during heavy weather can be particularly susceptible to corrosion at damage sites, and a different coating is sometimes used for this cargo hold. This also applies to cargo tanks for oil carriers with a class notation for “Clean Products”, where any cargo tank may be used for heavy weather ballast.

2 Paint Composition (1 January 2017)

Paint can be **defined** as a liquid-applied **coating** which subsequently dries or hardens to form a continuous, adherent film.

Paints basically consist of three major components and many types of additives included in minor quantities. The major components are:

- Binder (also called vehicle, medium, resin, film or polymer)
- Pigment and extender
- Solvent

Of these, only the first two form the final dry paint film. Solvent is only necessary to aid paint application and the initial film formation, but inevitably, some solvent is always retained in practice depending upon the level of ventilation **and dry time**.

3 Binders (1 January 2017)

Binders are the film-forming components of paint which determine the principal characteristics of the coating, both physical and chemical. Paints are generally named after their binder component (e.g. epoxy paints, chlorinated rubber paints, alkyd paints, etc.). The binder forms a continuous film which is responsible for adhesion to the surface and which will contribute to the overall resistance to the environment.

Binders used in the manufacture of paints fall into two classes, thermoset and thermoplastic. A thermoset coating when dry will be chemically different from the paint in the can. Thermoset coatings are not **dissolved** by solvents once cured. With a thermoplastic coating, the dry film and the wet paint differ only in solvent content and chemically, these remain essentially the same. If the solvent originally used is applied to a thermoplastic coating, it will soften and can be redissolved in that solvent.

4 Cross-linked (Thermoset) Coatings

(1 January 2017) These paints are usually supplied in two separate packs which are mixed together immediately before application. In **solvent-based** paints, drying is considered a two-stage process. Both stages actually occur together but at different rates.

Stage One: Solvent is lost from the film by evaporation and the film becomes dry to touch.

Stage Two: The film progressively becomes more chemically complex by one of the following four methods:

- 1) Reaction with atmospheric oxygen, known as oxidation.
- 2) Reaction with an added chemical curing agent.
- 3) Reaction with water (moisture in the atmosphere).
- 4) Artificial heating.

This transformation in the paint is known as drying or curing. The films formed by the above methods are chemically different from the original binders and will not redissolve in their original solvent.

4.1 Epoxy Resins (1 January 2017)

These resins are particularly important and their development for use as binders was one of the most significant advances in paint technology. The rate of cross-linking or curing is dependent on temperature. The curing rate of standard epoxies is considerably reduced **below 5°C (41°F)**. Full cure is essential **to obtain optimal film properties**. Epoxies will cure or set **with special curing agents** at temperatures down to **-5°C (23°F)**. It is essential that the coating manufacturer's recommendations on application temperatures are strictly followed.

The choice of curing agent is very important as with the base, this determines the properties of the film. There is a wide choice of both resins and curing agents which allows for formulation of products to suit most applications.

Epoxies are used in both underwater and above water situations and show good resistance to many marine environments, but they have a tendency to chalk in sunlight. This occurs when the binder is degraded by ultraviolet light to produce a loose and friable surface, with the pigment particles remaining on the surface.

4.2 Polyurethane Resins

These are polymers formed by reaction between hydroxyl compounds and compounds containing isocyanates.

In two-pack systems, a special polyether or polyester resin with free hydroxyl groups is reacted with a high molecular weight isocyanate curing agent. A possible problem with these materials is their water sensitivity on storage and on application. Transport and storage should be in strict compliance with the manufacturers' recommendations. Due to their poor curing properties at low temperatures, **manufacturers' recommendations** must be followed during application.

Polyurethane resins have excellent chemical and solvent resistance and are superior to standard epoxies in acid resistance. Epoxies are more resistant to alkaline than polyurethanes. Polyurethane finish coats are very hard and have extremely good gloss, gloss retention, and can be formulated to be non-yellowing. However, they can in some instances be difficult to overcoat after ageing and require very clean surfaces for optimum adhesion. Because of the isocyanate curing agent, there is also a potential health hazard when sprayed, which can be overcome with the appropriate protective equipment.

4.3 Alkyd Resins (1 January 2017)

Alkyd resins are formed by the reaction between a special organic acid (e.g., phthalic acid), a special alcohol (e.g., glycerol or pentaerythritol) and a vegetable oil or its fatty acids. The final properties of the alkyd depend on the percentage of oil (termed “oil length”) and also on the alcohol and organic acid used.

Alkyds are not resistant to acids or alkalis and many of the modifications are aimed at improving this weakness. However, none provide complete resistance. Alkyd resins can be further modified with different resins for specific purposes.

4.4 Inorganic Resins (1 January 2017)

These types comprise the silicates which are almost always used in conjunction with zinc dust pigments. There are water-based inorganic silicates based on lithium, potassium, or sodium silicate and solvent based inorganic silicates normally based on ethyl silicate. Coatings based on these resins are very hard, corrosion resistant and temperature resistant. They require a good standard of surface preparation and are often repaired using organic coatings.

The zinc in the inorganic resins can dissolve under acid or alkali conditions, but the coatings perform well around neutral pH and are often used as tank coatings.

5 Thermoplastic Coatings

These types of paint binders are simple solutions of various resins or polymers dissolved in suitable solvent(s) and are usually supplied as one pack products, making them especially suitable for maintenance work. Drying is simply effected by the loss of the solvent by evaporation. This is termed physical drying as no chemical change takes place. The resulting film is therefore always readily soluble in the original solvent and can also be softened by heat. Since these coatings, by definition, require the presence of significant amounts of solvent, they are disappearing from markets where volatile organic content is regulated, particularly the USA and the EU. Generic types of binders in this category include:

5.1 Chlorinated Rubber Resins

Chlorinated rubber resins have good acid and water resistance on well-prepared surfaces. Their temperature sensitivity can lead to various film defects when used in very hot climates. In addition, white and pale colors have a pronounced tendency to yellow when exposed to bright sunlight. Chlorinated rubber paints will dry at low temperatures and give good inter-coat adhesion in both freshly applied and aged systems, making them suitable for maintenance purposes.

5.2 Vinyl Resins

Vinyl resins are based on film forming polymers consisting of varying ratios of polyvinyl chloride, polyvinyl acetate and polyvinyl alcohol. Plasticizer types used are tricresyl phosphate or dioctyl phthalate.

Higher volume solid materials can be produced by blending the vinyl resin with other materials such as acrylic resins. Generally, the film properties and weathering characteristics also show good low temperature drying and inter-coat adhesion characteristics. Coal tar can be added to increase water resistance.

6 Pigments and Extenders

Pigments and extenders are used in paints in the form of fine powders. These are dispersed into the binder. The particle sizes are of about 5-10 microns for finishing paints and about 50 microns for primers.

These materials can be divided into the following types:

Type	Purpose
Anti-corrosive pigments	To prevent corrosion of metals by chemical and electrochemical means, in above water areas.
Barrier pigments	To increase impermeability of the paint film.
Coloring pigments	To give permanent color.
Extending pigments	To help give film properties required.

6.1 Anti-corrosive Pigments (1 January 2017)

6.1.1 Zinc

Metallic zinc is widely used in primers for protecting steel from corrosion. Initial protection is by galvanic action. However, as the coating is exposed to the atmosphere, a progressive buildup of zinc corrosion product occurs to fill up pores in the coating, producing an impermeable barrier with little or no galvanic protection. To give both good galvanic and barrier protection, high levels of zinc, such as about 85 percent of zinc in the dry film by weight, are necessary.

Resins which may be considered are epoxies and silicates. Obviously, for the zinc to function correctly, it has to be in intimate contact with the steel substrate and good surface cleanliness prior to application is therefore essential.

6.1.2 Aluminum Pigments

Metallic aluminum flake is commonly used as an anti-corrosive pigment by producing a circuitous pathway for water and ions around the lamellar flakes, as well as reacting to form aluminum oxides, which fill up pores in the coating. Where the aluminum is in contact with steel, a limited cathodic protection mechanism will also be provided, although when used on oil and chemical tankers where flammable gases build up, the aluminum content in the dry film should not exceed 10 percent by weight to avoid possible spark hazards.

6.1.3 Zinc Phosphate

Zinc phosphate ($\text{Zn}_3(\text{PO}_4)_2$) pigments are also widely used in corrosion-inhibiting coatings for steel surface corrosion protection. Zinc phosphate hydrolyzes in water to produce zinc ions (Zn^{2+}) and phosphate ions (PO_4^{3-}). The phosphate ions act as anodic corrosion inhibitors by phosphating the steel and rendering it passive. The zinc ions act as cathodic corrosion inhibitors. Zinc phosphate can be incorporated into almost any binder and paint with any color of paint.

Please note that IMO performance standards of protective coatings require shop primers containing inhibitor free.

6.2 Barrier Pigments

The most common types of these pigments are aluminum (leafing aluminum) and Micaceous Iron Oxide (MIO). Both have particle shapes which are termed lamellar (plate-like). These materials can be used in combination, the aluminum lightening the almost black shade of MIO.

MIO-pigmented films have durability, but to achieve this, high levels of MIO are necessary in the order of 80 percent of the total pigment. Aluminum has been used for many years as the principal pigment in paints for use underwater. The lamellar shape helps to make the film more water impermeable. Glass flake is also used as a barrier pigment.

6.3 Coloring Pigments (1 January 2017)

These pigments provide both color and opacity and can be divided into either inorganic or organic types. The most common coloring pigment is titanium dioxide, which is white. In paint, all pigments are normally dispersed to a very fine particle size in order to give maximum color and opacity (hiding power). Traditionally, bright colors were obtained using lead and chrome pigments. However, due to health and safety concerns, these are less common. Organic pigments are **now** used instead, but the opacity is not as high with these products.

Where the IMO PSPC is applicable, a multi-coat system **with** contrasting color **is recommended**. The top coat **shall** be a lighter color to facilitate in-service inspection.

6.4 Extender Pigments

As the name suggests, they basically adjust or “extend” the pigmentation of the paint until the required pigment volume concentration (PVC) is achieved. Extender pigments are inorganic powders with various particle shapes and sizes. Although making little or no contribution to the color opacity of the paint, they can have significant influence on physical properties. These include flow, degree of gloss, anti-settling properties, spray-ability, water and chemical resistance, mechanical strength, hardness and firm build (volume solids, hold up thixotropy). Mixtures of extenders are often used to obtain the desired properties. They are relatively inexpensive when compared to resins, anticorrosive pigments and coloring pigments.

7 Solvents (1 January 2017)

Solvents are used in paints principally to facilitate application. Their function is to dissolve the binder and reduce the viscosity of the paint to a level suitable for the various methods of application, such as brush, roller, conventional spray, airless spray, etc. **Solvents also can help with coating wetting on the surface to be coated**. After application, the solvent evaporates and plays no further part in the final paint film. Liquids used as solvents in paints can be described in one of three ways:

7.1 True Solvent

True solvent is used to dissolve the binder and is completely compatible with **the binder**.

7.2 Latent Solvent

Latent solvent is not a true solvent. **It is designed to mix** with a true solvent. **The mixture** has stronger dissolving properties than the true solvent alone.

7.3 Diluent Solvent

Diluent solvent is not a true solvent. **It is** normally used as a blend with true solvent/latent solvent mixes to reduce the cost. Binders will only tolerate a limited quantity of diluent.

There are numerous solvents used in the paint industry and this is partly due to the number of different properties which have to be considered when selecting a solvent or solvent mixture. In addition to commercial factors such as price and availability, properties include toxicity, volatility, flammability, odor, compatibility and suitability.

In some countries, certain types of solvents are not allowed. This is especially true in the USA, where the Hazardous Air Pollutant Substances Act, (HAPS) dictates a timeline for removing many solvents and extenders from coatings. Application properties, dry times and overcoat windows will most likely be affected as this Act is implemented.

8 Anti-corrosion Paints

(1 January 2017) With few exceptions (such as anti-fouling paints, cosmetic effects, fire retardants, etc.), the majority of coatings applied to a vessel are used for anti-corrosion protection. There are many types of anti-corrosion coatings, but epoxy paints generally cover the greatest area on a vessel, particularly when they are used in sea water ballast tanks.

8.1 Pure Epoxy (1 January 2017)

Pure epoxy coatings are generally regarded as paints which contain only epoxy polymers, the cross linking agent, pigments, extenders and solvents. The coatings contain high levels of epoxy binder and are therefore expected to provide the maximum possible performance from a coating in terms of anti-corrosion protection, long life and low maintenance.

In addition, some products also claim abrasion-resistance properties. Pigments such as aluminum can be added to pure epoxy coatings to provide additional anti-corrosion performance.

Epoxy Phenolic coatings can be used in cargo tanks where a high cargo resistance is required, such as on oil-product and chemical carriers. Special care needs to be taken with the surface preparation, **high temperature, and curing during construction of tanks**. Coating manufacturers **can provide advice** on the specific requirements for each tank.

8.2 Modified Epoxy

Modified epoxy is also known as epoxy mastic, tar-free epoxy and bleached tar epoxy. This group covers a wide range of products and anti-corrosion performance capabilities. In service, modified epoxies can be effective. However, as there are many possible modified epoxy formulations, it is not possible to make generalizations on their anti-corrosion performance.

Modified epoxies can contain non-epoxy materials which are capable of cross-linking into the final film. They may also contain non-reactive materials, either solid or liquid, which do not take part in film formation, but remain like pigments or extenders in the final coating. If these materials are water (or cargo) soluble, they can leach out over an extended time period leaving a porous or brittle film with reduced anti-corrosive properties.

8.3 Coal Tar Epoxy (1 January 2017)

Coal tar is a naturally occurring product. Coal tars are available in a wide range of types from liquid to solid. The inclusion of coal tars in a coating results in a very dark brown or black color to the coating, which can be slightly lightened by the addition of aluminum flake pigment for lighter colored paints. However, it is unlikely that coal tar epoxies can be sufficiently light in color to be used in compliance with the IMO PSPC for the **top** coat. A light colored, non-tar based epoxy top coat can be used over a tar based first coat. However, tar “bleed through” may discolor the top coat.

Certain constituents of the coating can leach out over long periods of time, leaving a more brittle and less protective coating. Coal tar epoxies have a long track record in service and generally have performed well. Since the 1990s, they have been phased out **in** ballast tanks due to health and safety issues for the coating applicators and the recommendation for light color coatings to aid **visual** inspections.

8.4 High Solid Content Epoxy (1 January 2017)

High solid content epoxy coatings usually have solid content 70-100% by volume. They have low solvent content and therefore they have less solvent retaining, so better coating flexibility and less potential for cracking. Those high solid content coatings can provide high DFT buildup and good “edge-retentive” – **save stripe coatings or less sharp edge grinding**.

The viscosity required to spray the paint is obtained from the selection of low molecular weight raw materials or by heating and the use of plural component systems. Typical applications include ballast and cargo tanks. They are sometimes used where volatile organic components (VOC) removal is difficult due to poor ventilation. It should be noted that the VOC for solvent-free systems is not necessarily zero.

Typical applications for solvent-free coatings include the inside of pipe work, some tanks and other areas where adequate ventilation cannot be provided or for areas where stringent VOC controls are in force.