



GUIDANCE NOTES ON

the Inspection, Maintenance and Application of Marine Coating Systems

THIRD EDITION, 2007

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American Bureau of Shipping
ABS Plaza
16855 Northchase Drive
Houston, TX 77060 USA
www.eagle.org

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Dr. Jane Lomas, AMTEC Corrosion Ltd.



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Executive summary

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 coatings in the various mandated Rules and Regulations and the unprecedented acceleration of coating technology, personnel involved with assessing 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.

CONTENTS

CHAPTER 1: Corrosion

1	General.....	1
2	Uncoated steel and the corrosion reaction.....	1
3	Factors influencing corrosion rates.....	3
4	Types of corrosion.....	4

CHAPTER 2: Coatings and corrosion

1	General.....	11
2	Factors affecting coating lifetime.....	11
3	Types of coating breakdown.....	13
4	Anti-corrosion protection by coatings.....	15
5	Coating compatibility.....	16
6	Stripe coats.....	17

CHAPTER 3: Coating types and their uses

1	General.....	19
2	Paint composition.....	20
3	Binders.....	20
4	Cross-linked (thermoset) coatings.....	20
5	Thermoplastic coatings.....	21
6	Pigments and extenders.....	22
7	Solvents.....	20
8	Anti-corrosion paints.....	23
9	Impact and abrasion-resistant coatings.....	24
10	Shop primers.....	25

CHAPTER 4: Surface preparation

1	General.....	27
2	Surface cleanliness.....	27
3	Surface cleaning and conditioning.....	28
4	Solvent cleaning.....	28
5	Abrasive blasting.....	29
6	Spot blasting.....	31
7	Sweep blasting.....	32
8	Hydro blasting/water jetting.....	32
9	Power tool cleaning.....	33
10	Pickling.....	35
11	Preparation of non-ferrous metals.....	35
12	Edge and weld preparation at new building.....	35
13	Surface preparation standards.....	38

CHAPTER 5: Paint Application

1	General.....	43
2	Surface preparation.....	43
3	Film thickness measurement.....	43
4	Methods of paint application.....	43
5	Curing conditions.....	46

CHAPTER 6: Cathodic protection in ballast tanks and cargo holds

1	General.....	49
2	Sacrificial anodes.....	49
3	Impressed current cathodic protection.....	52

CHAPTER 7: Anti-Fouling

1	General.....	55
2	Fouling.....	55
3	Anti-fouling system (AFS).....	56
4	Self-polishing anti-fouling coatings.....	58
5	Insoluble matrix (controlled depletion) coatings.....	58
6	Foul release coatings.....	58
7	Coating compatibility.....	58

CHAPTER 8: Performance Standards for Protective Coatings

1	Introduction.....	59
2	Scope and application.....	60
3	Review of the inspection agreement.....	60
4	Primary surface preparation.....	60
5	Secondary surface preparation.....	62
6	Coating application.....	64
7	Coating inspection requirements.....	65
8	Verification requirements.....	67
9	Coating film thickness measurements.....	67
10	Coating system approval.....	68
11	ABS CPS Guide.....	70

CHAPTER 9: Coating requirements for void spaces.....73

CHAPTER 10: Coating requirements for cargo spaces

1	Oil tankers.....	75
2	Bulk carriers.....	75

CHAPTER 11: Coating Technical File

1	Statement of Compliance or Type Approval Certificate.....	77
2	Technical datasheet.....	77
3	Shipyards work records.....	78
4	Inspection procedures.....	78
5	Daily logs.....	78
6	Shipyards verification report.....	79
7	In-service repair procedure.....	79

CHAPTER 12: Coating failures

1	General.....	81
2	Coating defects during application.....	81
3	In-service coating failures.....	85

CHAPTER 13: Assessment of coating breakdown

1	Introduction.....	97
2	Assessment of existing coating systems for all vessels except tankers.....	97
3	Assessment of existing coating systems cargo holds.....	99
4	Assessment of existing surface coating systems in oil carriers chemical carriers, and double hull oil carriers.....	101

CHAPTER 14: Examples.....111

CHAPTER 15: Glossary and definitions	137
CHAPTER 16: Appendices	141
Appendix A – IMO PSPC MSC.215 (82).....	142
Appendix B – IACS PR 34	161
Appendix C – IACS SC 122.....	164
Appendix D – IACS SC 127.....	165
Appendix E – IACS PR Z17.....	166
Appendix F – IACS Z9	177

Introduction

The IMO Performance Standards for Protective Coatings (PSPC) are intended to delay the onset of corrosion of the structure of dedicated seawater ballast tanks in all types of ships and the double-side skin spaces of bulk carriers. The standards represent the latest in the line of many regulatory actions taken to enhance vessel longevity and thereby enhance safety. More comprehensive vessel inspections by national maritime administrations and concerns by charterers over the condition of vessels with respect to corrosion have contributed to an increased awareness of the contribution made by coatings towards maintaining structural integrity.

Additionally, the positive impact of an effective coatings system in tanks and holds has been underscored as the design of vessels has changed in recent years. For example, the selected use of high tensile steel may impose increased stress on both steel and coatings, placing greater emphasis on the performance characteristics of the latter.

The adoption of ballast water exchange practices (as per IMO Resolution A.868(20)) may potentially place further stress on the hull structure, particularly if a ballast tank is first emptied and then refilled (sequential ballast exchange). In addition, whether ballast exchange is performed by the sequential or flow-through method, the process of re-introducing oxygen-enriched ballast water within the tanks may also affect the longevity of the coatings.

In recent years there has been an increased industry focus placed on the consequences of corrosion and an increased demand for better performance from the coatings used for corrosion control. This has led to the introduction of SOLAS Chapter II Part A-1 Regulation 3-2 which specifies that the protective coatings for dedicated ballast tanks and double-side skin spaces of bulk carriers shall comply with the Performance Standards for Protective Coatings mandated by the IMO.

To help industry understand the major elements of coatings and corrosion, ABS has produced two previous versions of this publication. As a direct response to the needs of industry personnel involved with the inspection of coatings, a complete revision has been undertaken that addresses the fundamentals of coating technology as applied to ship structures and the regulatory requirements for coatings in ballast tanks, void spaces, cargo tanks, cargo holds and outer hull anti-fouling systems.

These Guidance Notes start with an explanation of the chemistry and mechanics of corrosion. While coatings act as a barrier to corrosion, they are porous. The Guidance Notes review the way coatings work to reduce corrosion rates. The myriad of different coatings available can be confusing without a framework to aid understanding. These Notes define the generic categories and their characteristics.

The methods of surface preparation are introduced along with safety guidance and the advantages or disadvantages of each. The factors affecting coating application are examined. These include environmental controls, film thicknesses and the methods of application, among others. Coating technology uses specific measuring equipment and the typical devices are briefly described. In addition to coating technology, the proliferation of coating regulations are explained in context for ballast water tanks, void spaces, outer shell and cargo holds.

Once a vessel is in-service the coatings are subject to various stresses. To aid in the assessment of how the coatings are performing, typical failures are illustrated and guidance is provided on their repair and maintenance.

Also summarized is the ABS *Guide for the Class Notation Coating Performance Standard (CPS)* which details the procedure to obtain the ABS CPS notation and provides useful summary information on the responsibilities of the various parties during the coating application process.

Still under discussion at IMO is the extension of the coatings regulatory regime to cover cargo holds/tanks as well as void spaces. In particular, void spaces below bulkhead decks, within and forward of the cargo area of oil tankers and the cargo length of bulk carriers.

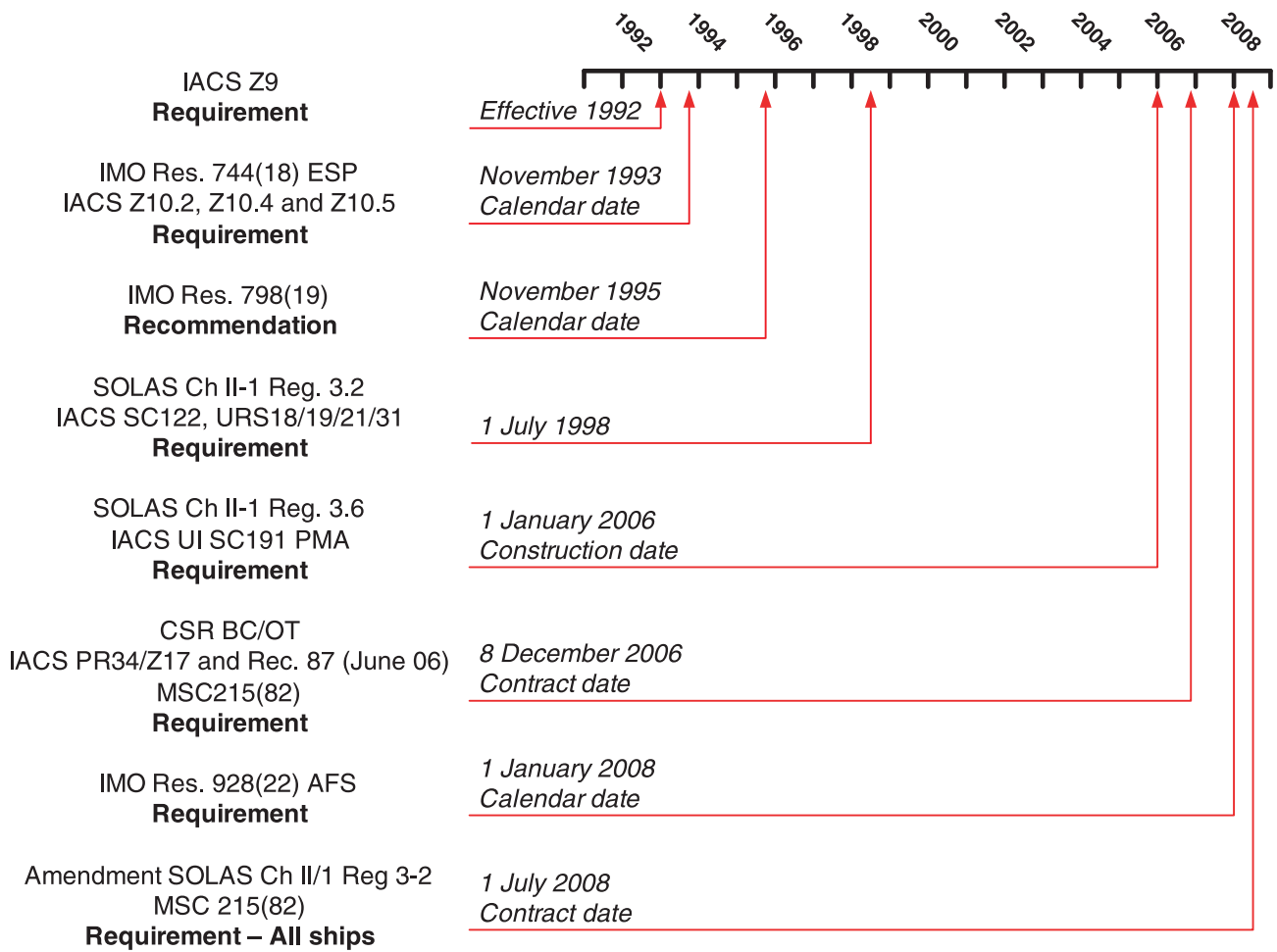


Figure 1. Timeline of development.
See applicable regulations for details of dates referred to.

CHAPTER 1: Corrosion

1 General

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 first line of defense against the corrosive marine environment. Coatings mainly serve to minimize the rate of corrosion, thereby potentially delaying the utilization of the built-in 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 chapter deals with the basic theory of corrosion and sets out the various factors controlling breakdown rates.

Corrosion of steel in ballast and cargo tanks may be defined as an electrochemical process in which the steel reacts with its environment to form an oxide, or other compound, similar to the ore from which it was originally obtained.

The majority of metals are found in nature in the mineral state, that is, in their stable oxidized condition as oxides, chlorides, carbonates, sulfates, sulfides, etc. The extraction of a metal from the mineral involves a reduction process which requires a great deal of energy. As a consequence of this large energy input, the metal is in a high energy condition and will try to return to its former stable, oxidized, low energy state as quickly as environmental conditions will allow. It is this energy difference between the pure metal and its oxidized forms which is the driving force for corrosion of the metal. Many corrosion products show a chemical similarity to the corresponding minerals. Iron, for example, is extracted from its ores, mainly oxide and carbonate, by reduction with carbon in a blast furnace. In the presence of moisture and oxygen, the iron metal so obtained is oxidized to rust, which is chemically the same as its ore.

2 Uncoated steel and the corrosion reaction

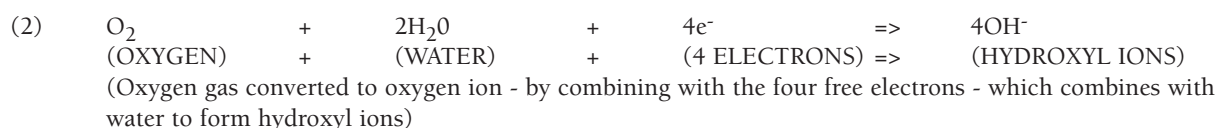
During the corrosion process, steel will lose iron atoms into its environment in the form of ions. In return some of the metal ions from the environment will plate out and return to the metallic state. This is known as a reversible reaction. When the rates of the forward and reverse reactions are the 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. This is called the anodic reaction:



This reaction can only occur if there is a suitable electron acceptor to combine with the electrons released by the iron atom. Freshwater or seawater contains dissolved atmospheric oxygen which readily serves this purpose. The oxygen is electrochemically reduced to hydroxyl ions in the cathodic reaction.



The heterogeneous character of the metal surface allows for some areas or sites to favor reaction (1) and become anodes and other areas to favor reaction (2) and become cathodes. The whole surface of the metal is therefore divided up into large numbers of anodes and cathodes, as shown in Figure 1-1.

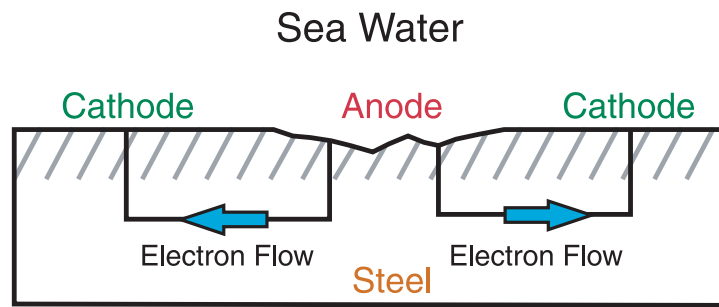


Figure 1-1. Anodic & cathodic areas form on the uncoated steel surface.

As the anodic reaction can take place much more rapidly than the cathodic reaction most of the surface is taken up with the production of hydroxyl ions, as shown in Figure 1-2.

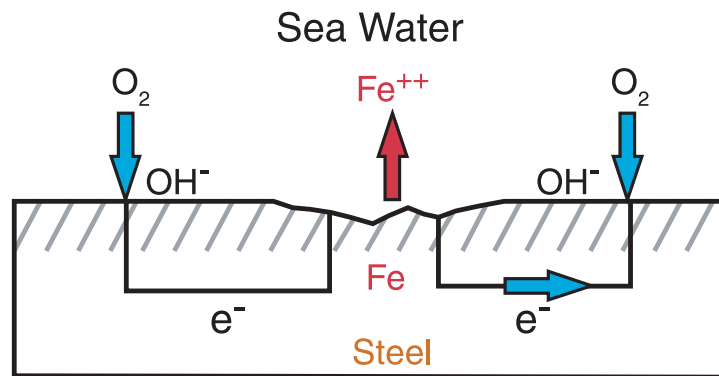


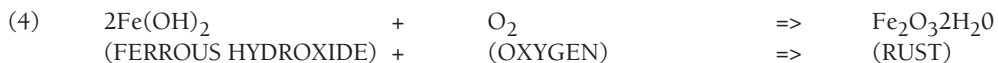
Figure 1-2. The cathode area is larger than the anode area on uncoated steel.

Figure 1-2 shows the progress of corrosion where metal is lost from the anode, causing it to progressively become thinner, accompanied by a flow of electrons from the anode to the cathode which in turn react with both oxygen and water from the environment to form hydroxyl ions.

Both the iron ions and the hydroxyl ions diffuse into the solution and then react together to produce ferrous hydroxide as shown in reaction (3):



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



Reactions (1), (2), (3) and (4) are the basic reactions which occur when iron or steel transforms to rust or, more specifically, to hydrated iron oxides. In practical situations the process is not so simple. For instance, corrosion of steel in seawater or in polluted atmospheres results in more rapid and complicated reactions producing corrosion products in association with iron oxide. Some of these iron salts are water soluble and, if not removed before their application, can cause major problems to coatings.

In given environments certain metals will form protective corrosion layers or products, called oxides, which prevent or retard further corrosion. Aluminum and stainless steel are examples of this.

3 Factors influencing corrosion rates

3.1 Diffusion

In the majority of cases, the corrosion rates of metals are controlled by the diffusion of reactants to and from the metal surface. Freshly exposed bare steel surfaces will corrode at a greater rate than those covered with a compact layer of rust.

The corrosion rate is also heavily controlled by the diffusion of oxygen through the water to the steel surface. In areas where oxygen diffusion is prevalent, corrosion appears to occur at faster rates. High flow areas, such as in the vicinity of bell mouths, will 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 the conditions found in ballast tanks after the ballast water is removed and the conditions in cargo tanks after sea water washing, will corrode faster than areas under immersion. Therefore the ullage space at the top of ballast tanks and at the top of double bottom tanks where air has become trapped, tends to corrode more quickly than deeply submerged areas where there is a lower availability of oxygen, as shown in Figure 1-3.

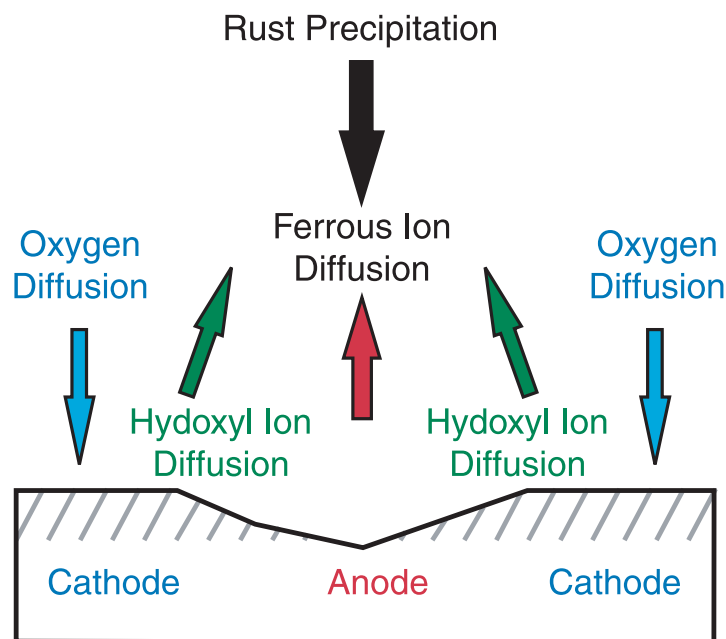


Figure 1-3. Diffusion pathways in the corrosion reaction on uncoated steel.

3.2 Temperature

As corrosion rates are determined by diffusion, diffusion rates are also controlled by temperature. Steel and other metals corrode at faster rates 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, will tend to corrode faster or preferentially.

One of the features of the modern double hulled tanker with fully segregated ballast tanks 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 design. 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 the ballast tanks. Corrosion rates in the cargo tanks themselves will also be higher due to the increased temperature.

3.3 Conductivity

For corrosion to occur there must be a conductive medium between the two parts of the corrosion reaction. Corrosion will not occur in distilled water and the rate of corrosion will increase as the conductivity increases due to the presence of more ions 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 will begin 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

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. 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 will corrode. The potential can be changed by connecting it to another dissimilar metal (as in galvanic corrosion or by using sacrificial anodes) or by applying an external potential, as occurs with an active cathodic protection system of the type employed on the external hull.

4 Types of corrosion

4.1 Uniform corrosion

The most common type of corrosion is uniform in nature. The loss of metal is concentrated at the anode sites and there is a continual change 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

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 mill-scale covered steel which has been left outdoors and has weathered, as shown in Figure 1-4.

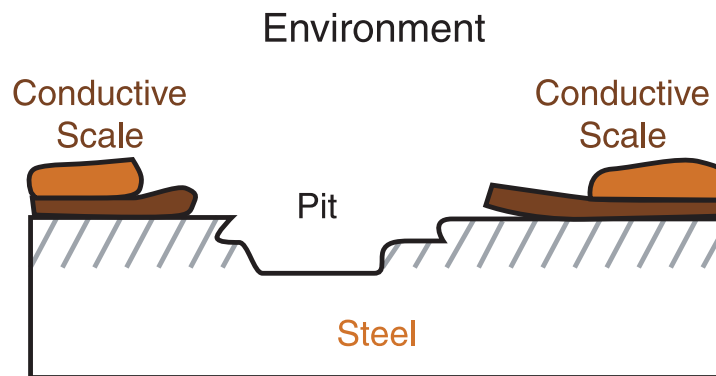


Figure 1-4. Pitting corrosion on uncoated steel, showing layers of iron oxides.

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. In vessels this can occur at isolated areas where the coating has been damaged. The corrosion occurs at the exposed steel area and the coating becomes the cathodic area. A ring of blisters surrounding an active anodic site are common, as shown in Photograph 1-1.



Photograph 1-1. Cathodic blisters surrounding an active anodic site.

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 products are not washed away from the surface, they will continue to cause corrosion and small pits will form. The materials needed for corrosion become trapped in the bottom of the pits and 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 Figure 1-5.

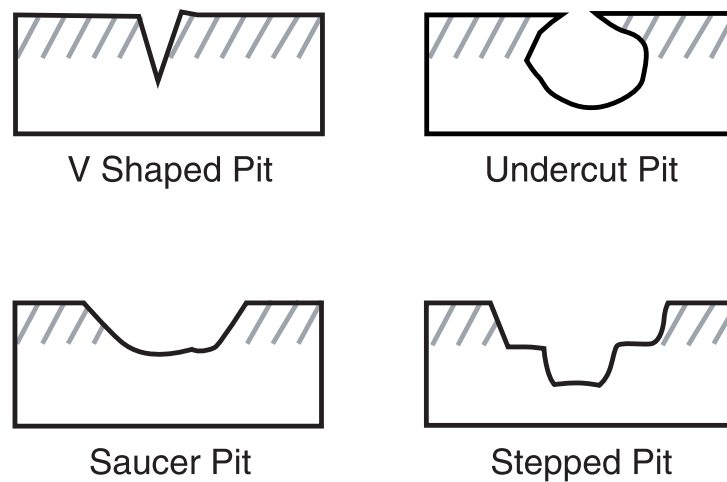


Figure 1-5. Different pit shapes.

V shaped pits are a serious type of pitting, as the rate of penetration through the steel can be very high. Once this type of pit becomes established, it is very difficult to clean the corrosion products from the base of the pit and the corrosion rate can become increasingly rapid.

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.

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.

4.3 Crevice corrosion

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 Figure 1-6.

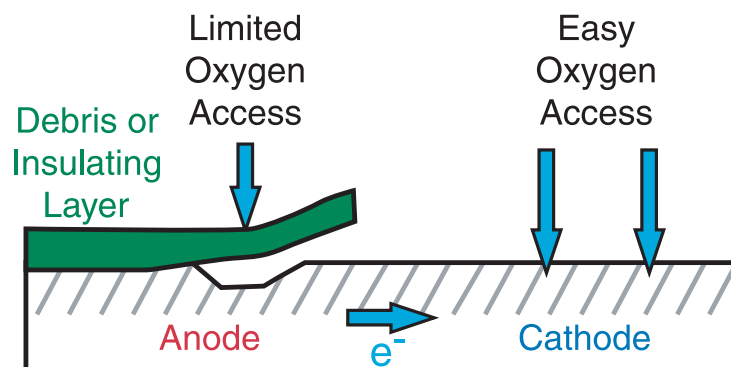


Figure 1-6. Crevice corrosion.

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 will be 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. If they are constructed from different metals, one will tend to corrode preferentially. Where they are made from the same metal, both may develop pits where they are in contact.

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

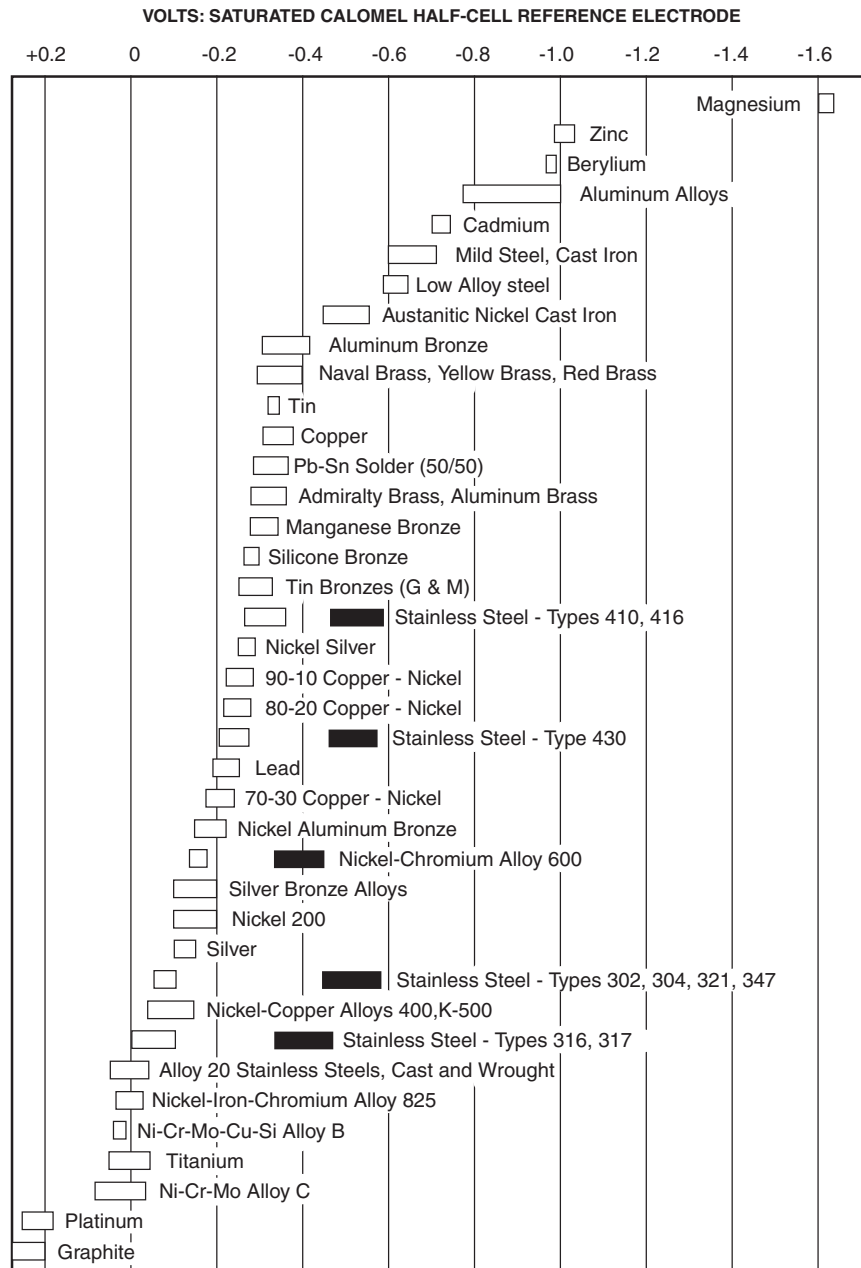


Photograph 1-2. Pits forming as a result of crevice corrosion between the U bolt support and the pipe.

4.4 Galvanic corrosion

In the galvanic series shown in Figure 1-7 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 will be protected against corrosion at the cost of the most negative (base) material.

GALVANIC SERIES CORROSION POTENTIALS IN FLOWING SEAWATER (8 TO 13 FT./SEC) TEMP RANGE 50° - 80°F



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.

Figure 1-7. The Galvanic series of metals with the most noble (least easily corroded) at the bottom.

When two different metals in the series are electrically in contact in an electrolyte e.g. sea water, one of them becomes the anode in the corrosion reaction and the other becomes the cathode. Anodes corrode in preference to cathodes. Cathodes will normally be at the sites of the oxygen reduction reaction.

For instance when steel and copper are connected as in Figure 1-8, steel is the less noble and therefore corrodes rapidly, whereas the copper is unaffected apart from its surface becoming more alkaline.

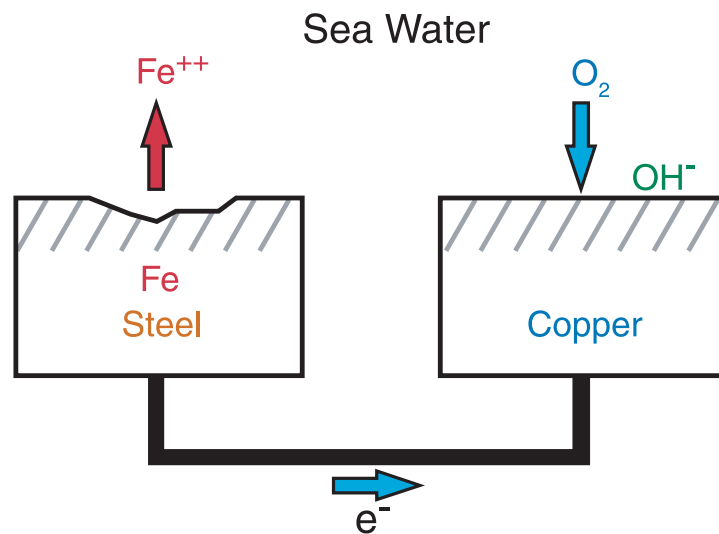


Figure 1-8. Flow of electrons in the iron/copper couple.

In accordance with the traditional concept, an electrical current travels from the copper to the steel (from the positive cathode to the negative anode). The electron flow is in the opposite direction.

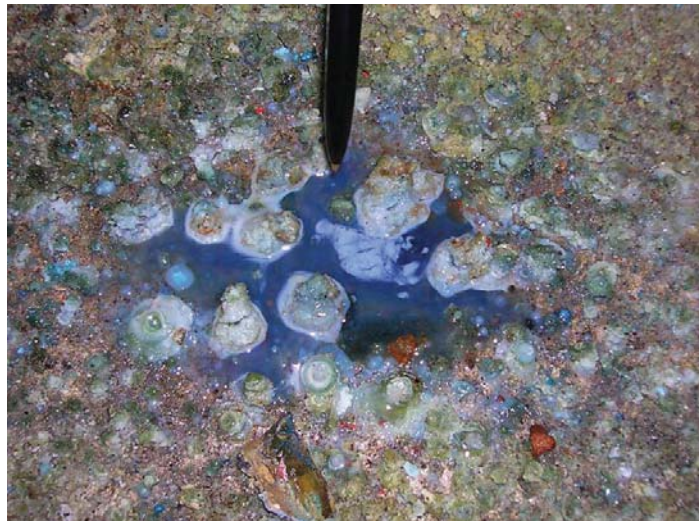
Corrosion of the steel is accelerated through its contact with copper. The steel suffers galvanic corrosion while the copper is protected cathodically.

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

4.5 Deposition corrosion

This type of corrosion occurs when the ions of a more noble metal come into contact with a less noble metal and the more noble metal plates out. This results in a local galvanic couple being formed and the less noble metal will corrode.

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



Photograph 1-3. Copper ions have deposited out on an aluminum structure and caused severe corrosion.

4.6 Impingement corrosion

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) will occur. See Photograph 1-4.



Photograph 1-4. Structures in 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. 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 wide spread. 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 is almost always 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.

CHAPTER 2: Coatings and corrosion

1 General

For the reasons described in the previous chapter, corrosion requires a ready supply of oxygenated, conducting sea water and somewhere for the corrosion products to form. Coatings work first, by excluding water, ions and oxygen from reaching the steel and secondly, by preventing the products of the corrosion reaction from escaping from the reaction site. In the second case, the iron ions saturate the local area and the iron dissolution reaction can no longer proceed. Coatings therefore work as a barrier mechanism. It is the efficiency of the barrier that 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

All coatings 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 Figure 2-1.

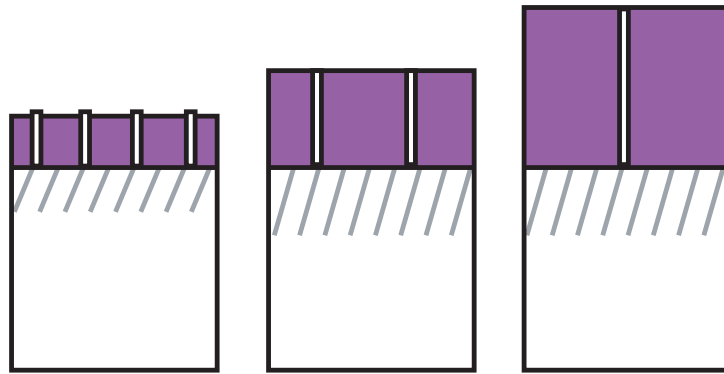


Figure 2-1. Schematic coating porosity in single coatings of different thickness.

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 Figure 2-2. 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.

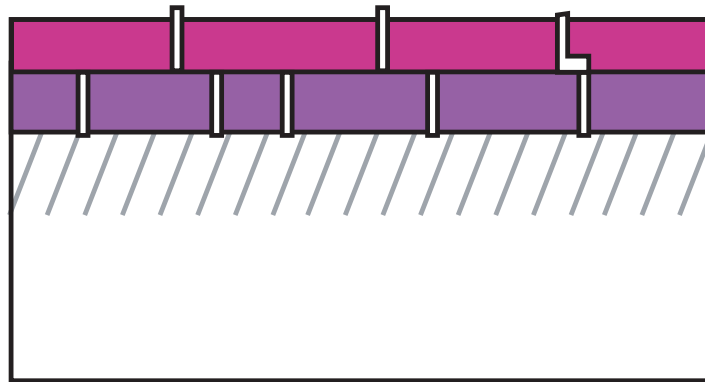


Figure 2-2. Schematic coating porosity in a two layer system.

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 specified dry film thicknesses (DFT) should be achieved. The final DFT is normally defined by the coating specification or regulations such as the IMO Resolution MSC.215(82) Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks in All Types of Ships and Double-Side Skin Spaces of Bulk Carriers, or IMO PSPC.

2.6 Surface contamination

It is almost impossible to produce a perfectly clean surface in a marine industrial environment such as a shipyard or dry dock. Surfaces are contaminated with a mixture of ions, water, oils and greases, blasting dusts, soot and other deposits. When the coating is applied on these contaminants, service lifetime is reduced. Ionic materials cause blistering and other disbonding phenomena whilst the other contaminants result in various degrees of lack of adhesion.

The coating manufacturers state the surface cleanliness standards required for each coating. 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 difference between these two measurement systems. In addition to the coating manufacturer's requirements, other regulations such as the IMO PSPC may determine the minimum surface cleanliness standard.

2.7 Surface profile

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 undercut sections of the surface which will allow the coating to flow into these in the manner of a dovetail. The mechanical key helps to resist rust jacking (and calcareous deposit jacking) together with providing a more circuitous path for the diffusion of water and ions along the interface from defects in the coating.

3 Types of coating breakdown

Coating breakdown is covered here from a physical viewpoint; real life examples are shown and discussed later in chapter 13.

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 Figure 2-3.

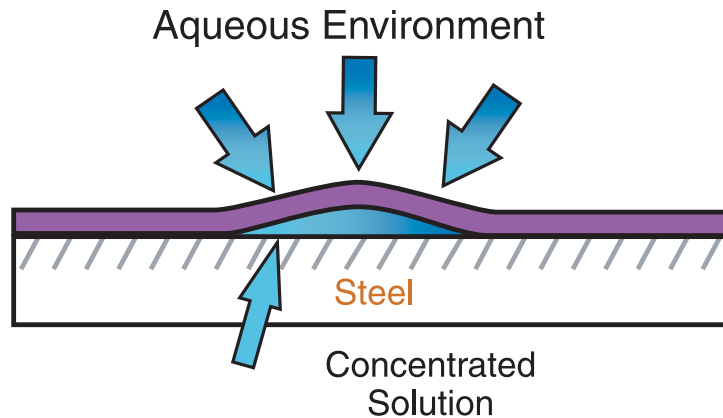


Figure 2-3. Schematic osmotic blister formation.

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 Figure 2-4.

In Figure 2-4 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.

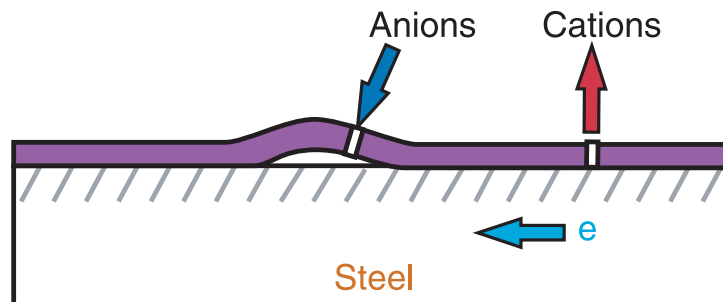


Figure 2-4. Schematic electro osmotic blister formation.

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, a volume increase of between eight and 12 times is involved when iron becomes rust. This volume change occurs beneath the coating and mechanically levers it from the surface in the manner shown in Figure 2-5. Good mechanical strength in the coating and a good mechanical key to the substrate both help to resist this occurrence.

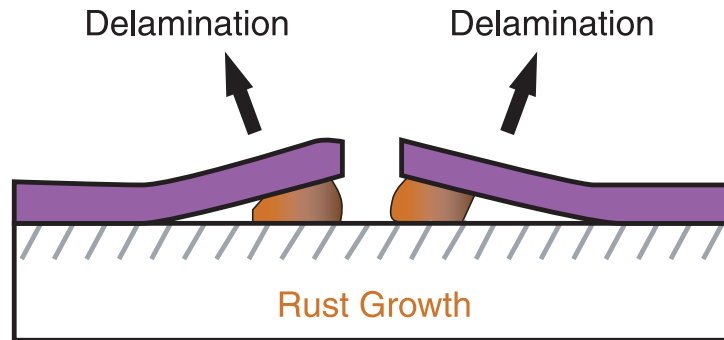


Figure 2-5. Rust jacking.

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 Figure 2-6.

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 which grow, help to protect the 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.

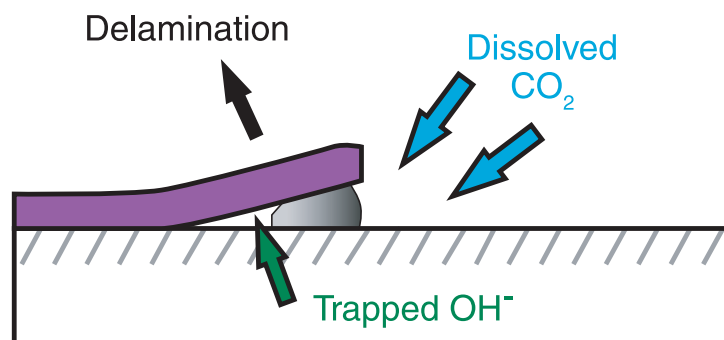


Figure 2-6. Calcareous deposits.

4 Anti-corrosion protection by coatings

In corrosion prevention by paints, three main principles are employed, either alone, or in various combinations:

- 1) Create a barrier that keeps out charged ions and retards the penetration of water and oxygen.
- 2) Ensure 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) Ensure that water on its passage through the paint coating takes 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 . 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 Figure 2-7.

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.

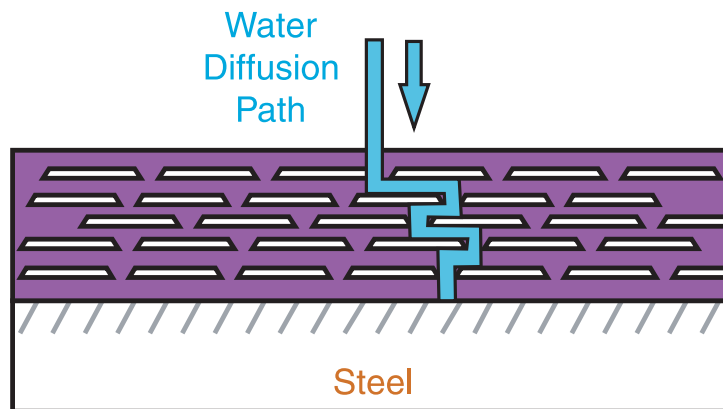


Figure 2-7. Complex pathway produced by lamellar pigments.

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. After a while 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 will occur.

4.4 Surface tolerant coatings

After a vessel enters service, corrosion will begin to occur under coatings in cargo 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 useful in the repair coating process. However, it should be remembered that no paint will perform 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 Figure 2-8.

Washing the surface with fresh water can help to reduce the residual contamination. The use of surface tolerant coatings in this situation can also be beneficial, providing that the levels of contamination are not excessive. Paint manufacturers specify the maximum contamination which can be tolerated by their products on blasted surfaces (i.e. see IACS Rec. 87.3a.2.)

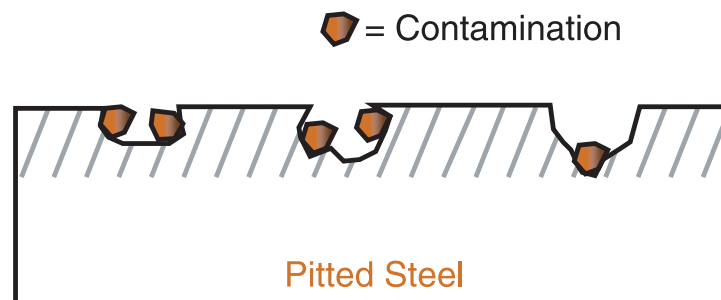


Figure 2-8. Residual contamination in pits.

5 Coating compatibility

The compatibility of coatings with a specific type of paint and between different types of paint 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 will be used, then advice should be sought from the manufacturer of each of the different paints. Coating compatibility is important in new building and its approval is specifically addressed in the Appendices of these Guidance Notes.

Coating compatibility is also important when maintenance and repair work is carried out, to ensure that the repair coat will adhere to the original paint, or failures will occur between the individual layers (inter-coat adhesion failure).

6 Stripe coats

Stripe coats are generally applied during the new building process as the blocks are being coated. 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 Figure 2-9.

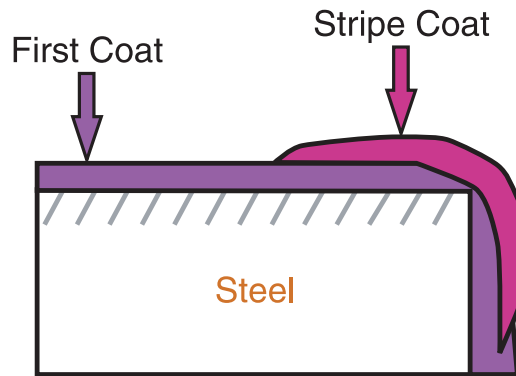


Figure 2-9. Schematic showing the need for stripe coatings.

Figure 2-9 shows the first layer of the scheme coat with the first stripe coat applied. For ballast tanks, a second scheme coat and a second stripe coat will be added, as shown in Figure 2-10. The purpose of the stripe coat is to add an extra thickness (preferably about $30\mu\text{m}$) 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) will prolong the life of the coating scheme.

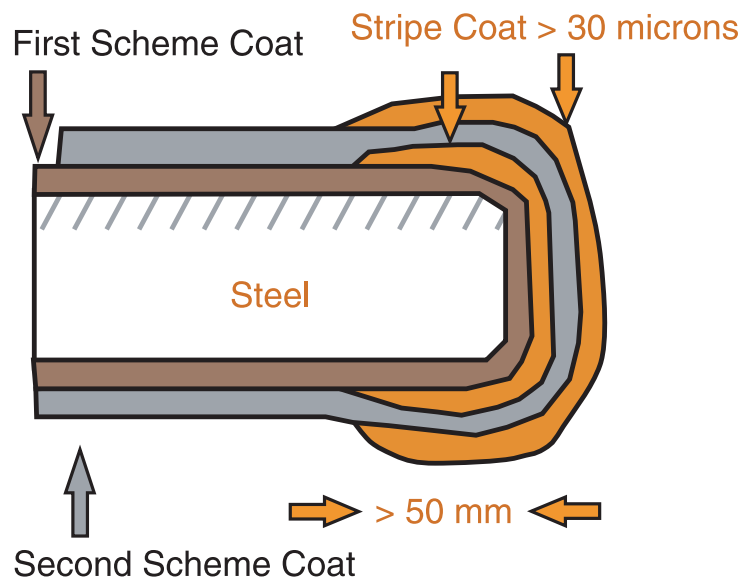


Figure 2-10. Schematic of a full stripe coat scheme.

CHAPTER 3: Coating types and their uses

1 General

This chapter 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 paint 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: 1) products for application at new building and; 2) 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 paint 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.

Repairs carried out by the crew of vessels in service are rarely successful in the long term, due to the difficulties of preparing the surfaces to a sufficiently high standard as shown by the example in Photograph 3-1. It may be noted that guidelines for the maintenance of protective coatings are planned to be developed by IMO.



Photograph 3-1. Localized repair in this coating has failed again at the same site.

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 and therefore the use of a highly effective (and often more expensive) coating is preferred to keep the steel in good condition.

In contrast, the holds of bulk carriers suffer from abrasion damage due to cargo impact and grab damage, which often leads to 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

Paint can be described as a liquid material capable of being applied or spread over a solid surface on which it subsequently dries or hardens to form a continuous, adherent, film.

Paints basically consist of three major components and many additives which are 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 necessary only to aid paint application and the initial film formation, but inevitably, some solvent is always retained in practice depending upon the level of ventilation.

3 Binders

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 permanent continuous film which is responsible for adhesion to the surface and which will contribute to the overall resistance of the coating 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 affected 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 re-dissolved in that solvent.

4 Cross-linked (thermoset) coatings

These paints are usually supplied in two separate packs which are mixed together immediately before application. In liquid paints where solvent is involved, 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 re-dissolve in their original solvent.

4.1 Epoxy resins

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. Below 5°C the curing rate of standard epoxies is considerably reduced and to obtain optimal film properties full cure is essential. Epoxies with special curing agents will cure or set at temperatures down to -5°C. It is essential that the coating manufacturer's recommendations on application temperatures are strictly followed, to ensure that the coatings are effective in service.

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, including cathodic protection utilizing zinc or other anodes, but they have a tendency to chalk in sunlight. This process occurs when the binder is degraded by ultra violet 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 in some instances, they can 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

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 given below 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

These types comprise the silicates which are almost always used in conjunction with zinc dust. 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 under 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 to particle sizes of about 5-10 microns for finishing paints and approximately 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

6.1.1 Zinc

Metallic zinc is widely used in primers giving resistance to corrosion of steel. Initial protection is by galvanic action. However, as the coating is exposed to the atmosphere, a progressive build up of zinc corrosion product occurs, producing an impermeable barrier with little or no galvanic protection. To give good galvanic and barrier protection, high levels of zinc are required, about 85 percent of zinc in the dry film by weight.

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 therefore good surface cleanliness prior to application is essential.

6.1.2 Aluminum pigments

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

6.1.3 Zinc phosphate

This is also a widely used anti-corrosive pigment and it is thought that under normal exposure condition protection is afforded by a barrier effect, since high pigmentation levels are needed to give adequate anti-corrosion protection. Zinc phosphate can be incorporated into almost any binder and, because of its low opacity or transparent nature, paints of any color can be produced.

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

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. Now organic pigments are used instead but the opacity is not as high with these products.

Where the IMO PSPC for ballast or other tanks is applicable and a multi-coat system is required, it is recommended that each coat be of contrasting color. The top coat should 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

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 which is suitable for the various methods of application, such as brush, roller, conventional spray, airless spray, etc. 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 solvents

A liquid which will dissolve the binder and is completely compatible with it.

7.2 Latent solvent

A liquid which is not a true solvent. However, when mixed with a true solvent, the mix has stronger dissolving properties than the true solvent alone.

7.3 Diluent solvent

A liquid which is not a true solvent. 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

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. In recent years there has been debate about the terminology used for epoxy coatings and the following are in common usage:

8.1 Pure epoxy

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. Other 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 level of additional cargo resistance is required, such as on oil-product and chemical carriers. Special care needs to be taken with the surface preparation; curing the coating by heating the tanks may be necessary. Coating manufacturers will advise on the specific requirements for each tank.

8.2 Modified epoxy

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

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 will be sufficiently light in color to be used in compliance with the IMO PSPC 4.4 Table 1 Item 1.2 requirements for the final 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 of ballast tanks due to health and safety issues for the coating applicators and the recommendation for light colored coatings to aid inspections in ballast tanks.

8.4 Solvent-free epoxy

Solvent-free (sometimes referred to as 100 percent solids) paints are, as the name implies, formulated and applied without the need for additional solvents, thereby overcoming the problems of retained solvents in the coating. 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, although 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.

9 Impact and abrasion-resistant coatings

This type of coating is generally applied to the areas of ships which are most susceptible to damage, such as boot-tops and decks, and are sometimes used for the holds of bulk carriers. The regions around suction pipe ends and bell mouths are occasionally coated with abrasion-resistant coatings as these areas can be subjected to damage from the high flow rates of the cargo or ballast water and may suffer from erosion due to the presence of sand or small particles of debris in ballast water.

Coatings which are described as abrasion- or damage-resistant exhibit an increased resistance to cargo damage, but will not be able to withstand the severe impact of grabs and hold cleaning equipment which results in deformation of the steel itself.

10 Shop primers

Shop primers, also referred to as pre-construction primers, are anti-corrosive coatings designed for application in automated plants to plates or profiles prior to assembly, or construction, at the new building of vessels.

Shop primers must:

- Provide protection against corrosion during the construction period
- Be spray applicable in a variety of automatic installations
- Permit a very short time between application and being dry to handle
- Not significantly influence the speed of welding or cutting
- Not produce noxious or toxic fumes during the welding or cutting process
- Not influence the strength of the welds or induce weld porosity
- Be able to withstand comparatively rough handling during vessel construction
- Form a suitable base for the widest possible range of coating systems
- Be capable of remaining on the steel and be over-coated or they may be partially removed prior to coating

Shop primers possess properties not normally found in paints designed for other marine purposes. They are applied at low film thicknesses, (typically 15µm to 20µm) so as to cause minimal interference to the speed of cutting or welding. The most common type of shop primer is zinc silicate.

Inherent in the formulation of shop primers are fast drying and retarded flow properties. A side effect of this is low cohesive strength. Shop primers that are applied with excessive dry film thickness (DFT) have a pronounced tendency to crack and split when over-coated.

To achieve the desired protection and avoid immediate or subsequent cracking, the dry film thickness of the primer must be closely monitored and the manufacturer's specification followed closely. Shop priming usually occurs in automated paint facilities and regular checks on the efficiency of the abrasive cleaning and shop primer application lines should be carried out.

The weathering characteristics of zinc silicate shop primers depend upon the type of binder, the level of zinc in the primer and the local weather conditions. Longer lifetimes are achieved with higher levels of zinc but the zinc salts caused by atmospheric corrosion must be removed from the surface before subsequent coatings are applied. Iron oxide epoxy shop primers are also used successfully in some parts of the world, but generally do not have a long weathering period. The weathering time will depend upon the local climate.

Where a temporary protection to blast cleaned steel is applied by hand spray, as in a maintenance situation, a suitable anticorrosive holding primer with a reasonably long re-coating interval is often applied at relatively low film thickness. Anti-corrosive primers used for this purpose are referred to as holding primers. They are generally epoxy-based materials capable of accepting other generic top coats.

CHAPTER 4: Surface preparation

1 General

Good surface preparation may be considered to be the most important part of the entire coating process in that the greatest percentage of coating failures can be traced directly to poor surface preparation. All paint systems will fail prematurely unless the surface has been properly prepared to receive the coating. If contaminants such as loose rust, oil, grease, dirt, salts, chemicals, dust, etc. are not removed from the surface to be coated, adhesion will be compromised and/or osmotic blistering will occur in addition to premature failure of the coating in service. No paint system will give optimum performance over a poorly prepared surface.

2 Surface cleanliness

The extent to which a surface is made clean before the coating is applied, is a balance between the expected performance of the coating, the paint manufacturer's recommendations, the time available for the job, the relative cost of the various surface preparation methods available, access to the area to be prepared and the condition of the steel prior to surface preparation. In many instances, coatings cannot be applied under ideal conditions, especially under repair and maintenance conditions.

The quality of surface cleanliness which is achieved (or it is possible to achieve) will be very different for an un-corroded high quality steel plate with tightly adherent mill-scale, arriving at a new building shipyard and steel on a vessel which has been in service for ten years, with poorly adherent coating, loose rust scale and heavy pitting.

Any substance which prevents a coating from adhering directly to the steel can be considered a contaminant. Major contaminants at the new building stage include:

- Moisture or water
- Oil and grease
- Salt and other Ionic species from the nearby sea and industrial areas
- White rust (zinc salts from weathered zinc silicate shop primers)
- Weld spatter
- Weld fume
- Cutting fume
- Burn through from welding on the reverse side of the steel
- Dust and dirt from the yard site and from neighbouring industrial processes

In maintenance and repair situations, the presence of pitting, corrosion products, cathodic protection products, aged coatings and trapped cargoes, etc., must also be considered, particularly if only localized surface preparation of the most severely affected areas is being carried out prior to re-coating. This is particularly important for outer hull refurbishment, water ballast tank and cargo tank coating repairs, as shown in Photograph 4-1.



Photograph 4-1. Outer hull showing application of primer after localized spot blasting.

3 Surface cleaning and conditioning

There are many methods available for cleaning and preparing steel surfaces prior to painting. The choice of preparation method will depend upon the areas of the vessel to be prepared and the equipment available. For example in a dry dock, the outer hull may be prepared by abrasive or water blasting before paint is applied.

At new building, water ballast tank blocks may be prepared for coating by thorough abrasive blasting to a pre-agreed standard such as ISO Sa 2.5, or by sweep blasting (a light blast which does not remove all of the intact shop primer) or by power tools.

On board maintenance may involve abrasive or water blasting, power and/or hand tool preparation depending upon the size and location of the area to be prepared and painted. As with edge preparation, a higher standard of surface preparation will result in a longer and more effective coating performance.

One of the major causes of coating blistering is the presence of retained soluble material, such as salt, on metal surfaces before painting. For some types of paint, such as chemical, cargo and ballast tank coatings, the level of soluble salts present is crucial to the long term performance of the coating.

While salts are easily removed from flat surfaces by water washing, it is the salts which become trapped in cracks in the coating, under old paint and rust and in pits in the steel surface that are more difficult to remove and can be problematic. Such residual salts will cause blistering or detachment of the new coating, if not removed. High pressure water washing will remove the majority of these trapped salts, if carried out effectively.

Paint manufacturers specify the maximum level of soluble salts which may be present on the surface before the coating application and these will vary depending upon the paint itself and its service environment.

4 Solvent cleaning

This is a process of using solvents or other cleaning compounds, to remove oil, grease and other similar contaminants, as shown in Photograph 4-2. This process is best utilized as a preliminary step in the total surface preparation procedure, since subsequent cleaning processes, such as abrasive blasting, may simply spread some of the contaminants more thinly over the surface rather than completely removing them.



Photograph 4-2. Oil and grease stain stains during block assembly show as dark stains on the shop primer.

Although widely used, solvents are not necessarily the preferred cleaner recommended by paint companies for large areas of contaminants, as they may become an impediment rather than a help if not properly removed. A proprietary, water soluble, oil and grease remover followed by plentiful fresh water washing would be the preferred method of achieving this standard. Care must be taken that the cleaner does not leave any ionic residues on the surface, particularly if the fresh water washing is limited to the use of buckets of water and cloths.

If solvent cleaning is chosen then safety is very important. Adequate ventilation and minimizing potential fire hazards are paramount. Clean-up rags should be changed often to prevent smearing, and two or three solvent applications may be necessary. Brush application should be avoided, or the oil will simply spread over a larger area, as shown in Photograph 4-3.



Photograph 4-3. Poor removal of oil contamination using solvent and a brush. The dark area at the top of the photograph shows the extent of oil contamination after cleaning.

5 Abrasive blasting

This is the most commonly used method of preparing a surface for the application of paint, as shown in Photograph 4-4. When properly carried out, abrasive blasting removes old paint, rust, salts, fouling, etc., and provides a good mechanical key (blast profile) for the new coating. The surface should be degreased if necessary before abrasive blasting. Weld spatters and deposits should also be removed before blasting. After the abrasive blasting is completed, the surface must be cleaned to remove loose debris and dust before painting commences.



Photograph 4-4. Abrasive blasting.

5.1 Blast profile

It is important that the correct blast profile is achieved before the substrate is coated. Paint manufacturers should specify the blast profile for each coating, in terms of the anchor pattern required for that paint. In general, thicker coatings will require a profile with a greater peak to trough measurement than a thin coating.

If too high, a blast profile is produced. Inadequate coating coverage will result over any high and sharp peaks and this could lead to premature coating breakdown. However, abrasive blasting can also result in an insufficient surface profile and may simply re-distribute contamination over the steel surface trapping contaminants under the surface as shown in Figure 4-1.

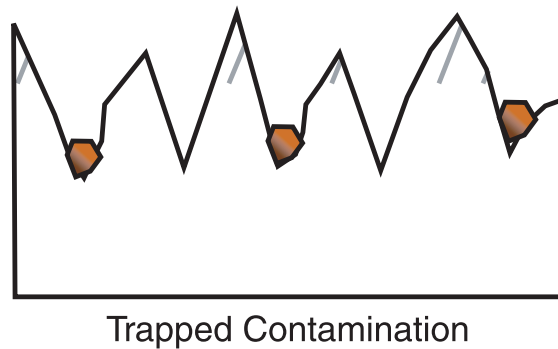


Figure 4-1. Contamination trapped in the blast profile will be over-coated.

If the blast profile is too shallow or the surface is insufficiently blasted to produce a uniform blast profile, the adhesion of the coating to the metal will be reduced and early failure in service can result. There are several methods for assessing the blast profile characteristics, such as test tapes, comparator gauges, rugotest gauges, etc.

If the blasting media is contaminated, the quantity of soluble salts remaining on the steel surface after blasting can be higher than before blasting. The quantity of soluble salts in blasting media can be checked by aqueous extraction techniques.

Soluble contaminants remaining on a surface should be quantified using commercially available tests to ISO 8502-6 and further surface preparation work should be carried out, if necessary, until the specified cleanliness standards are achieved. Coating manufacturers' representatives and relevant shipyard personnel can perform these tests when necessary. An example of soluble contamination measurement is shown in Photograph 4-5.



Photograph 4-5. Salt contamination testing.

5.2 Abrasive blasting media

There are many types of abrasive blasting media available and each has its own characteristics in terms of the shape and peak-to-trough profile produced, recycling properties, etc. Shot produces a shallow and round profile, while abrasive grits result in a rougher and more irregular profile. The choice of blasting media will depend on local availability and the desired results. The blast profile should be specified as part of the tripartite agreement between the shipyard, owner and coating manufacturer. It is not possible to list all the blast media here, but common examples are:

TYPE OF ABRASIVE	MESH SIZE	TYPICAL MAX. HEIGHT OF PROFILE
Iron shot	14	90 μ m (3.6 mils)
“Copper slag” (1.5-2.0mm grain size)	—	75-100 μ m (3-4 mils)
Iron grit (G16)	12	200 μ m (8 mils)

*Table 4-1. Profiles produced by different abrasives.
(IMO PSPC Section 4.4 Table 3.4 Profile Requirements = 30-75 μ m).*

Specialist blast media, such as garnet, are also available. Garnet can be used where disposal of used blast media is difficult (for example during on board maintenance), as it can be recycled several times without loss of blast quality and does not decompose into rust (compared with iron grit) if it becomes damp, thus aiding its removal from the interior spaces of tanks.

The choice of blast media will also depend on the substrate to be cleaned. Galvanized steel and aluminum (for example) should never be blasted with iron or copper based media.

5.3 Abrasive blasting advantages

- Can be used to clean large areas of steel
- Gives a good profile to steel before painting
- Removes rust, old paint, some oils, grease and soluble salts

5.4 Abrasive blasting disadvantages

- Environmentally unfriendly – noisy, dirty and produces large quantities of dust.
- Can leave retained grit in the steel which is not fully over-coated. The grit breaks down early in service giving the appearance of a poor coating performance.

6 Spot blasting

Spot blasting is an abrasive, localized preparation process commonly used on the outside of ships hulls during repair and maintenance work, when patches of localized corrosion have occurred. Care must be taken to avoid the following problems:

- Undercutting and loosening of paint edges around the cleaned spot. According to IMO PSPC Section 4. Table 1-3.3, edges must be feathered as shown in Figure 4-2.
- Stray abrasive particles (ricochet damage) will damage surrounding paint in confined spaces and this must be treated and repaired as necessary.
- Blasting should be discontinued when moving from one spot to the next rather than trailing blast media over the surface. Any damage caused in this way should be repaired.

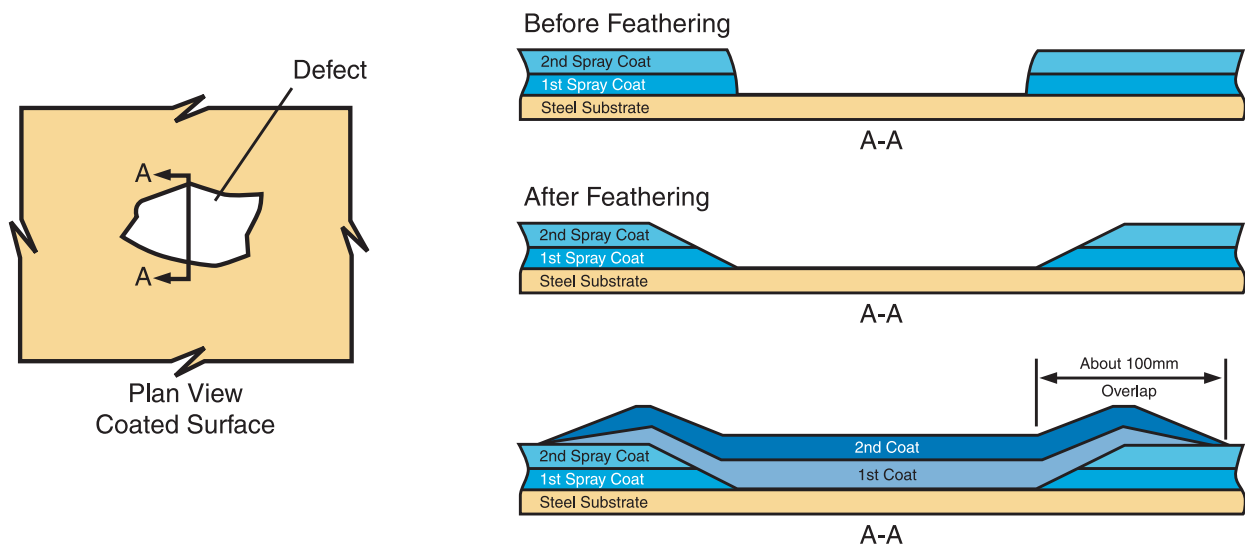


Figure 4-2. Schematic of feathered edges.

7 Sweep blasting

A jet of abrasive is swept across the surface of the steel rather than being focused on one area for any period of time. Its effectiveness depends upon the type and particle size of the abrasive used, the condition of the surface and the skill of the operator. Three major types of sweep blast are in common use:

- Light sweeping is used to remove surface contamination or loose coatings. It is also used for etching of existing coatings to improve adhesion. Fine abrasive (0.2-0.5mm) is commonly used for light sweep blasting.
- Heavy or hard sweeping is used to remove old coating, rust, etc., back to the original shop primer or bare steel.
- Sweeping shop primers at new building is used to partially remove the shop primer to an agreed standard, immediately prior to over-coating according to IMO PSPC Section 4.4 Table 1-2.3, 3.2.

8 Hydro blasting/water jetting

While dry abrasive blasting is the most commonly used method of surface preparation, government and local regulations are continuously changing and require the development of more environmentally-sensitive and user-friendly methods of surface preparation. The use of hydro blasting (also known as hydro jetting, water blasting and water jetting) is becoming an increasing viable means to accomplish this. ASTM F20-16-00 (2006), SSPC-SP12 and NACE No.5 all include information on water jetting.

It should be noted that water blasted surfaces are visually very different from those produced by abrasive cleaning or power tools and surfaces often appear dull or mottled after the initial cleaning is completed.

One drawback of water blasting is the formation of flash rust (also called flash back or gingering) after blasting. Heavy rust formed in a short time period is indicative of residual salt on the steel and re-blasting is necessary before painting. Light rusting is generally acceptable to the paint manufacturers, subject to the coating to be applied and the area in which it will be used.

Water blasting does not produce a profile on the steel surface as compared with abrasive blasting. It does however remove rust and loose paint, as well as soluble salts, dirt and oils, from the steel to expose the original abrasive blast surface profile plus the profile produced by corrosion and mechanical damage. The use of ultra high pressure water blasting can also remove adherent paint from steel.

The terms water washing (usually used to remove salts, slimes and light fouling from vessels in dry dock) and water blasting (used to remove rust and paint) can easily become confused. To clarify the situation, the following pressure guidelines are given:

- Low pressure water washing/cleaning: pressures less than 1,000 psi (68 bar)
- High pressure water washing/cleaning: pressures between 1,000 and 10,000 psi (68-680 bar)
- High pressure water blasting: pressures between 10,000 and 25,000 psi (680-1700 bar)
- Ultra high pressure water blasting: pressures above 25,000 psi (1700 bar). Most machines operate in the 30,000 –36,000 psi (2000-2500 bar) range

Inhibitors can sometimes be added to the water to help prevent flash rusting prior to coating being applied, however they are often ionic in nature and must be completely removed by further washing before the paint is applied. It is also important to ensure that the water being used should be sufficiently pure so that it does not contaminate the surface being cleaned.

The use of slurry blasting, where an abrasive is included in the water stream, is also popular in some locations. This has the advantage of producing a profile on the steel as well as washing away soluble salts.

8.1 Advantages of water blasting

- Removes soluble salts from the steel surface
- Water as a cleaning material is generally inexpensive and available in large quantities. (The Middle East is an exception.)
- Lack of contamination of surrounding areas because there are no abrasive particles
- Lack of dust

8.2 Disadvantages of water blasting

- No surface profile is produced. It relies on the original profile, if present.
- Flash rusting may be a problem in humid environments.
- Visibility during hydro blasting is very poor unless good ventilation is provided, particularly in confined spaces.
- The areas behind angles require particular attention as they are difficult to clean effectively by water blasting.

9 Power tool cleaning

A pictorial series of standards published by the Shipbuilding Research Association of Japan, the “Standard for the Preparation of Steel Surface Prior to Painting 1998” shows welds and burn through damage both before and after different types and grades of cleaning. The effectiveness of cleaning using power tools rather than abrasive or water blasting methods depends on the effort and endurance of the operator as working above shoulder height is especially tiring. Some of the more popular methods are as follows:

9.1 Rotary power disk

This one is the most commonly used surface preparation methods for the majority of on-board maintenance situations. It is also widely used at new building for the preparation of welds and cut edges prior to painting. Normally, silicon carbide disks are used and the grade selected to suit the conditions of the surface to be abraded. It is important to change the discs at regular intervals in order to maintain efficiency.

Care should be exercised in the selection of the grit size and type of disk to be utilized, so that the surface is not excessively smoothed, thereby reducing the ability of the paint to adhere. Irregular and pitted surfaces may require a combination of the various power tool cleaning methods to maximize effectiveness.

Power disk preparation is also widely used in shipyards for edge and weld preparation and is used in some shipyards at new building for the preparation of all block surfaces prior to coating (as blasting is only used for plate preparation prior to shop primer application). A similar alternative is using a belt grinder, as shown in Photograph 4-6.



Photograph 4-6. Edge preparation using a belt grinder.

9.2 Mechanical de-scaling

Needle guns, Roto-Peen and other pounding-type instruments are effective to some degree in removing thick rust and scale and are frequently used by ships crew for maintenance of vessels in service. The action of these types of devices is dependent upon cutting blade or point pounding the surface and breaking away the scale. Cleaning is only effective at the actual points of contact. The intermediate areas are only partially cleaned, because the brittle scale disintegrates, but the lowermost layer of rust and scale remains attached to the substrate.

9.3 Rotary wire brushing

This method has some merits, depending upon the condition of the surface. Loose “powdery” rust can be removed, but hard scale rust will resist the abrasion of the wire bristles. When rust scale is intact and adherent to the substrate, rotary wire brushing tends to merely burnish or polish the surface of the rust scale, but does not remove it. Care should be exercised, in that the burnished surface may give the appearance of a well cleaned surface, which is often misleading. A typical rotary wire brush tool can be seen in Photograph 4-7.



Photograph 4-7. Rotary wire brush.

9.4 Hand tool cleaning

This method is the slowest and usually the least satisfactory method of surface preparation. It is frequently used in confined areas where power tool access is not possible. Scrapers, chipping hammers or chisels can be used to remove loose, non adherent paint, rust or scale but it is a laborious method and very difficult to achieve a good standard of surface preparation. Wire brushing can make the surface worse by polishing rather than cleaning the rusted surface. Soluble salts, dirt and other contaminants are frequently trapped and over-coated, leading to early paint breakdown.

10 Pickling

In new building shipyards, an acid pickling process can be used for the preparation of small items before coating. The items, such as pipes, are alkali cleaned followed by a wash and then an acid pickling bath to remove rust. Thorough washing must take place to remove all the acid, particularly if the item is to be painted, as shown in Photograph 4-8.



Photograph 4-8. Pipes undergoing pickling.

11 Preparation of non-ferrous metals

11.1 Galvanized steel

The surface must be dry, clean and free from oil and grease before painting. Degreasing requires some effort to obtain a clean surface, as the zinc corrosion products can trap grease and other contaminants. Any white zinc corrosion products should be removed by high pressure, fresh water washing or fresh water washing with scrubbing.

Sweep blasting or abrading are suitable preparation methods, but fresh water washing should be used additionally to remove soluble salts. An etch primer can also be used after cleaning to provide a key for further coatings. Paint companies should be consulted on suitable preparation methods, primers and coatings for galvanized steels and will advise on individual cases.

11.2 Aluminum

The surface should be clean, dry and free from oil and grease. Corrosion salts should be removed by light abrasion and water washing. Clean surfaces should be abraded or very lightly blasted using a low pressure and a non-metallic abrasive (e.g. garnet).

Alternatively, a proprietary etch primer should be used to provide a key for subsequent paint coats. Paint companies should be consulted regarding suitable primers and coatings.

12 Edge and weld preparation at new building

Experience has shown that edges and welds are generally the first areas to show corrosion and coating breakdown, particularly in ballast and cargo tanks. This is due to a number of inter-related processes including surface preparation, coating application, deflection, and shear and buckling stresses on the edges and welds and so on. The quality of the surface preparation will play a major role in determining the service lifetime of the coating. Ring stiffeners around openings may reduce this effect.

12.1 Weld preparation

The process of welding generally produces some type of slag on the weld itself, together with spatter (small droplets of the parent or weld material) and fume (smoke), as shown in Photograph 4-9. Submerged Arc Welding (SAW) does not generally produce welding fume as the arc is covered by a slag blanket. Slag may have to be removed manually. Residual slag on a surface can result in early failure of the paint in service.



Photograph 4-9. Weld fume (brown stains) & spatter.

Removal of the weld spatter is essential as this material will cause an irregular surface and will result in poor coverage by the paint. Spatter is adherent in the welding process and must be removed by chipping or other mechanical means.

Weld fume must also be removed as it is loosely adherent to the steel and depending upon the type of weld consumable used, the fume may contain water soluble species. If weld fume is over-coated, the paint may blister and/or peel from the steel in service. Blisters can also form where the shop primer is damaged due to the welding of stiffeners on the other side of the plate. This is often referred to as “burn through” and Photograph 4-10 is typical of the results in service when the burn through is not adequately cleaned or removed prior to coating application.



Photograph 4-10. Blistering where a stiffener was welded on the other side of the plate.

The position of welds can present difficulties for the cleaning and surface preparation process, particularly when the weld forms part of a complex structure such as the bulbous bow on a forepeak ballast tank, as shown in Photograph 4-11.



Photograph 4-11. Complex structure, with lower welds only accessible through the hole.

In many cases, only an abrasive or water blasting process will provide an efficient cleaning of the weld, however this may not be practical in some new building shipyards or for on board maintenance of vessels in service. Welds must be prepared efficiently so that the possibility of creating voids under the coating is eliminated. Porosity can also occur in welds and this may not become visible until the weld has been blasted clean at the new building stage, as shown in Figure 4-3.

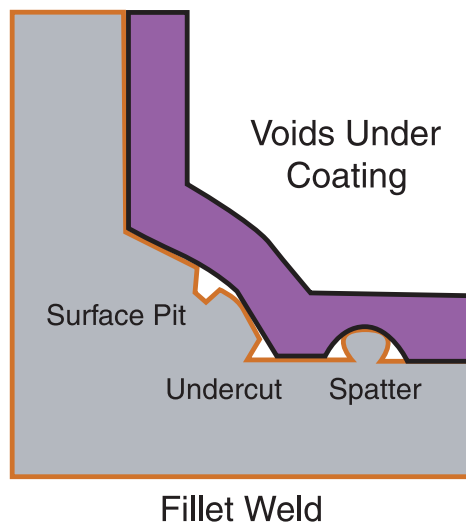


Figure 4-3. Schematic fillet weld showing typical defects that form voids under the coating.

12.2 Edge preparation

After application as the coating is still liquid, there is a tendency for many coatings to pull back from sharp edges leaving a very thin layer of paint which can quickly breakdown in service. Grinding profiles into the edges of cut outs, drainage holes, etc., as shown in Figure 4-4, greatly improves the adhesion and coverage of the coating around the edge. Rounded edge preparation will generally provide the most effective service performance from the coating. Three passes of the grinding disc over the cut edge will give the next best preparation, then two passes. Even one pass of the grinding tool will give a better surface for painting than no preparation. The addition of a stripe coating to the edges is also beneficial in providing long term protection.

Current IMO PSPC requirements for ballast tanks at new building include three passes of the grinding tool on edges. Void tanks will be treated to one pass on the edges at new building.

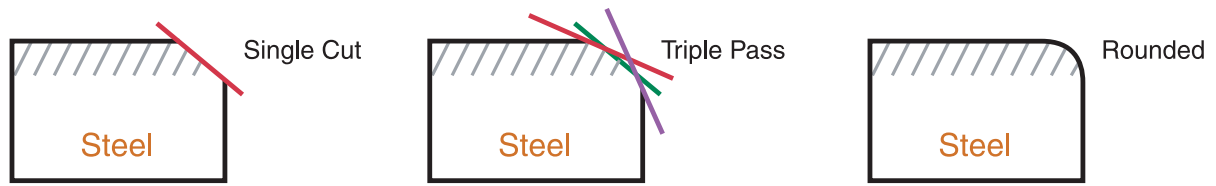


Figure 4-4. Types of edge profile.

Good surface preparation around cut edges is also very important. Cutting fume is an additional source of contamination at edges and this must be removed for good coating adhesion. Ring stiffening around manholes may prove beneficial for the longevity of the coating around the opening.

13 Surface preparation standards

Table 4-2 provides a summary of surface preparation standards and a cross-reference of those standards by various worldwide agencies. There are differences which can be important in some instances and care is advised when a cross-over is required. While these standards are limited to steel substrates, many of the techniques, with their inherent advantages and disadvantages, hold true for other substrates, although advice should be sought directly from the individual coatings manufacturers when over-coating other metals such as galvanized parts or stainless steels.

13.1 Summary of visual preparation standards

CLEANING METHOD	DESCRIPTION (SUMMARY)	SWEDISH/ISO	SSPC	JSRA	NACE
Abrasive blast	White metal/visually clean	Sa 3	SP 5		1
				Sh/Sd 3	
	Near white metal/very thorough clean	Sa 2.5	SP 10		2
				Sh/Sd 2	
	Commercial/thorough clean	Sa 2	SP 6		3
				Sh/Sd 1	
	Brush/light blast	Sa 1	SP 7		4
Water blast			SP 12		5
	Sa 2.5 equivalent	**	VIS-4		VIS-7
	Sa 2 equivalent	**			
Power tool	Very thorough cleaning	St 3	SP 3	Pt 3	
	Thorough cleaning	St 2	SP 2	Pt 2	
Hand tool	Very thorough cleaning	St 3	SP 3		
	Thorough cleaning	St 2	SP 2		

Table 4-2. Comparison of visual preparation standards.

- ** = An ISO standard is in preparation, based on the International Paint Ltd. standards
- ISO = ISO 8504:1992(E) and 8501-1:1998(E) and 8501-2:1994
- Swedish = SIS 05 59 00 (1967)
- SSPC = Steel Structures Painting Council (now the Society for Protective Coatings)
- JSRA = Japan Shipbuilding Research Association – Standard 1984
- Sh = shot blasting
- Sd = sand blasting
- NACE = National Association of Corrosion Engineers

13.2 Standards for abrasive blast cleaning

It should be noted that the majority of the standards such as ISO or JSRA for steel preparation, are based on a visual assessment of the surface condition only. Note that it is possible for steel to appear visually clean while a sufficiently high level of soluble salt contamination remains on the surface, to cause blistering of the paint when the vessel is in service.

The following standards are used for judging the surface cleanliness of steel and are based on visual observations only. They are all assessed relative to the original condition of the substrate prior to cleaning. Steel is usually categorized into four grades: A, B, C and D grade, where A grade is in the least corroded condition. D grade steel can be very difficult to clean satisfactorily.

The visual standards are not indicative of the extent of cleanliness of a substrate with regard to ionic contamination, nor are they an indication of the surface profile. Both of these should be checked separately to ensure they match the specified requirements:

ISO Sa 3 Blast cleaning to visually clean steel

When viewed without magnification, the surface shall be free from visible oil, grease and dirt and shall be free from mill-scale, rust, paint coatings and foreign matter. It shall have a uniform metallic color.

ISO Sa 2.5 Very thorough blast cleaning

When viewed without magnification, the surface shall be free from visible oil, grease and dirt and shall be free from mill-scale, rust, paint coatings and foreign matter. Any remaining traces of contamination shall show only as slight stains in the form of spots or stripes.

ISO Sa 2 Thorough blast cleaning

When viewed without magnification, the surface shall be free from visible oil, grease and dirt and from most of the mill-scale, rust, paint coatings and foreign matter. Any residual contamination shall be firmly adhering.

ISO Sa 1 Light blast cleaning

When viewed without magnification, the surface shall be free from visible oil, grease and dirt and from poorly adhering mill-scale, rust, paint coatings and foreign matter.

13.3 Water blasting/water jetting standards

The major paint companies have worked for many years with the water blasting technique to produce standards for use with their products. A typical example is the hydro blasting standard from International Paint Ltd. shown in Figures 4-5 and 4-6.

Paint can be applied successfully over light flash rusting, as the levels of ionic surface contaminants are usually low. If the rust layer becomes thick or powdery then paint cannot be applied as the coating will detach in service. Loose rust must be removed before coating application. The paint manufacturer's representative can advise on the acceptable degree of flash rusting.

Rust Grade Standards



Rust Grade C



Rust Grade D

Preparation Standard C HB 2



Rust Grade C



*C HB 2 Rust Grade C
Hydroblasted to an Sa 2
equivalent*

Degree of Flash Rusting



*C HB 2 L Light Flash
Rusting*



*C HB 2 M Moderate
Flash Rusting*



*C HB 2 H Heavy Flash
Rusting*

Preparation Standard C HB 2.5



Rust Grade C



*C HB 2.5 Rust Grade C
Hydroblasted to an
Sa 2.5 equivalent*

Degree of Flash Rusting



*C HB 2.5 L Light Flash
Rusting*



*C HB 2.5 M Medium
Flash Rusting*



*C HB 2.5 M Heavy Flash
Rusting*

Figure 4-5. International Paint hydro blasting standard for C grade steel, showing the original condition and degrees of flash rusting. ©International Paint Ltd.

Preparation Standard D HB 2

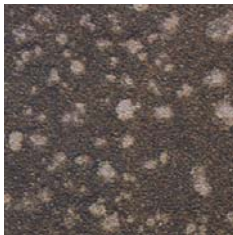


Rust Grade D

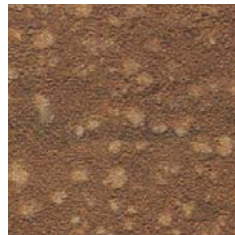


*D HB 2 Rust Grade D
Hydroblasted to an
Sa 2 equivalent*

Degree of Flash Rusting



*D HB 2 L Light Flash
Rusting*



*D HB 2 M Medium Flash
Rusting*



*D HB 2 H Heavy Flash
Rusting*

Preparation Standard D HB 2.5



Rust Grade D



*D HB 2.5 Rust Grade D
Hydroblasted to an
Sa 2.5 equivalent*

Degree of Flash Rusting



*D HB 2.5 L Light Flash
Rusting*



*D HB 2.5 M Medium
Flash Rusting*



*D HB 2.5 H Heavy Flash
Rusting*

Figure 4-6. International Paint hydro blasting standard for D grade steel, showing the original condition and degrees of flash rusting. ©International Paint Ltd.

CHAPTER 5: Paint application

1 General

The objective in applying coatings is to provide a film which will give protection and/or decoration to the structure being painted. The variables which govern the success of any application and subsequent performance are:

- Surface preparation
- Film thickness of the paint system
- Methods of application
- Conditions during application

2 Surface preparation

As detailed in the previous chapter, it is essential that a good standard of surface preparation is achieved, if the coating is to perform successfully in service.

3 Film thickness measurement

An adequate film thickness is necessary for a coating system to perform to expectations and provide good anti-corrosion protection or achieve the expected anti-fouling lifetime, etc. Under thickness will result in premature failure. However, over application can also cause problems, such as solvent entrapment and subsequent loss of adhesion, cracking of the paint (including mud-cracking) or splitting of primer coats. Ideally the coating thickness should be that specified, allowing for practical application variations.

The wet film thickness (WFT) of the coating is measured and can be converted to a dry film thickness (DFT) following the paint manufacturer's guidelines for that product. The wet film thickness measurement can serve as an aid in determining how much coating should be applied to reach the specified DFT. The dry film/wet film ratio is based on percentage of solids by volume of the coating being used. Coating manufacturer's data sheets sometimes list solids by weight as well as solids by volume. The basic formula using solids by volume is:

$$\text{WFT} = \frac{\text{DFT}}{\% \text{ solids by Volume}}$$

The actual DFT specified will depend upon the type of paint being applied and the nature of the substrate surface. To determine whether a coating thickness is acceptable, there are guidelines produced by the coatings manufacturers, such as the 80-20 and 90-10 rules. For example, the 90-10 rule means: no measurement may be below 90 percent of the DFT specified without repair being undertaken and not more than 10 percent of the measurements may be in the range 90-100 percent of the DFT specified without repair being undertaken. The figures will depend upon the type of coating being applied and the area of the vessel being coated.

Measurements of the dry film thickness are influenced by the profile of the substrate, particularly when abrasive blasting has been used. Thin films (of less than 25µm) cannot be measured accurately over blasted surfaces using commercially available paint thickness gauges. Measurements of DFT at edges and corners are not accurate due to the measurement techniques used by these gauges. Paint companies can advise on suitable methods for these circumstances.

4 Methods of paint application

The normal methods of application of paint coatings are by:

- Brush
- Roller
- Conventional air spray
- Airless spray

4.1 Brush application

Brush application is a relatively slow method and is generally used for the coating of small complicated or complex areas or where the need for 'clean' working with no overspray precludes the use of spray application. Brushes are also used for applying surface tolerant primers, where good penetration of rusty steel surfaces can be achieved with operator persistence. Brushes are a commonly used method for "touch up" of coatings during service. Photograph 5-1 shows touch up work to a stringer in a ballast tank. During new building and maintenance and repair, the use of brushes for the application of stripe coats to welds and cut edges is common.



Photograph 5-1. Brush applied touch up paint on a forepeak stringer.

It is important not to 'over-brush' the surface, as this will result in large variations in film thickness, which is the inherent problem with brush application. Care must also be taken when applying thermoplastic coatings over one another as the solvents in the wet top coat can dissolve the lower coating. Even and light brush strokes are required to avoid pick up of the previous coat, otherwise a very rough finish will result.

The choice of brush, brush size, length and type of bristle and brush shape, are important and the type of paint being applied will also influence the selection of the brush. Special brushes are available with offset heads and long handles to facilitate painting the 'backs' of structures and inaccessible areas.

It is generally not possible to achieve the required film thickness in the same number of coats as with spray paint application and multi-coat applications are necessary to give the specified film build. During new building brush application is mainly used for stripe coating, as shown in Photograph 5-2.



Photograph 5-2. Stripe coating on welded details.

4.2 Roller application

Application by roller is faster than with a brush on large, flat surfaces, such as walkways and deck areas, but it is not so good for complex shapes. It is hard to control film thickness and high film build is generally attained by applying multiple coats. The correct choice of roller pile is dependent on the type of coating and the roughness and irregularity of the surface being coated and is essential for a good finish. Rollers can be used for applying stripe coats under certain circumstances to areas such as rat holes and cut outs.

4.3 Conventional spray

This is a method commonly used for applying zinc silicates to large surfaces. The equipment is relatively simple and inexpensive and is usually confined to fairly low-viscosity paints. Paint under pressure and air are fed separately to the spray gun and mixed at the nozzle. The paint is atomized and air is mixed with these droplets forming a fine mist of paint which is carried by the air pressure to the work surface. It is essential to use the correct combination of air volume, air pressure and fluid flow to provide good atomization and a paint film which is free from defects. Poor control gives rise to overspray and rebound from the work surface defects in the paint.

4.4 Airless spray

This is by far the most important and efficient method for the application of heavy-duty marine coatings, which allows the rapid application of large volumes of paint as well as the application of high build coatings without thinning. Compared to conventional spray methods, overspray and bounce back are reduced. Photograph 5-3 shows the application of paint onto the topsides of a vessel in dry dock.



Photograph 5-3. Airless spray application of paint onto the vessel's topsides.

As the name implies, airless spray is a technique of spray application which does not rely on the mixing of paint with air to provide atomization. Instead, atomization is achieved by forcing the paint through a specially designed and precisely constructed nozzle or 'tip' by hydraulic pressure. The choice of tip determines the film thickness applied per pass of the spray gun and should be selected in accordance with the coating manufacturer's guidelines. The speed of each pass and the volume solids of the paint are also influential in determining film thickness.

Airless spray equipment normally operates at fluid line pressures up to 5,000 psi (352Kg/cm²) and care should be taken to follow the equipment manufacturer's operating instructions and safety guidelines.

Handheld spray guns are used in areas where there is direct access to the surface, for example in tanks; pole guns, such as the one in the photograph, are used for large surface areas.

4.5 Plural component airless spray

To spray solvent free coatings, it is often necessary to heat the components to reduce their viscosity to an acceptable level for spraying. As these paints can cure very rapidly once mixed, the components are often heated separately and fed to a mixing head which is a short distance from the spray tip. Some solvent free coatings do not require pre-heating but rely on a higher pressure system to apply the paint.

5 Curing conditions

There are a number of factors which must be considered when marine coatings are applied. The major ones include:

- Condition of the substrate
- Temperature
- Relative humidity
- Weather conditions
- Condensation
- Ventilation
- Ultraviolet light (UV)

5.1 Condition of the substrate

The surface must be clean and free from dirt, dust, abrasive blast medium (if used), oil, grease and soluble salt contamination.

5.2 Temperature

The temperature of both the air and the substrate must be considered. Direct sunlight on steel can increase the surface temperature significantly in excess of the air temperature. Paint application must not occur when the temperatures are either higher or lower than those specified on the coating manufacturer's data sheets. In general, coatings are not applied at ambient temperatures below 5°C.

Below 5°C, curing of coatings such as epoxies slows dramatically and can stop altogether for certain paints. Some epoxy coatings are available in both winter and summer temperature versions to allow for seasonal temperature variations and it is important that the change-over to the winter grade occurs ahead of seasonal temperature drops. Chlorinated rubber and vinyl may be applied below 0°C (32°F) provided that there is no frost on the surface. However these coatings are being phased out due to volatile organic compounds (VOC) legislation.

Above 40°C, rapid loss of solvent can cause sprayed paint to dry before it reaches the substrate. This is known as dry spray. As the paint does not flow to form a coalesced film, this significantly reduces the performance of the coating. Paint manufacturers guidelines should be carefully followed if paint is to be applied at temperatures above 40°C.

5.3 Relative humidity

Most paints will tolerate high humidity but condensation must not form on the surface being painted. Paint application should not take place when the steel temperature is less than 3°C (6°F) above the dew point.

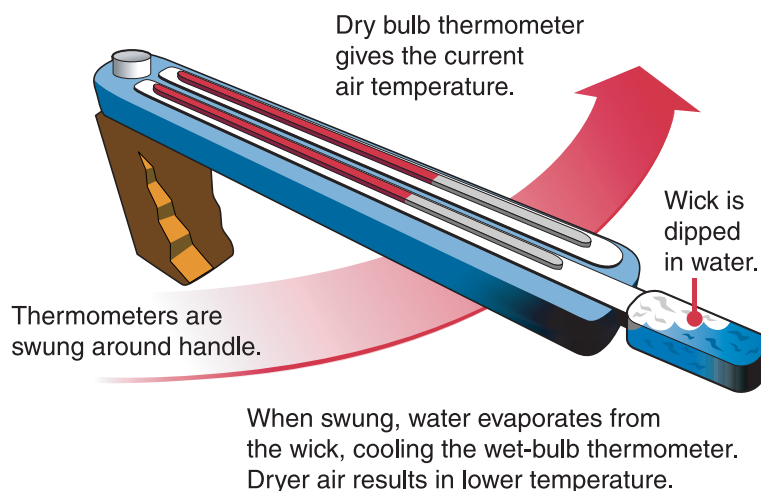


Figure 5-1. Schematic diagram of a humidity gauge.

5.4 Weather conditions

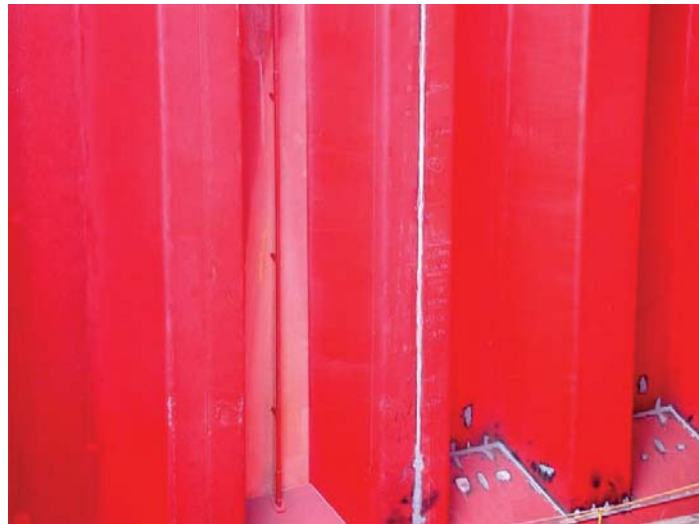
Paint should not be applied during fog or mist or when rain or snow are either falling or imminent. Generally under these conditions, it is difficult to maintain the steel temperature above the dew point.

When paint is being applied outdoors, particular care should be taken under windy conditions. An even paint coverage of the intended surface may be difficult. Solvents may be extracted by the wind, affecting the coating cure, and paint often falls on neighboring structures (overspray).

5.5 Condensation

Temperatures fall during the night and then rise again during the day. The lag in air movement can allow condensation to form if the steel temperature is below the dew point of the atmosphere.

Some coatings, such as epoxies, are particularly sensitive to water during curing. If the outer surface is exposed to moisture before the paint has cured sufficiently, components in the coating react with the water to produce a condition known as amine bloom or amine sweating. This layer prevents successful adhesion of the next paint layer and it peels off. An example of this is shown in Photograph 5-4.



Photograph 5-4. The vertical pink areas have been affected by amine bloom. When the block was left outside for the coating to cure, water collected on the exposed areas and adversely affected the paint.

5.6 Ventilation

When coatings are applied in the open air, adequate ventilation is usually available. However care should be taken in high winds so that the dry spray does not result from rapid solvent loss or formation of a skin over the surface which results in retained solvent within the paint film. Within confined spaces, it is important that good ventilation is provided so that the coatings dry properly and do not retain solvent which will seriously impair the coating performance in-service.

5.7 Ultraviolet light (UV)

In some locations, high levels of UV light are present. Certain coatings (such as epoxies) are sensitive to UV light, which breaks bonds in the surface layers of the coating. Under service conditions, this effect is known as chalking. During new building, the action of UV light on epoxy coatings can cause problems when applying additional coats of paint or when painting around erection seams, etc. Care must be taken so that the surfaces are suitably prepared to remove any affected paint before application of the subsequent layer.

CHAPTER 6: Cathodic protection in ballast tanks and cargo holds

1 General

Cathodic protection (CP) has been employed in metal ships since Sir Humphrey Davy first used the method to protect several British Naval vessels in 1824.

As explained earlier, the dissolution of steel is an anodic process which takes place when metallic iron loses two electrons and becomes an iron ion in solution. If the potential of a corroding object is lowered (i.e. it is made more electronegative) to the reversible potential of the anodic reaction, then the metal dissolution will stop, since the rate of dissolution will exactly balance the rate of re-deposition.

When measured against a reference electrode such as a Saturated Calomel Electrode (SCE), the reversible potential of corroding steel referred to above, is in the order of -860mV (SCE). The measured potential for mild steel in sea water (which is a combination of the potential of the anodic and cathodic reactions taking place) is in the order of -640mV (SCE) measured with the same reference electrode.

To protect steel successfully using cathodic protection, it is therefore only necessary to lower its potential by around a quarter of one volt (250mV).

2 Sacrificial anodes

Cathodic protection using sacrificial anodes, as shown in Figure 6-1, produces a decrease in the potential of the ship by connecting the vessel to a metal which takes up a reversible potential of less than -850mV (SCE) and allowing the sacrificial metal to produce the electrons rather than the corrosion reaction of the steel.

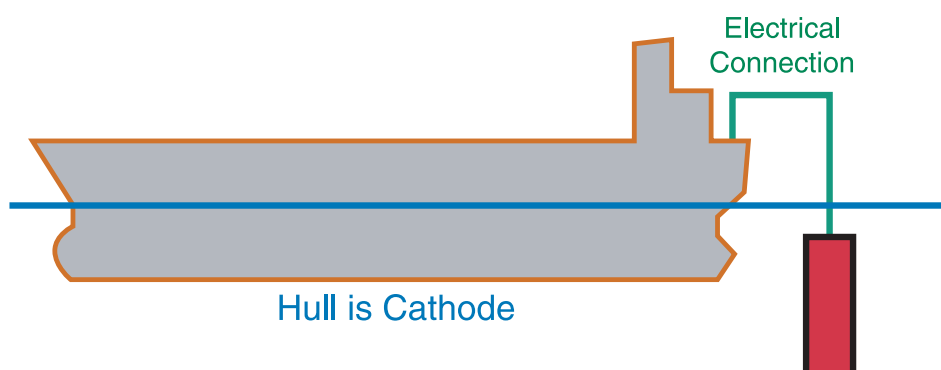


Figure 6-1. Sacrificial Cathodic Protection schematic.

Common choices for the sacrificial anodes are zinc, aluminum and their alloys. Both zinc and aluminum produce potentials of less than -1000mV (SCE). Aluminum has to be alloyed with other metals such as tin in order to make it corrode freely in service.

Magnesium anodes cannot be used in ballast tanks because they generate hydrogen in use and can have deleterious effects on some ballast tank coatings. Aluminum anodes have limited use in tankers as they can produce a spark hazard if they fall or are dropped from significant heights.

The protection current available from the zinc and aluminum anodes are similar. Zinc requires 11.3Kg (25 pounds) of material to produce one Ampere-year of current, while 8.2Kg (18 pounds) of aluminum is necessary.

In addition to protection via an electrochemical potential change, sacrificial anodes also protect by forcing the cathodic reaction to occur on the steel. The cathodic reaction reduces oxygen and water to generate alkaline hydroxyl ions as described previously. The production of calcareous deposits initially enhances the protection effect. Sacrificial systems in ballast/cargo holds and ballast tanks are not capable of working during the period when the tanks are empty. This may constitute 60 percent of the vessel usage pattern.

Unfortunately, steel corrodes most rapidly when it is damp with a conducting film over the surface rather than fully immersed and the sacrificial anode system cannot act directly at this time. The CP system does have an indirect effect during this period before the tank dries, as the retained hydroxyl ions work to keep the steel surface passive and the calcareous deposits act as a barrier to oxygen.

In very general terms, a steel surface which is coated with a good quality system of paint will drain in the order of about 5mA/m^2 from a cathodic protection system and an exposed steel surface may require 110mA/m^2 for protection. Consequently, the current requirement for a tank will increase with time as the extent of coating breakdown (and thus exposed metal area) increases.

The efficiency of a cathodic protection system can be assessed by examination of both the condition of the sacrificial anodes and the nature of the calcareous deposit produced. Photograph 6-1 shows an anode functioning normally. The surface is covered with a compact layer of coherent white deposit.



Photograph 6-1. Normally working anode.

Photograph 6-2 displays an overworked zinc anode. The deposit is very loose and is easily removed from the surface of the anode.



Photograph 6-2. Overworked zinc anode.

Photograph 6-3 shows an overworked aluminum anode. The gelatinous deposits dripping from the anode are indicative of high current drain.



Photograph 6-3. Overworked aluminum anode.

Photograph 6-4 shows a ballast tank where the coating barrier properties are failing and calcareous deposits are forming throughout the tank. These deposits form as a result of hydroxyl ions being generated at the cathodic site. The hydroxides then react with both carbon dioxide from the air (which is dissolved in the water) and carbonates and bicarbonates present in the sea water, to form the complex deposit known as a calcareous film.



Photograph 6-4. Heavy calcareous deposits.

The location of sacrificial anodes is also important as they must be placed clear of any overhanging stiffeners whenever possible, to aid the ionic flow around the anodes and prevent incorrect current flow. Wrongly positioned anodes can result in severe blistering of the coating of structures in their immediate vicinity, such as stiffeners, ballast, other pipes and brackets, and can prevent the current from being thrown to areas where it is required for protection. Figure 6-5 is an example of this effect.



Photograph 6-5. Poorly sited anode, the anode is enclosed and can only protect a small area.

3 Impressed current cathodic protection

On exterior hulls, it is also possible to use an Impressed Current Cathodic Protection (ICCP) system in the same way that coupling mild steel to zinc results in a flow of electrons to the mild steel to prevent metal loss, as shown in Figure 6-2. In the ICCP system, an auxiliary anode made from a non-consumable material, such as platinized titanium or mixed metal oxides, replaces the zinc or aluminum anode of the sacrificial system.

A reference electrode is also required to monitor the polarization voltage produced on the hull by the current flowing from the anode. It allows feedback control in the voltage rectifier that is used to produce the current, as shown in Figure 6-2 and Photograph 6-6.

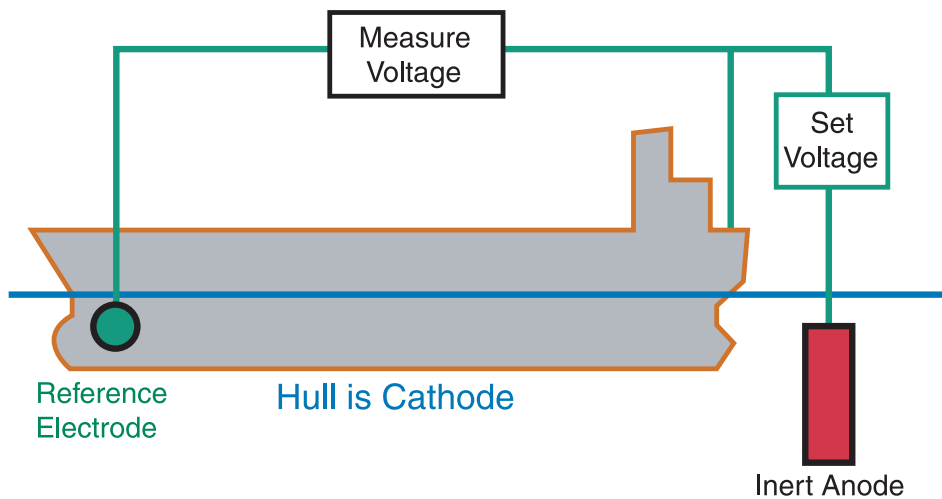


Figure 6-2. Schematic diagram of an impressed current system.



Photograph 6-6. An example of a zinc reference electrode on a ship.

Areas immediately around the impressed current anodes can suffer from blistering and a thick layer of anode shield material is applied to prevent the loss of the paint, as shown in Photograph 6-7. The electrodes in such an impressed current system are capable of drawing very high currents locally and thus producing copious quantities of oxygen, hydrogen and chlorine if the system malfunctions. This is totally unacceptable in holds and tanks and consequently impressed current systems are not used in these areas.

It is very important that the active anodes and reference electrodes are not painted over during re-coating work, as this will prevent the ICCP system from operating and could cause the paint to disband from the steel.



Photograph 6-7. An example of an ICCP anode on a ship.

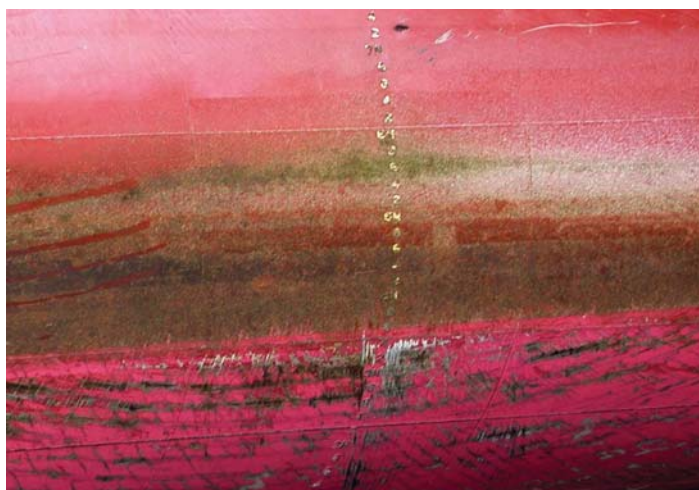
CHAPTER 7: Anti-fouling

1 General

Ships' underwater hulls are painted to protect the building material and prevent undue roughness. The effect of roughness on the hull area is an increase in resistance to movement, resulting in reduced speed and/or increased fuel consumption and consequently a higher operating cost.

2 Fouling

The most significant cause of hull roughness is fouling. Micro-fouling organisms are the first to settle. They form the primary bio-film or slime layer (micro-fouling). The most significant micro-fouling organisms are bacteria (animal) and unicellular algae.



Photograph 7-1. Light plant fouling.

Macro-organisms such as the green algae enteromorpha and ectocarpus are sometimes known as “grass” fouling because of the similarity in appearance. Since all algae need some light intensity, they are usually found only on the side shell of vessels. When divers are used to remove algae growth by scrubbing, they may leave the roots embedded on the surface. Because of the simplicity of the plant, rapid growth occurs and further cleaning becomes necessary. It is likely that scrubbing of the vessel hull further roughens the surface and that attracts more algae colonization.

Soft bodied animals such as hydroids and tunicates may also be present. Of the larger fouling species, hard bodied animals such as barnacles, mussels, tubeworms, bryozoans are the most common.



Photograph 7-2. Early stages of barnacle fouling on an area where the anti-fouling paint has been damaged.

The adult forms of fouling such as mussels and barnacles are not floating around in the water ready to be attached to the hull structure; it is the larvae or sea spores which float around in the top 30 m or so of the sea water. Once attached to a structure, they have the ability to withstand extreme temperatures and salinity. Although the seaweed spores and certain barnacle larvae are capable of attaching in water flows up to 10 knots and other barnacle larvae of attaching at up to 5 knots, it is still assumed that the bulk of settlements to vessel's hull occurs while the vessel is stationary in a moored position or under very slow sailing conditions, such as movement between berths in a port.



Photograph 7-3. Mussel fouling in a sea chest.

3 Anti-fouling system (AFS)

The anti-fouling paints used today are based on physically drying binders. The majority of paints prevent fouling by releasing bioactive materials that interfere with the biological processes of the fouling organisms. Bioactive materials used today are mainly cuprous oxides or organic biocides. The ability to register new biocides is based on the environmental profile of the new product. It is very difficult and expensive to register new biocides. Anti-fouling paints are subject to the most extensive regulations of any paint. In some countries they have to be registered and approved for use by the relevant regulatory bodies of that country.

New advances in anti-fouling technology have resulted in improved biocide release systems and in foul release coatings which do not use biocides to control the fouling but prevent the fouling organisms from adhering effectively to the paint surface.

The IMO International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS Convention) was adopted on 5 October 2001. AFS will enter into force 12 months after being ratified by 25 States that represented 25 percent of the world's merchant shipping gross tonnage. Ratification could be as early as 2008.

IMO Resolution A928 (22), effective from 1 January 2003, prohibits the application or re-application of organotin compounds which act as biocides in anti-fouling systems. In this respect, anti-fouling should not contain TBT (tributyltin). When existing vessels replaced the anti-fouling after 1 January 2003, they complied with this requirement or provided sealer to avoid a non-compliant anti-fouling to avoid leaching.

All vessels after 1 January 2008 shall either:

1. not bear such compounds on their hulls or external parts or surfaces; or
2. apply coating that forms a barrier (sealers) to such compounds leaching from the underlying non-compliant anti-fouling systems.

Additionally EU Regulation (EC) No 782/2003 of 14 April 2003 requires the following:

1. For EU flag vessels an AFS with Organotin compounds acting as a biocide shall:
 - a. be removed or re-coated with a sealer coat to prevent the leaching of the undercoat by 1 July 2003; and
 - b. not be applied on or after 1 July 2003.
2. For non-EU flag ships entering EU ports or offshore terminals, an AFS with organotin compounds acting as a biocide shall be removed or be re-coated with a sealer coat to prevent the leaching of the undercoat by 1 January 2008.

The AFS Convention states that vessels of 400 gross tons and above engaged in international voyages (excluding fixed or floating platforms such as FSUs and FPSOs) as specified in Regulation 1(1) of Annex 4 to the Convention must be certified.

The type of anti-fouling systems prohibited by Annex 1 of the AFS Convention, organotin compounds which act as biocides in anti-fouling systems, must be removed or sealed, with an uncontrolled AFS.

In order to assist owners of ABS-classed vessels with a smooth transition when the Convention enters into force, the following documentation may be issued for compliance:

1. A statutory Statement of Compliance (SOC), on behalf of the vessel's flag Administration when authorized; or
2. A Statement of Voluntary Compliance (SOVC), at the request of the ship owner, if no authorization has been received from the flag Administration.

In order to comply with the above the following is required to be submitted for review prior to commencing an AFS survey:

From the AFS manufacturer:

- Type of anti-fouling system
- Name of anti-fouling system manufacturer
- Name and color of anti-fouling system
- Active ingredient(s) and their Chemical Abstract Service Registry Number (CAS number)
- Copy of the purchase order or contract linking the identified AFS with the ship to which it is (or has been) applied

Where organotin-free compounds are used, suitable wording describing such compounds are to be indicated in the documentation. Typical examples include: organotin-free self polishing type; organotin-free ablative type; organotin-free conventional; and biocide-free silicon type paint. If the AFS contains no active ingredients, the words "biocide-free" should be indicated. Supporting documentation (e.g., Material Safety Data Sheet or similar document) should also be submitted with the product information.

A documentation check should be carried out whenever the anti-fouling system is initially applied for new construction or is subsequently changed, replaced or repaired.

From the AFS application facility:

A statement indicating that the non-compliant paint has been either removed and replaced or sealed with the AFS identified by the information provided by the AFS manufacturer; and a purchase order for the AFS that is to be or has been applied which provides a link to the information requested from the AFS manufacturer.

ABS will perform a review of the documentation required to be submitted. The documentation review is to check that the:

- Declaration indicates all of the information required from AFS Manufacturer per above;
- Product identification on the AFS containers corresponds to the declaration of AFS provided by the facility; and
- Identification system exists that establishes a traceable link between the supporting documentation and the AFS container based on a random check of the containers.

A survey (documentation check) should be carried out whenever an anti-fouling system is initially applied for new construction or is subsequently changed, replaced or repaired. Resolution MEPC.102 (48) recommends that a repair which affects approximately 25 percent or more of the AFS (generally measured by repair area versus the AFS covered area) should require a survey to be carried out.

4 Self-polishing anti-fouling coatings

When this coating is in contact with sea water the binder dissolves at an even and predictable rate. As the anti-fouling paint is removed by a polishing action or the friction effect of the water, the bioactive material is released at an even rate and this enables coatings to remain fouling free when the vessel is not moving. The polishing nature of the coating results in a smooth finish to the hull, as the polishing rate is highest at the roughest points.

5 Insoluble matrix (controlled depletion) coatings

This is an old anti-fouling technology and is based on the use of rosin which is slightly soluble in sea water, but it is also brittle and slowly releases biocides. Rosin-based paints need other film forming resins to provide their mechanical strength and the load of bioactive material must be high enough for the particles of this material to be in contact with each other.

6 Foul release coatings

This type of paint is a relatively new addition to the category of anti-fouling paint. The mechanism for effective anti-fouling in this coating type is based on the low free surface energy of the coating surface. Fouling organisms find the surface unattractive. Biocides are not used and therefore these coatings are not affected by legislation commonly affecting other biocide containing anti-fouling paints.

7 Coating compatibility

Many of the coatings used on vessels today are compatible with each other, providing that the over-coating times and conditions recommended by paint manufacturers are followed. This is particularly true for epoxy coatings, where the time intervals between coats are critical for the performance of the paint.

Some paints are specifically designed as repair or maintenance products which are suitable for application to vessels in service using rollers or brushes. The types of coating onto which they can be applied and the surface preparation required is specified by the coating manufacturer.

CHAPTER 8: Performance Standards for Protective Coatings

1 General

Ballast tank coatings are exposed to severe service conditions. Regulations have evolved to produce a standard for the coating of ballast tanks in all types of ships and in double-side skin spaces of bulk carriers at new building. Regulations for other types of spaces such as voids and crude oil cargo tanks are under development at IMO.

Coatings are the primary barrier against corrosion. Coatings are supplementary to the corrosion addition for plating and structural members. The corrosion addition provides a margin should corrosion take place in order to protect the ships scantlings required for minimum structural strength. The presence of a coating does not enable any reduction in the corrosion addition.

The IMO Performance Standard for Protective Coatings (PSPC) has been written with the aim of providing a target useful life for ballast tanks coatings of 15 years using existing coating technology. In order for this to be achieved, it is necessary to refine and upgrade surface and coating practices accordingly.

Special attention has been paid to primary and secondary surface preparation together with an increase in minimum coating film thickness. More stringent inspection requirements have been imposed with more tightly-specified DFT measurements being required.

This chapter considers each step in the coating process referencing the regulatory requirements.

1.1 PSPC main elements

Significant amendments have been made to the SOLAS Regulations II-1, A-1/3-2 and XII/6. The main changes can be summarized as follows:

- PSPC applies to all type of ships 500 gross tonnage and over and replaces the Corrosion Prevention regulation in SOLAS (Reg. II-1/3-2) that applied only to tankers and bulk carriers irrespective of their tonnage.
- PSPC requirements intend to provide a target useful coating life of 15 years.
- PSPC includes specific detailed requirements for the application of coating systems including surface preparation, condition of surfaces and environment during and prior to coating, as well as inspection of the steel surfaces at each stage of the coating process.
- PSPC requires the specification and details of the application of the coating system to be documented in the Coating Technical File (CTF) and kept on board the vessel for future reference and use during maintenance.
- PSPC requires verification of compliance by the Administration.

1.2 IACS procedural requirement 34 (PR34)

Under the IACS Common Structural Rules (CSR) for oil tankers of 150 m in length and above and bulk carriers of 90 m in length and above, the application of the IMO PSPC becomes mandatory for ships contracted for construction on or after 8 December 2006. IACS PR34 has been developed to encourage uniform understanding and application of the requirements of the PSPC.

IACS' role in applying the standard is limited to that of verification as outlined in Section 7 of the PSPC. It does not involve IACS members in the day-to-day process of coating application and inspection.

IACS PR 34 contains procedures for: coating system approval; assessment of the coating inspector's qualifications; review of the inspection agreement; verification of the application of the PSPC; review of the Coating Technical File; review of coating technical specifications; measurement of soluble salts; and the application of stripe coating.

IACS PR34 is to be read in conjunction with the IMO PSPC. Application of the referenced international standards footnoted in the PSPC is mandatory under this procedural requirement.

The information contained in PR 34 will not be valid after 1 July 2008. It is anticipated that a Unified Interpretation or similar document containing equivalent information will be developed to support PSPC and submitted to IMO. A copy of IACS PR34 may be downloaded from the IACS website: <http://www.iacs.org.uk/>.

2 Scope and application

PSPC is not a regulation but a standard for protective coatings for dedicated seawater ballast tanks and double-skin spaces of bulk carriers. It is applicable to all ships under Regulation Chapters II-1/3-2 and XII/6 of SOLAS 1974 after 1 July 2008 and for CSR vessels after 8 December 2006.

2.1 SOLAS Ch. II-1/Reg. 3-2 – Applicable to all type of ships

The standard applies to all ships 500 gross tonnage and over:

1. for which the building contract is placed on or after 1 July 2008; or
2. in the absence of a building contract, the keels of which are laid or which are at a similar stage of construction on or after 1 January 2009; or
3. the delivery of which is on or after 1 July 2012.

The standard is applicable to:

1. all dedicated seawater ballast tanks arranged in ships; and
2. double-side skin spaces arranged in bulk carriers of 150 meters in length and upwards.

2.2 CSR vessels

The standard applies to all oil tankers of 150 meters in length or greater and all bulk carriers of 90 meters in length or greater, with a building contract date on or after 8 December 2006. The standard is applicable to:

1. all dedicated seawater ballast tanks arranged in Oil Tankers of 150 meters in length or greater; and
2. all dedicated seawater ballast tanks arranged in Bulk Carriers of 90 meters in length or greater; and
3. double-side skin void spaces arranged in Bulk Carriers of 150 meters in length and upwards.

3 Review of the inspection agreement (PSPC section 3.2/IACS PR34 section 3)

As part of the Coating Technical File (CTF) requirement a tripartite inspection agreement is to be made between the ship owner, shipbuilder and the coating manufacturer on the following items:

1. Selection of areas (spaces) to be coated
2. Selection of coating system
3. Statement of Compliance or Type Approval of the coating system
4. Inspection process
5. Surface preparation
6. Coating process
7. Appointment of a qualified coating inspector (responsible for verifying that the coating is applied in accordance with the PSPC)

The shipbuilder is to present the inspection agreement to the classification society/Administration for review, prior to commencement of any coating work on any stage of a new building.

4 Primary surface preparation (PSPC section 4.4 Table 1-2)

Primary surface preparation relates to the preparation of the steel plate at the start of the ship building process and usually occurs as part of an automated system that removes mill scale and applies a layer of shop primer to the steel.

Steel from the stockyard is usually flame-heated to remove water and burn off oil residues. The steel then passes through an abrasive blasting process that is designed to remove the mill scale, rust and any other contaminants from the surface. The basic elements of an automated blast system are:

- the centrifugal throwing wheel which throws the abrasive in a controlled pattern; and
- the recycling system which separates and returns good abrasive to a storage hopper for reuse.



Photograph 8-1. Steel plate after blasting on the shop primer line.

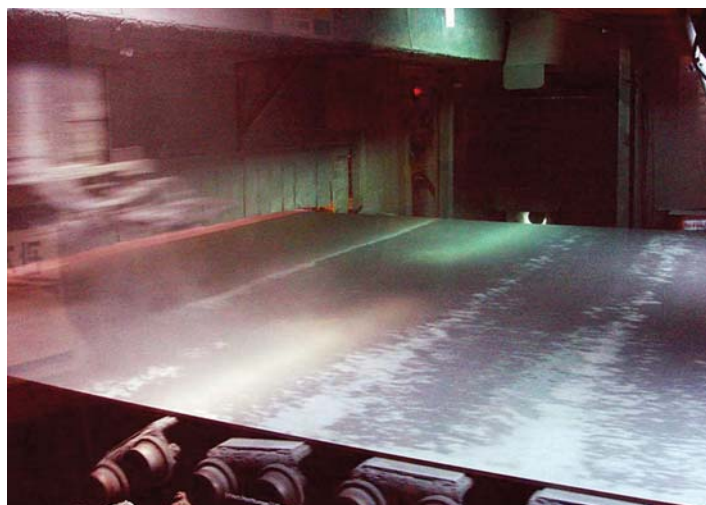
A surface profile should be introduced onto the steel plates and stiffener sections as specified by the coating manufacturer or the inspection agreement.

IMO PSPC specifies a blasting standard of Sa 2.5 with profiles between 30-75 μ m. The blasting is to be carried out in a controlled environment with a relative humidity of 85 percent or less and with a surface temperature of the steel more than 3°C above the dew point. The total water soluble salt limit should be less than or equal to 50 mg/m² of sodium chloride which can be verified using a Bresle Patch.

After removal of any blasting dust, the steel should be examined to see that it meets the agreed standard before the application of shop primer.

In an automated process the compliance with the standard may be demonstrated through a quality control system. The quality control system should include methods for:

- Periodic sampling of the abrasive to see if the correct operating mix is maintained for the required profile.
- Verifying that there is no contamination of the abrasive with regard to oil and salts.
- Verifying the efficiency of the abrasive throwing wheel, e.g. the use of an ammeter that shows the loading on the drive motor.



Photograph 8-2. Steel plate after shop primer application.

5 Secondary surface preparation (PSPC section 4.4 Table 1-3)

Secondary surface preparation relates to the preparation of the steel prior to application of the top coats and may occur under very different conditions, such as in paint shops, in dry docks or on slipways. The removal of contaminants and preparation of the profile on the steel is important for the longevity of the coating. The IMO PSPC specifies two different surface treatment requirements, one for the block stage and one for the erection stage.

5.1 At block stage

Secondary surface preparation at the block stage is carried out after steel work is completed and the block has been accepted by the yard quality control, owner's inspector and class surveyor. The surface preparation may occur indoors and under controlled conditions such as in the blast shop.

5.1.1 Steel condition (PSPC section 4.4 Table 1-3.1)

The steel surface shall be prepared so that the selected coating can achieve an even distribution at the required NDFT with adequate adhesion by removing sharp edges, grinding weld beads and removing weld spatter and any other surface contaminant. Edge preparation is generally achieved by three pass grinding, or by any other method proven to provide a 2mm radius.

5.1.2 Surface treatment (PSPC section 4.4 Table 1-3.2)

Abrasive blasting is used on the welds and flat areas to remove damaged shop primer. The IMO PSPC minimum requirements for abrasive blasting at this stage is Sa 2.5 with a profile of 30-75µm or as specified in the CTF. Undamaged shop primer may be left on the block if the shop primer has passed a pre-qualification test to demonstrate its compatibility with the top coating. If the shop primer is not compatible with the top coating then 70 percent of the shop primer is to be removed by abrasive blasting to Sa 2; 70 percent refers to the volume of the shop primer to be removed.

Shop Primer Failure

After shop primer is applied to steel, it is subject to many fabrication processes, such as cutting, welding, edge preparation and fairing and as a result receives many mechanical damages. It will also collect contaminants including oil, grease, soluble salts, dust and debris. When exposed to the atmosphere, particularly under wet or humid conditions, corrosion of any exposed steel will begin to occur. The zinc in the shop primer will corrode sacrificially to protect steel in contact with the shop primer and the extent of this sacrificial protection will depend on the quantity of zinc in the shop primer.

After a period of weathering, the zinc will have corroded to produce white zinc salts and edges and welds will have corroded showing red iron rusts, as shown in Photograph 8-3.



Photograph 8-3. Shop primed block showing corrosion of edges and welds and zinc corrosion products at sites of burn through and fairing processes.

Damaged shop primer is poorly defined in the Standards, however it is essential that all the steel corrosion, the welding fume, the zinc corrosion products and other contaminants are removed before a coating is applied, or the coating will fail prematurely in service. Some of these issues are shown in Photograph 8-4.



Photograph 8-4. Block stage with shop primer, prior to secondary surface preparation. Note the corrosion at all the welds and edges and the presence of welding fume, chalk marks and oil contamination.

5.1.3 Dust (PSPC section 4.4 Table 1-3.1)

Thorough removal of dust residues from abrasive blasting is essential. Dust is categorized by quantity of dust and dust size. IMO PSPC requires that all visible dust is removed.

5.1.4 Soluble salts (PSPC section 4.4 Table 1-3.6)

The salt level is to be measured using the Bresle test method (ISO 8502-9). The measured conductivity is to be used without conversion and the value is to be less than the conductivity of 50 mg/m² sodium chloride.

Secondary surface preparation also applies to the preparation of surfaces between coats of paint and it is equally important that contaminants are removed from painted surfaces before the next layer is applied, otherwise inter-coat failures will result in service.

5.2 At erection stage (PSPC section 4.4 Table 1-3.3)

Preparation of the steel for painting at the erection stage is more difficult as the environmental conditions cannot be controlled. It is essential that good surface preparation is achieved since welds are vulnerable areas. Many welds are prepared for coating by the use of power tooling rather than by abrasive blasting and this often results in an inferior surface condition before painting. Care should be taken not to over-polish the surface of the substrate since this changes the surface profile and influences the adhesion of the coating. The coating manufacturers have clarified that the St 3 should result in a surface profile of 25µm.

IMO PSPC requires the weld butts to be treated to St 3 (which is a very thorough cleaning with power tools) or Sa 2.5 where practicable. Damaged areas up to 2 percent of the total area may be treated to St 3. Contiguous damages over 25m² or over 2 percent of the total area of the tank shall be treated to SA 2.5.

Contaminants such as salts and grease should be removed before the coating is applied to the erection weld. The coating scheme applied at the block stage is normally “feathered”, as shown in Photograph 8-5. This allows the coating scheme to be built up around the weld without creating steps or excessive thickness in the coating.



Photograph 8-5. Feathered paint layers on an outer hull.

6 Coating application (PSPC section 4.4 Table 1-1.4, 1.5)

Coating application at the block stage is usually carried out indoors and under controlled environmental conditions. This may occur in the same location as abrasive blasting or in another, nearby building.

It is important that the correct conditions of temperature, relative humidity, etc., are maintained as specified by the coating manufacturer and/or the documentation in the CTF Poor application or curing conditions can cause defects in the paint and therefore early failure in service (PSPC section 4.4 Table 1-4.2).

The coating system shall be a minimum of two stripe coats and two spray coats. The sequence of application is not specified but it is recommended that a spray coat is applied to the block first in order to protect it against corrosion. In certain circumstances the second stripe coat may be omitted. This is the case for automatic welding where the weld is smooth and it can be demonstrated that the minimum DFT can be reached. The minimum DFT for epoxy-based systems is 320 μ m with the 90-10 rule, and other systems to the coating manufacturer's specification.

Coating application over large areas is normally carried out by spraying. Brushes and rollers are used for complex shapes and stripe coats. Stripe coats must be applied as a cohesive film achieving the required NDFT, and showing good film formation and no visible defects, such as pores or de-wetted areas.

The application method of stripe coats must ensure that all areas which cannot be adequately coated by spray application are properly stripe coated by alternative application methods, which includes brush and roller. Where areas cannot be adequately coated by roller, for example in way of SMAW welds, a brush should be used.

Each main coating layer shall be properly cured before application of the next coat, in accordance with the coating manufacturer's recommendations. The dry-coat times and walk-on times given by the coating manufacturer are to be observed.

The paint applied should be checked by the coating inspector and other personnel if necessary, to ensure that the correct parts are used (for two pack paint) and that they are thoroughly mixed in accordance with the manufacturer's technical data sheets included in the CTF. Induction times should be respected before application. The use of excessive quantities of thinners should be avoided and only the specified paint thinner should be used.

7 Coating inspection requirements

7.1 Coating inspectors (PSPC section 6.1)

Any individual required to carry out inspections in accordance with the IMO PSPC section 6 is to be qualified to NACE Coating Inspector Level 2, FROSIO Inspector Level III, or an equivalent qualification. Equivalent qualifications are described by IACS in PR34 section 2: Assessment of Coating Inspectors' Qualification.

The appointed coating inspector shall carry out inspections and record the results of the inspection at the various stages and verify that these are in compliance with the IMO PSPC. All deficiencies/non-compliances found at any stage of the surface preparation and coating application process shall be reported and rectified before proceeding to the next stage.

7.2 Coating inspection items (PSPC section 6.2)

The coating inspector should be satisfied that the surface preparation meets the agreed standards and that the environmental conditions are suitable for coating application and curing, before coating application commences. The required drying and curing times should be allowed before further coating work is carried out.

The condition of the first layer of paint should be inspected and accepted before each successive layer of paint, including the stripe coats. Manufacturer's technical data sheets should be carefully followed, particularly for coatings such as epoxies, which have minimum and maximum over-coating times. These are often called the over-coating window.

The coating inspector is to carry out measurements at the different stages of the surface preparation and coating application process. Various measurements need to be taken and recorded usually in a daily log and where applicable, in a non-conformity report. These reports are part of the final CTF and should include the date of completion of inspection, description of the results of the inspection (with comments if any), the inspector's name and signature.

7.3 Environmental conditions (PSPC section 4.4 Table 1-4.2)

Measurement of relative humidity and surface temperature is to be carried out at different stages, to assure that the relative humidity is 85 percent or less and the surface temperature of the substrate is 3°C above the dew point as specified in the IMO PSPC. Conventionally these measurements are carried out using a wet and dry bulb hygrometer of the type shown in Photograph 8-6 and a surface temperature gauge.



Photograph 8-6. Wet/dry bulb hygrometer. ©Elcometer 2007.

7.4 Soluble salts (PSPC section 4.4 Table 1-2.2, 3.6)

Soluble salts are to be measured in accordance with ISO 8502-9 (Bresle Patch method), to ensure contaminants have been removed by fresh water washing and maintained free of contaminants until the time when coating process commences. The Bresle Patch is attached to the surface, where demonized water is injected with a syringe, then extracted and measured with a conductivity meter. The measurement will indicate the quantity of salts in $\mu\text{g}/\text{cm}^2$. Photograph 8-7 shows this technique.



Photograph 8-7. Bresle patch test for soluble salts.

7.5 Oil, grease and other contaminants (PSPC section 4.4 Table 1-3.7)

The surface should be free, and kept free, of contaminants such as oil, grease, flame burns and chalk marks. The visual inspection for contamination by oil can be aided through use of a fluorescent light.

7.6 Substrate surface profile (PSPC section 4.4 Table 1-2.1, 3.4)

The inspection of surface profiles is required to be carried out at the primary and secondary surface preparation using a visual comparator gauge (PSPC Annex 1 Table 1/3.4 and 2.1). An example is shown in Photograph 8-8.



Photograph 8-8. Grit comparator gauge. Similar gauges are available for shot blasted surfaces. ©Elcometer 2007

7.7 Dust levels

A report is to be made on the dust levels prior to coating application to confirm compliance with IMO PSPC Annex 1 paragraph 6.2, Table 1/3.5 and 1.4.

7.8 Wet film thickness (WFT) (PSPC section 4.4 Table 1-1.5)

Measurement of wet film thickness (WFT) is usually done by the applicators/shipyard as part of their quality control procedures to ensure that the final DFT levels required will be achieved for each coat. The WFT does not need to be recorded as part of the CTF.

7.9 Dry film thickness (DFT) (PSPC section 4.4 Table 1-1.5)

The final dry film thickness needs to be measured and recorded to prove that the coating has been applied to the thickness specified by the PSPC or the coating manufacturer.

8 Verification requirements (PSPC section 7, IACS PR34 section 4)

ABS, acting on behalf of the Flag Administration, will verify that the relevant documents required by the IMO PSPC are included in the Coating Technical File for the vessel. These include the technical data sheets, Statement of Compliance or Type Approval Certificate of the coating system and the coating inspector's reports.

The attending ABS surveyor is to verify that the coating inspector is qualified in accordance with the IACS PR34 Standard.

The attending ABS surveyor will monitor the implementation of the coating inspection requirements on a sampling basis, to confirm that the inspectors are using the correct equipment, techniques and reporting methods, as described in the inspection procedures included in the CTF reviewed by ABS. The monitoring process is to include identification of a representative number of paint tins used, comparing them with the coating identified in the Technical Data Sheet.

Any deviations found by the surveyor are to be raised and discussed with the coating inspector who is responsible for identifying and implementing the corrective actions. In the event that corrective actions are not satisfactorily resolved or not closed out, then ABS is to inform the shipyard.

An Interim Class Certificate and/or Safety Construction Certificate will not be issued until all required corrective actions have been closed to the satisfaction of the ABS surveyor.

9 Coating film thickness measurements

The wet film thickness (WFT) of the coating is required to be measured regularly, so that the required dry film thickness is achieved in compliance with the appropriate requirements and coating manufacturer's recommendations

The NDFT (Nominal Dry Film Thickness) required by PSPC is 320µm with the 90-10 rule which means that 90 percent of all thickness measurements shall be greater than or equal to 320µm and none of the remaining 10 percent measurements shall be below 288µm (0.9 x 320µm) for epoxy-based coatings.

DFT measurements should be carried out by a qualified coating inspector using a thickness gauge such as the type shown in Photograph 8-9. Electronic gauges with extension leads for the measuring sensor are also available. The use of magnetic pull-off gauges (also called banana gauges) is not recommended.



Photograph 8-9. Dry Film Thickness Gauge.

10 Coating system approval (PSPC section 4.4 Table 1-1.2, 1.3/IACS PR34 section 1)

The coating manufacturer can apply for approval of its coating system by three different methodologies: laboratory testing, five year's of field exposure, or existing Marintek B1 approval. The coating manufacturer is to comply with sections of the procedural requirements for service suppliers (UR Z17). The three methodologies have been clarified in the IACS PR34.

10.1 Laboratory testing (PSPC section 4.4 Table 1-1.3)

The paint manufacturer is to pre-qualify the coating with a laboratory test in accordance with Annex I of the IMO PSPC. The test laboratory is to be independent and recognized by the class society. The tests simulate ballast conditions and it takes in total eight months to complete the tests – two months weathering of shop primer followed by six months of testing.

Results from satisfactory pre-qualification tests of the coating system shall be documented and submitted to ABS.

For new systems approved after 8 December 2006 the following documents need to be submitted:

- For Type Approval of epoxy systems tested with primer A in accordance with Annex 1
- Type Approval Certificate of the epoxy system with primer A and a listing of primers for which a cross-over test has been successfully carried out.
- The approved epoxy system can also be used on bare steel. Epoxy systems tested on bare steel in accordance with Annex 1 are considered as an alternative system. In this case a Type Approval Certificate of the epoxy system with a listing of primers for which a cross-over test has been successfully carried out, is to be submitted.

For ABS, this means the following:

1. ABS will review the Technical Data Sheet on the paint and issue Product Design Assessments (PDA) if found satisfactory.
2. The manufacturer must have a certified quality system and be under the appropriate Product Quality Assurance (PQA) category.
3. For each batch manufactured for marine use, the manufacturer is required to issue an affidavit declaring conformity with approved type that is co-signed by the laboratory. The manufacturer is to demonstrate that the laboratory is independent from production.
4. The manufacturer is responsible for identifying all containers in the batch with some form of permanent marking.
5. The manufacturer can download the Confirmation of Type Approval from the ABS website at www.eagle.org which would be considered equivalent to a Type Approval Certificate or Statement of Compliance as mentioned in MSC 215(82).
6. If the manufacturer wants to subcontract the process, the secondary company is to be given a duplicate PDA and is required to do a Type Test on the product as part of its enrollment into PQA.

10.2 Five year's field exposure (PSPC section 4.4 Table 1-1.3)

The coating manufacturer's records are to be examined to confirm a coating system has five year's field exposure, and that the current product is the same as that being assessed. The following documentation must be submitted:

1. Manufacturer's records
2. Original application records
3. Original coating specification
4. Original technical data sheet
5. Current technical data sheet for the current production site
6. Specific gravity and Infrared identification of original product
7. Specific gravity and Infrared Identification of the current product
8. If the original SG and IR cannot be provided then a statement is required from the manufacturer confirming that the readings for the current product are the same as those of the original
9. In addition:
 - a) Either class survey records from a class society reported in accordance with IACS Recommendation 87 or a joint (coating manufacturer/Society) survey of all ballast tanks of a selected vessel is to be carried out for the purpose of verification of compliance with the requirements of sections 1.3
 - b) The selected ship is to have ballast in regular use, of which:
 - 1) At least one tank approximately 2,000m³
 - 2) At least one tank shall be adjacent to heated tank and
 - 3) At least one tank under deck exposed to sun
 - c) In the case that the selected vessel does not meet all of the selection requirements, then the limitations shall be clearly stated on the Type Approval Certificate. For example, the coating cannot be used in tanks adjacent to heated tanks or under deck or in tanks with a volume greater than the size surveyed.
 - d) All ballast tanks are to be in GOOD condition, without touch up or repair in the prior five years.
 - e) GOOD is defined as per IACS Recommendation 87: *Condition with spot rusting on less than 3 percent of the area under consideration without failure of the coating. Rusting at edges or welds, must be on less than 20 percent of edges or welds in the area under consideration.*

Examples of how to report coating conditions with respect to areas under consideration should be as those given in IACS Recommendation 87 Appendix I.

10.3 Existing Marintek B1 approvals (PSPC section 4.4 Table 1-1.3)

Epoxy coatings systems with existing satisfactory Marintek test reports minimum level B1 with relevant infrared identification and specific gravity records, issued before 8 December 2006, can be accepted. If the original SG and IR cannot be provided, then a statement is required from the manufacturer confirming that the readings for the current product are the same as those of the original coating system.

Such coatings are to be applied in accordance with Table 1 of the PSPC rather than the application conditions used during the approval test which may differ from the PSPC, unless these are more stringent than Table 1 of the PSPC.

For existing coating systems before 8 December 2006 the following applies:

- Marintek B1 Report with relevant infrared identification and specific gravity report
- Type Approval Certificate with the primer as specified in the Marintek B1 report with a listing of primers for which a cross over test has been successfully carried.

11 ABS CPS Guide

ABS has developed a Guide with the objective of promoting the effective use of the qualified protective coatings on ABS-classed vessels. The requirements specified in this Guide are additional to all other relevant requirements of ABS Rules and Guides. Vessels and marine structures designed, built and coated in full compliance with the International Regulations, standards, guidelines and recommendations may be assigned a class notation CPS, Coating Performance Standard at the request of the applicant.

11.1 Coating process flow

Generally the coating process flow is typically as shown in Figure 8-1. Each of the major coating steps are indicated along with a cross reference to the applicable section within the IMO PSPC. The various documentation and review steps necessary to demonstrate compliance with the IMO PSPC and the review steps performed by ABS as a Recognized Organization (RO) in line with IACS Procedure Requirement PR No. 34 are also indicated along with cross reference to the applicable section within the IMO PSPC.

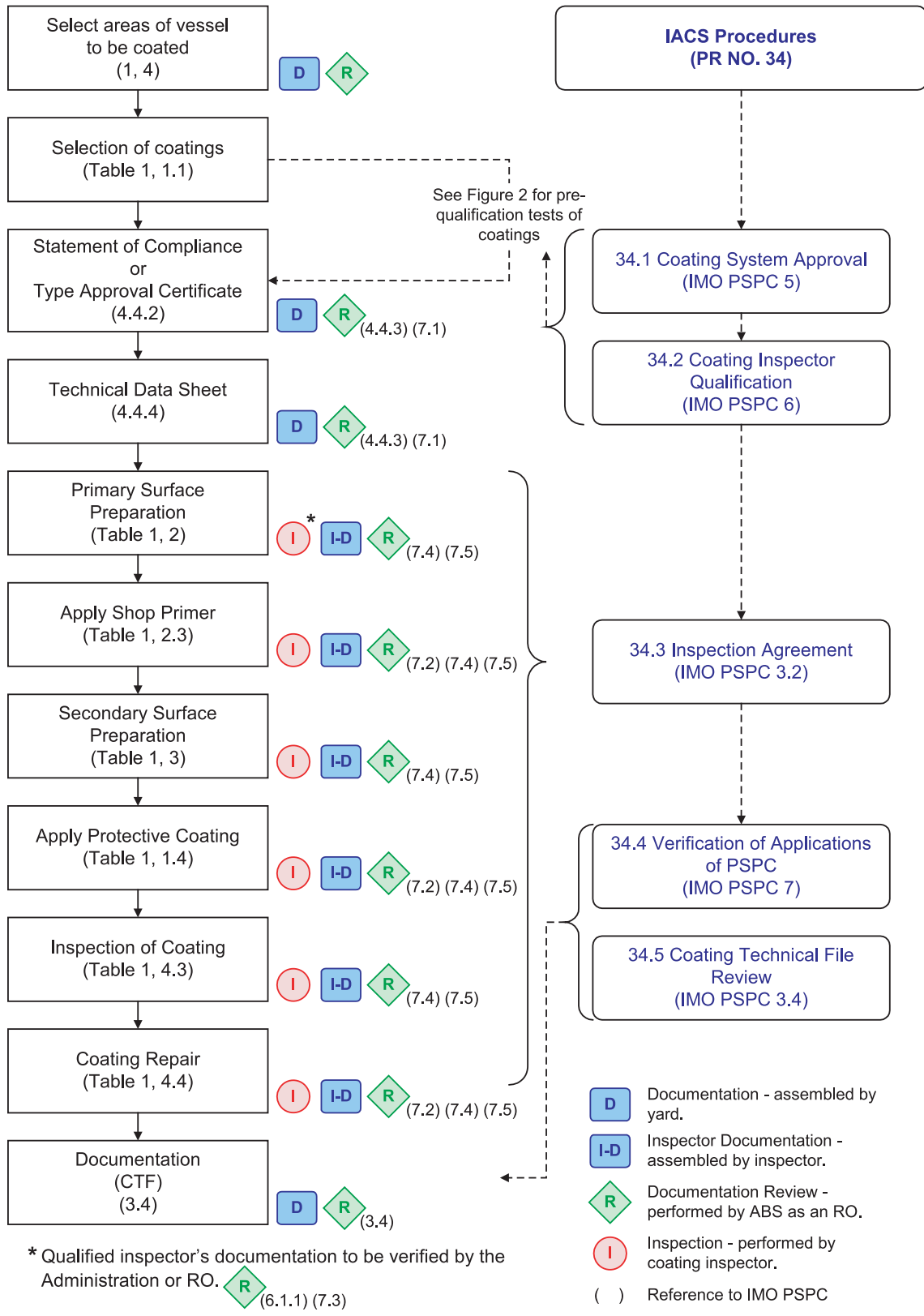


Figure 8-1. Coating process flow.

11.2 Coating pre-qualification testing process flow

The IMO PSPC also includes requirements for pre-qualifying coating systems for the vessel structure. The general process flow for pre-qualifying coatings is shown in Figure 8-2.

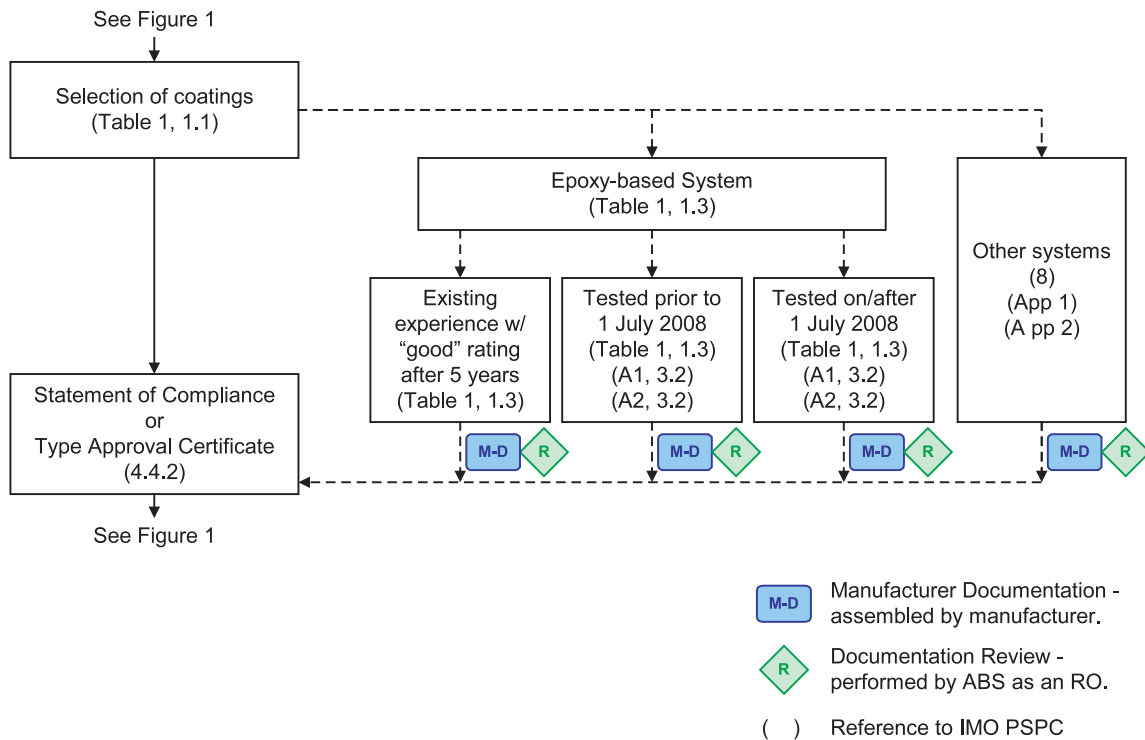


Figure 8-2. Coating pre-qualification testing process flow.

11.3 DFT Measurement Guidance

Annex 3 of Annex 1 of IMO PSPC MSC215(82) includes verification check points of dry film thickness (DFT) on structural elements in the ballast tanks of Double Hull Tankers and Bulk Carriers and double side skin void spaces on Bulk Carriers.

CHAPTER 9: Coating requirements for void spaces

A draft Performance Standard for Protective Coating for void spaces located within the cargo block area and forward, applying only to oil tankers and bulk carriers (PSPC/voids), has been drafted and approved at IMO DE 50/WP2 and DE50/WP3 (March 2007). This has been put forward for adoption at the MSC 83 meeting (October 2007).

At the IMO DE50 meeting it was also decided that PSPC/voids for all other types of vessels will be discussed at a later IMO meeting.

CHAPTER 10: Coating requirements for cargo spaces

1 Oil tankers

A performance standard for the protection of cargo oil tanks for oil tankers is under development by a working group in close consultation and participation with the marine industry (IACS, shipbuilders, designers, owners and coating manufacturers). It is anticipated that a draft standard will be submitted to IMO MSC.83 (October 2007) for debate and adoption.

2 Bulk carriers

ABS Rules 5-3-5/1.3 and IACS UR Z9 include requirements for the protection of cargo hold spaces for the areas shown in Figures 10-1 and 10-2 and described below.

The current revision of IACS UR Z9 is applicable to new vessels for which the request for class is received on or after 1 July 1998. A copy of the latest revision of IACS UR Z9 may be obtained from the IACS website: <http://www.iacs.org.uk/>

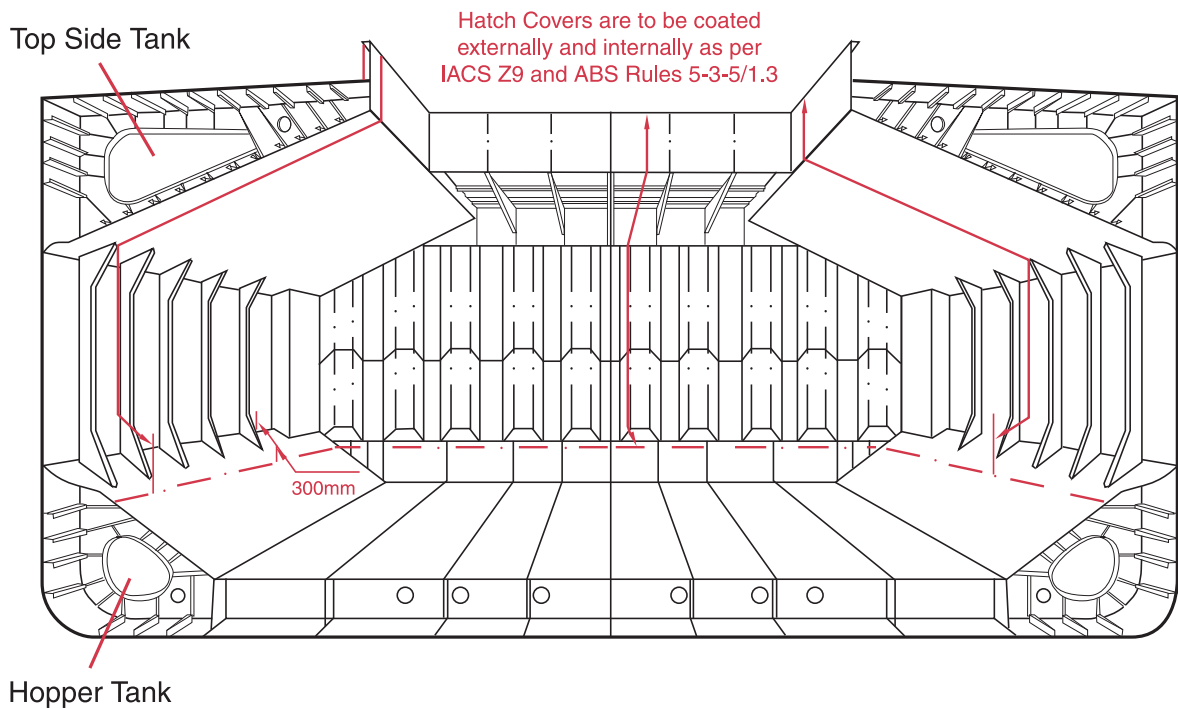


Figure 10-1. Extent of internal cargo space areas required to be coated as per IACS Z9 in a single side skin bulk carrier.

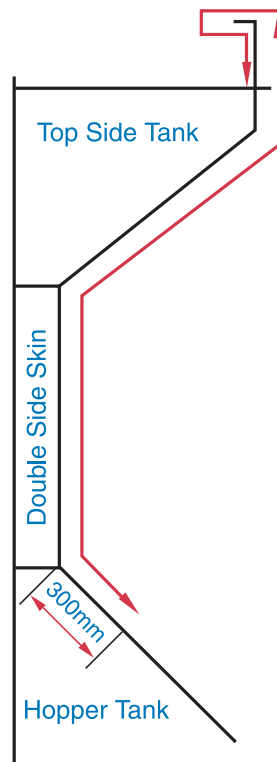


Figure 10-2. Extent of internal cargo space areas required to be coated as per IACS Z9 in double side skin bulk carrier.

At the time of new construction all internal and external surfaces of hatch coamings and hatch covers and all internal surfaces of cargo holds, excluding the inner bottom area and part of the hopper tank sloping plate and lower stool sloping plate, are to have an efficient protective coating, of an epoxy type or equivalent, applied in accordance with the manufacturer's recommendation.

The technical agreement between the ship owner, the coating manufacturer and the shipbuilder may include selection of coatings and details of the coating procedure for the cargo holds.

CHAPTER 11: Coating Technical File

The purpose of the Coating Technical File (CTF) is to provide a record of all the coating planning and application work that has been carried out on a vessel, from the specification stage, through building and into service. The file is to stay onboard the vessel and is intended to act as a readily available reference for all matters pertaining to coatings specific to the ship. The CTF will also include a service maintenance schedule and information on any major repairs. Any minor repairs carried out by the crew would not need to be recorded; however, full or partial refurbishment would be recorded. A standard for maintenance and repair of the protective coating is under development at IMO.

1 Statement of Compliance or Type Approval Certificate

The coating manufacturer is to provide the shipyard with a statement of compliance or Type Approval Certificate for the coating system that will be used for the vessel. This is required to be provided for each batch of paint.

2 Technical datasheet

The coating manufacturer is to provide copies of the technical data sheets and the Material Safety Data Sheet (MSDS). The coating manufacturer technical data sheet typically consists of the following data:

- **Product description**
The product name, type and identification mark and/or number which should also be shown on tight cans containing the agreed paint
- **Recommended use**
Indicates for which area of the vessel the coating is recommended to be used
- **Film thickness**
Minimum and maximum DFT
- **Physical properties**
Materials, components, composition and colors of the coating system
- **Surface preparation**
Recommendations for the condition of the surface to be coated; including the steel profile, (roughness) as well as the edge roundness, degree of removal of rust and the extent of cleanliness from contaminants
- **Conditions during application**
Limitations concerning the Environment (temperature, humidity, etc) during the application and curing of the coating system
- **Application methods**
Application method, tools and/or machines
- **Application data**
Coating application should be stated, indicating clearly the number and sequence of coats and stripe coats to be applied, plus where and how each of these coats and stripe coats are to be applied
- **Drying time**
- **Storage**
- **Handling**
- **Packing Size**
- **Health and Safety (details are noted in the MSDS)**

3 Shipyard work records

Shipyard work records of coating application must be maintained and will include the following items.

- A list of ballast tanks and voids where the agreed coating system is to be applied. This should include the corresponding area to be coated in m².
- The applied coating system for each area, number of spray coatings, stripe coatings and sequence.
- The time required for the application of each coat plus the time between coats and stripe coats for a multi-coated system as stipulated in the IMO PSPC. If the wet film thickness (WFT) is also required/agreed to be measured then this should also be stipulated.
- The ambient temperature during the coating application and curing process should be continuously monitored and recorded.
- The method of surface preparation of the steel substrate and/or primer prior to the application of any coating system is to be stipulated.
- The method of surface preparation with regard to repairs of the coating system including the removal of any contaminants, holidays and inclusions between coats and stripe coats should be clearly specified. The dry-to-recoat times and walk-on times should also be specified.

4 Inspection procedures

The procedures for inspection of surface preparation and coating processes shall be agreed by all three parties involved namely the ship owner, shipbuilder and coating manufacturer. This should also include a procedure for repairing the coating during the ship construction. The shipbuilder should submit all necessary documentation to an ABS technical office for review indicating as a minimum, compliance with the IMO PSPC requirements.

5 Daily logs

The CTF is to include specific requirements that the inspector is required to address on a daily basis during any coating process agreed between the parties. The ABS surveyor will monitor the process followed by the inspector at regular intervals to review that the minimum IMO PSPC requirements are met.

The qualified coating inspector is to maintain a daily log which would typically include:

- Date
- Vessel identification
- Name of structure or block
- Environmental information
- Steel condition
- Surface preparation conditions
- Coating type and identification numbers
- Coating application (number of coats, stripe coating)
- Dry-film thickness measurement
- Non-conformity and rectification

The qualified coating inspector is required to fill out these logs at each stage of the process.

IMO PSPC includes sample forms, these include; a daily log, a surface preparation form, a coating application form and a non-conformity form. Other forms have been suggested such as Primary Surface Preparation (PSP), Secondary Surface Preparation (SSP), Coating Application (CA), Dry Film Thickness Measurement and Inspection Report (IR).

6 Shipyard's verification report

The shipyard's verification report is a summary report stating the results of the coating inspection and is to include the following data:

- Name of part or structure
- Inspection completion date
- Inspection results and remarks
- Coating inspector's signature
- Shipyard representative's signature

7 In-service repair procedure

Guidance for maintenance of the coatings in-service is to be provided by the shipyard and this will include details for the repair of the coating systems while the vessel is in operation, which the operator should follow. As previously mentioned, a standard for maintenance and repair of the protective coating is under development at IMO which, when adopted and depending upon its applicability, may also have to be referenced by the ship owner.

CHAPTER 12: Coating failures

1 General

Coatings do not last forever. They age, weaken and deteriorate and eventually their useful life ends. The most common cause for premature coating failure is insufficient care during the mixing, application and curing processes. Poor application technique can typically cause problems such as improper thickness, pinholes, sags, mud-cracking, and holidays. Inadequate surface preparation results in poor adhesion to the substrate. This includes blistering, peeling and inter-coat delamination. In addition, structures are typically not designed and fabricated with the coating process in mind. For example items such as skip welds, sharp edges and crevices may lead to early coating failures.

2 Coating defects during application

2.1 Sags

Sags generally occur on vertical surfaces when paint is applied too thickly in localized areas in excess of the DFT. They can also be caused when too much thinner has been added to the paint, if the spray nozzle is held too close to the surface, or if it is held in one position for too long a time.

2.2 Runs

Runs are also caused by over-thinned paint or the application of a thick layer of low viscosity paint.

2.3 Cissing

This is also known as fisheye. They are small holes in the coating that are caused by entrapped air bubbles leaving the paint or improper wetting of the substrate by the paint. This is caused by surface contamination such as moisture, oil or grease.

2.4 Orange peel

Typically the surface is pock-marked and looks like an orange peel, as shown in Photograph 12-1. This is caused by the use of incorrect solvents, too much paint thinner or improper spray technique.



Photograph 12-1. Poor coating application control.

2.5 Cracking or mud cracking

This failure usually occurs on horizontal surfaces when paint has been applied too thickly. Internal stress build up in the coating as it dries and cures thereby causing cracking.

2.6 Holidays

These are small areas, typically less than 1mm, where the coating has not adhered to the surface, as shown in Photograph 12-2. Holidays are usually caused by residual contamination such as oil. Corrosion sites usually initiate at these areas.



Photograph 12-2. Small holes or holidays in the coating allow rapid corrosion to initiate in service.

2.7 Over thickness

Over thickness is when the applied layer of coating is greater than the maximum thickness specified by the coating manufacturer for that product. If the coating is very thick, it can peel away from the substrate as shown in Photograph 12-3.



Photograph 12-3. Over thick coating detaches easily. Poor preparation between coats of paints causes early failure.

2.8 Under thickness

Under thickness is when the applied layer of paint is less than the minimum specified by the coating manufacturer and/or the 90-10 rule for that coating. This is shown in Photograph 12-4.



Photograph 12-4. Where the coating is too thin, early failure occurs in service.

2.9 Overspray

Overspray or dry spray occurs when the sprayed coating lands on an unprepared surface. This may be due to the influence of factors such as wind for external painting on outer hulls. When spraying indoors, overspray may be the result of poor spray patterns, ricochet effects or operator error. Overspray particles are typically small and poorly adherent to the surface. If the overspray layer is sufficiently thick and not removed, the next coating layer could adhere poorly and fail prematurely in service.

2.10 Grit inclusions

Grit can be trapped under the paint, through the paint or on top of the paint. If the steel surface is not properly cleaned after abrasive blasting or if blasting dust and grit is deposited onto a layer of paint prior to application of the next coat, the grit will be trapped. Steel grits will corrode when water penetrates through the paint and the coating will be locally forced away from the steel when the grit is under the coating. If grit is trapped between coating layers, then the outer layer of paint will be damaged, as shown in Photograph 12-5.

Grit trapped in the outer layer of paint will also corrode and this will cause stresses in the coating that will weaken its integrity and shorten its service life.



Photograph 12-5. Trapped grit at the welds and in the coating has caused rust staining. Grit that penetrates through the coating will allow corrosion of the substrate to initiate.

2.11 Human Error

Human error covers instances where the wrong type of paint is applied, the paint is poorly mixed or paint is applied that has exceeded its pot life. The application of paint under unsuitable environmental conditions or during other processes can also be categorized as human error, as shown in Photograph 12-6.



Photograph 12- 6. Washing was occurring on the area above the wet paint and the washing water caused coating removal.

2.11.1 Poor penetration

Coatings should completely cover the item to be coated. Poor application practices can cause incomplete coverage. On edges and welds, it is difficult to obtain a good and even coverage of paint and it is also difficult to ascertain that the correct thickness of paint has been applied.

2.11.2 Footprints

When the specified “walk on time” has not been allowed or if the curing conditions are not suitable, operators walking on the coatings to check DFT’s can leave footprints in the soft paint. The paint at the footprint areas will be below the specified thickness.

2.11.3 Winter and summer grades

In countries where the temperatures in winter fall below the stated minimum curing temperatures for a specific coating, paint manufacturers may supply a “winter grade” paint for low temperature application. It is essential that the change over from summer to winter grades takes place before the minimum temperatures occur. Compatibility between winter and summer grades should be checked with the paint manufacturer before the application of a layer of winter grade paint onto a summer grade layer or vice versa.

2.11.4 Poor mixing

Poor mixing of paint, either by insufficient stirring or mixing the wrong ratios of a two-component system, can result in uneven or incomplete curing of the coating. This will seriously affect the service lifetime of the coating.

2.11.5 Pot life exceeded

The pot life of a coating will be specified by the paint manufacturer and will depend on the type of paint and the ambient conditions. Paint that has exceeded its pot life may appear to be applicable, but should be discarded as it will not produce a satisfactory coating in service.

2.11.6 Induction period not allowed

Some coatings require an induction (waiting) period after mixing before application can occur. This will be specified on the paint manufacturer’s data sheet and should be followed or the coating may not adhere to the substrate, cure satisfactorily or perform acceptably in service.

2.11.7 Shelf life exceeded

All coatings should be labeled with a “use by” date. Out-of-date paint should not be applied as the film forming and curing properties will be affected.

2.11.8 Storage temperature too high or too low

Paint manufacturers’ data sheets specify storage conditions for the paints and these should be followed. Storage outside the specified temperature range can seriously affect the application, curing and performance of the paint.

3 In-service coating failures

3.1 Shop primer failure

After shop primer is applied to steel, it is subject to many fabrication processes, such as cutting, welding, edge preparation and fairing and receives many mechanical damages. It will also collect contamination including oil, grease, soluble salts, dust and debris. When exposed to the atmosphere, particularly under wet or humid conditions, corrosion of any exposed steel will begin to occur. The zinc in the shop primer will corrode sacrificially to protect steel in contact with the shop primer and the extent of this sacrificial protection will depend upon the quantity of zinc in the shop primer.

After a period of weathering, the zinc will have corroded to produce white zinc salts and edges and welds will have corroded showing red iron rusts, as shown in Photographs 12-7 and 12-8. It is essential that all the steel corrosion, the welding fume, all of the zinc corrosion products and other contaminants are removed before a coating is applied, or the coating will fail prematurely in service.



Photograph 12-7. Shop primed block showing corrosion of edges and welds and zinc corrosion products at sites of burn through and fairing processes.



*Photograph 12-8. Corrosion at all the welds and edges of a shop primed block.
Note also the presence of welding fume, chalk marks and oil contamination.*

3.2 Through film breakdown

Through film breakdown most often occurs in the ullage space at the top of ballast tanks and tends to be a common occurrence in the under-deck plating. An example is shown in photograph 12-9. The coating breakdown shown is in the later stages of development, where the rust spots have grown due the warm and humid conditions found in these areas.



Photograph 12-9. Through film breakdown.

Through film breakdown typically occurs first on the upper surfaces of longitudinal stiffeners (Photograph 12-10) and on stringer decks (Photograph 12-11), where residual water remains on both surfaces for longer periods after the tank is first emptied.

Water and condensation will drain down vertical and sloping surfaces and collect on suitable horizontal surfaces. Water may be trapped on horizontal stiffeners due to the design of the stiffener, end plates, bulkheads, etc. It will also be trapped by mud and debris on the stiffener.

Stringers and tank bottoms will also collect pools of water due to the vessel trim, poor drainage at cut outs and rat holes, at the intersection of web frames and horizontal structure and where buckling of the plates has occurred. Residual mud, cargo and other debris will also trap and hold water against the paint and any exposed metal surfaces.



Photograph 12-10. Corrosion spots on longitudinal stiffener.



Photograph 12-11. Corrosion spots on stringer deck.

3.3 Blistering

Blisters often take the form of clusters of either liquid filled or dry, hemispherical bubbles at the paint/metal interface. Although blisters can form between layers of paint, these are less common. Typical blister rashes are shown in Photographs 12-12 and 12-13. In order to give a sense of scale, a small notebook has been included in the Photograph 12-13.



Photograph 12-12. Blister rash.



Photograph 12-13. Blister rash.

Blisters either originate from ionic contamination on the substrate, prior to coating, or are due to soluble material leaching out from the coating itself and migrating to the interface with the substrate. Driven by osmosis, water will always migrate through the film and when the osmotic pressure within the blister balances the coating adhesion around its circumference, the blister ceases to grow.

Blisters are also associated with areas of corrosion. In this instance, their growth is electrochemically driven and complex rules govern their eventual size. Typically, blisters do not show corroded steel underneath (due to the highly alkaline blister fluid) and such cathodic blisters are of concern only in areas where they can be broken mechanically e.g. by the action of water or foot traffic. It is recommended that blisters containing high pH fluid should not be broken unless a complete repair of coating of an area is undertaken. If the blisters become deflated or leak fluid, then the coating should be repaired as soon as possible.

3.4 Edge breakdown

One of the areas to exhibit early coating breakdown is the edge of stiffeners (Photograph 12-14) and around cut outs (Photograph 12-15), which frequently fail through edge breakdown mechanisms.

Special care should be taken with the coating process in these areas. Edges are to be ground smooth and stripe coats of paint must be applied by hand. Surface tension effects in the wet film, high coating velocity during spraying and poor local surface preparation are common causes of edge breakdown.



Photograph 12-14. Coating breakdown on stiffener edge.



Photograph 12-15. Coating breakdown around cut out.

3.5 Weld Corrosion

Welds are susceptible to enhanced localized coating breakdown in the same manner as edges. Commonly, two types of weld corrosion occur. The first type of weld corrosion failure is illustrated in Photograph 12-16 where corrosion initiates on either side of the weld bead in the area associated with the heat affected zone and oxide build up from the welding process. Coating breakdown is associated with poor surface preparation after welding.

The second type of weld coating failure occurs much closer to the weld and is again associated with poor surface cleanliness prior to coating. An example is shown in Photograph 12-17. Over thickness at the edges of the weld bead is also a contributing factor to weld corrosion. Weld spatter, (which takes the form of small beads of metal close to the weld) can cause micro-blistering if over coated.



Photograph 12-16. Corrosion around weld.



Photograph 12-17. Corrosion at welds.

3.6 Calcareous deposit induced coating failures

The presence of sacrificial anodes in ballast tanks induces the formation of hydroxyl ions at the coating/metal interface, which results in inhibiting or preventing corrosion from occurring beneath the coating. A side effect is that a white, chalky material (called calcareous deposit) forms beneath the coating.

The calcareous deposit originates partially from the reaction of carbon dioxide with the hydroxyl ions and partly as the result of semi-soluble carbonates being deposited from the sea water. When the cathodic protection system is working well, the volume of the deposits is sufficient to fill in cracks in the damaged area, as shown in Photograph 12-18.



Photograph 12-18. Well performing cathodic protection system, with tight calcareous deposits.

When the anodes are overworked, then the voluminous deposits forming beneath the coating can lever it off the steel, as shown in Photograph 12-19.



Photograph 12-19. Voluminous calcareous deposits.

3.7 Poor surface preparation

The most common cause of coating failure is poor surface preparation. However, when the coating is also poorly applied or too thin, then failures of the type shown in Photograph 12-20 tend to occur. In practice, a combination of blistering and corrosion may be observed at the failed area.



Photograph 12-20. Example of poor surface preparation prior to coating.

3.8 Reverse impact damage

Reverse impact damage occurs on the inside of ballast tanks due to a sharp, high intensity impact from the outside of the tank. It is extremely common in bulk carriers, particularly on the hopper sides due to the action of grabs. The underside of the double bottom also receives many reverse impacts from grabs and bulldozers. A typical example is shown in Photograph 12-21, which illustrates the shatter patterns that result from the coating failing in a brittle manner.



Photograph 12-21. Reverse impact from grab causing brittle coating to shatter.

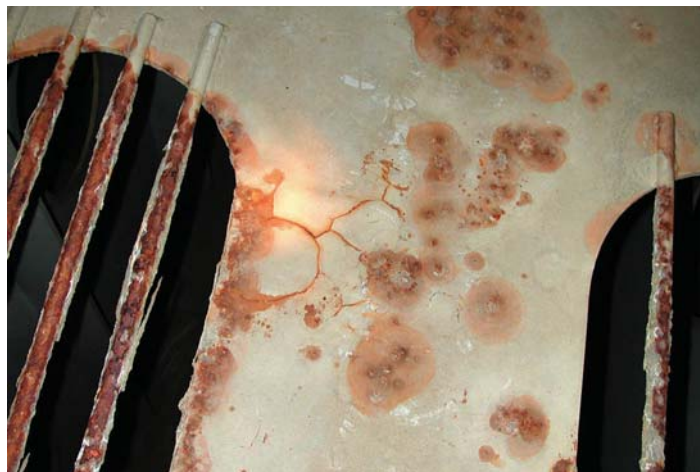
Reverse impact damage is also common in the shell plating in way of and above the water line on the vessel. It is especially common around tug contact areas, where the vessel changes shape forward and also in way of the forepeak tank as a result of collisions with floating objects or piers and mooring facilities (Photograph 12-22). These types of reverse impact damages are usually slower than grab damage and result in distortion of the coating, which in turn leads to through film corrosion at the damaged site.



Photograph 12-22. Reverse impact from external collision.

3.9 Mud cracking

Cracks in a typical pattern extend down from the surface of the coating and can reach the coating/metal interface. Mud cracking is generally a result of either a very high buildup of coating (high DFT) or can be due to excessive thinning in conjunction with thick films. Often the interface with the steel is weakened and corrosion quickly initiates in the cracks. Very thick paint that cracks often detaches from the steel, due to internal stresses in the coating, leaving exposed metal. Mud cracking of coatings typically takes the form shown in Photographs 12-23 and 12-24.



Photograph 12-23. Typical mud cracking in a thick coating.



Photograph 12-24. Mud cracking of a very thick coating.

3.10 Stress-related coating failures

Corrosion can initiate at heavily stressed areas within tanks. Stress-related coating failures can be recognized by their location or by the presence of a repetition of the same failure in the same place along the length of a structure, as shown in Photograph 12-25.



Photograph 12-25. Stress-induced coating failure.

Often stress-related coating failures can initiate at cut outs as shown in Photograph 12-26 or at the toes of welds as shown in Photograph 12-27. Both stress and strain are causes of the coating failure. Stress concentrations can cause local anodic areas to develop, which then concentrates corrosion at that location. Strain can lead to cracking and detachment of the coating, due to differences in mechanical properties between the coating and the underlying steel.



Photograph 12-26. Stress corrosion at cut outs.



Photograph 12-27. Stress induced corrosion at toes of welds.

CHAPTER 13: Assessment of coating breakdown

1 Introduction

The assessment of coating for ballast tanks has been revised and aligned with the IACS Unified Requirements for existing vessels Z10.1 (single hull tankers), Z10.2 and Z10.5 (bulk carriers), Z10.3 (chemical tankers) and Z10.4 (double hull tankers) and the ABS *Rules for Building and Classing Steel Vessels* (paragraphs 7-3-2/1.1.9 and 7-3-2/1.13.5) addressing oil carriers (ESP), chemical tankers and bulk carriers (ESP). This chapter also includes IACS Recommendation 87 for oil carriers.

IMO is also developing requirements addressing the maintenance and repair of protective coatings for vessels in service (IMO MSC.215(82)).

This chapter was developed with the aim to assist surveyors and owners' personnel with grading coating conditions of ballast tanks consistently. This will allow better comparisons of the corrosion and coating condition from each individual survey and provide a manner to monitor the evolution of the coating breakdown and associated increase of corrosion over time.

2 Assessment of existing coating systems for all vessels except tankers

The protective coating system in ballast tanks for all types of ships except oil carriers is required to be maintained in at least FAIR coating condition in order to avoid annual re-examination of the ballast tank. The definition of each grade is shown in Table 13-1 (IMO Resolution A.744(18)):

Rating / Condition	Good	Fair	Poor
Spot Rust Light Rust	Minor	>20%	
Edges and welds		Local break down	
Hard Scale			≥10%
General Breakdown			>20%
Other References			
ISO	RI3	RI4	RI4
European Rust Scale	RE3	RE5	RE7

Table 13-1. Coating and rust ratings.

The frequency of inspections for ballast tanks other than double bottom tanks in the various conditions for single and double side skin bulk carriers (according to ABS Steel Vessels Rules section 7-3-2/1.1.19 and 1.1.10 and IACS Z10.2 and Z10.5) is shown in Table 13-2.

Coating Condition	Ballast Tank Internal Inspection during Periodical Survey															
	S			I		S			I		S			I		S
GOOD	S			I		S			I		S			I		S
FAIR	S			I		S			I		S	A*	A*	I	A*	S
POOR**	S	A	A	I	A	S	A	A	I	A	S	A	A	I	A	S
Vessel Age	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

S: Special Survey
I: Intermediate Survey
A: Annual Survey
A: Annual Survey on minimum 3 ballast tanks (one forward, one amidships, one aft within the cargo hold area other than double bottom tanks) and fore and aft peak*
*** Double bottom tanks with hard coatings of vessels over 5 years of age found in POOR condition and with substantial corrosion are to be surveyed Annually (ABS SVR – 2007 7-3-2/1.1.10(ii))*

Table 13-2. Survey frequency of ballast tanks (other than double bottom and cargo/ballast holds in single and double side skin bulk carriers).

Recognizing that different areas in the tank experience different breakdown and corrosion patterns, it is recommended to divide a tank in logical areas and grade each area separately. The areas of the structure where stresses are high are also those prone to coating breakdown. Typical critical areas of the tank are shown in Figures 13-1 and 13-2.

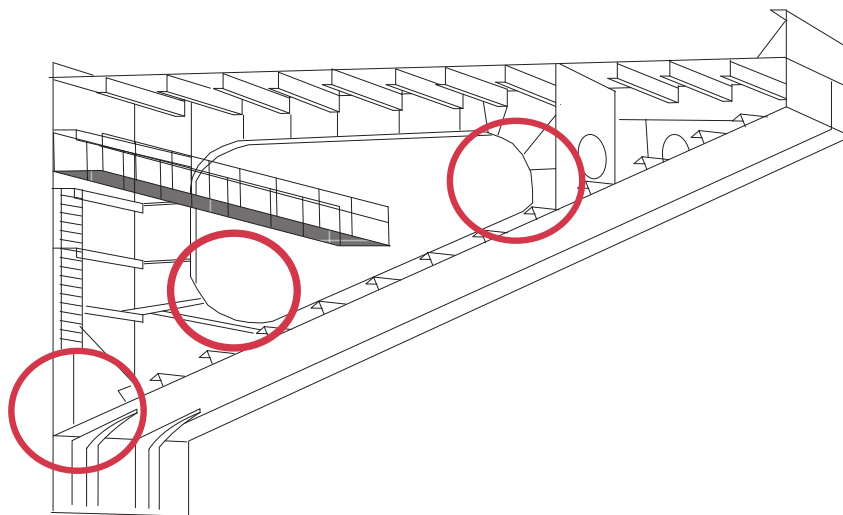


Figure 13-1. Critical areas for corrosion in topside tank of a bulk carrier.

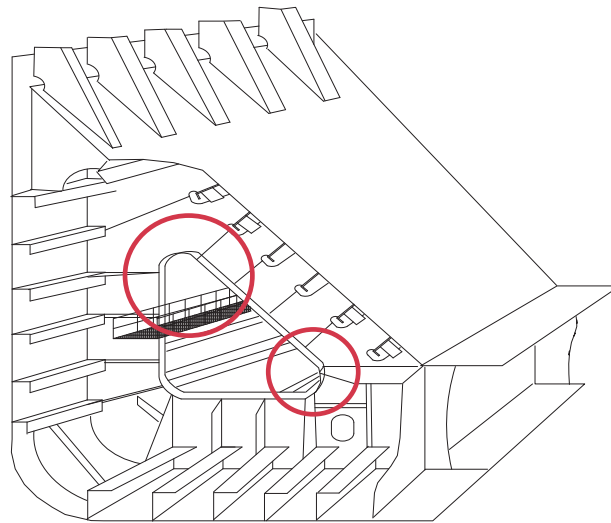


Figure 13-2. Critical areas for corrosion in hopper tank of a bulk carrier.

3 Assessment of existing coating systems cargo holds

Overall and close-up surveys are to be carried out at the intervals noted in Table 13-3.

	Cargo Hold Inspection during Periodical Survey															
Inspections	S		I			S	A	A	I	A	S	A	A	I	A	S
Vessel Age	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
<i>S: Special Survey</i> <i>I: Intermediate Survey</i> <i>A: Annual Survey</i>																

Table 13-3. Survey frequency of cargo holds in bulk carriers.

Critical areas, as defined per SOLAS Ch. II-1 Part A-1/Reg. 3-6/4.2, are locations which have been identified to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the ship, as shown in Figures 13-3 and 13-4.

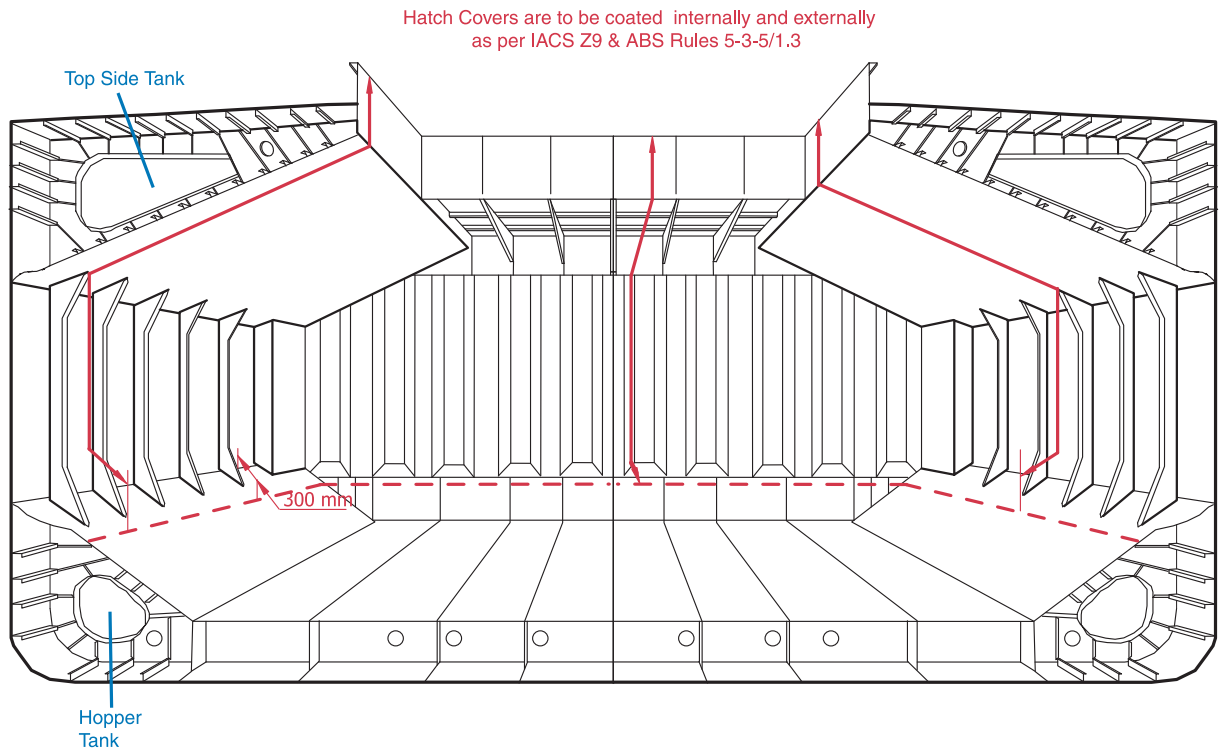


Figure 13-3. Single side skin bulk carrier: typical areas in way of cargo holds required to be coated at new construction.

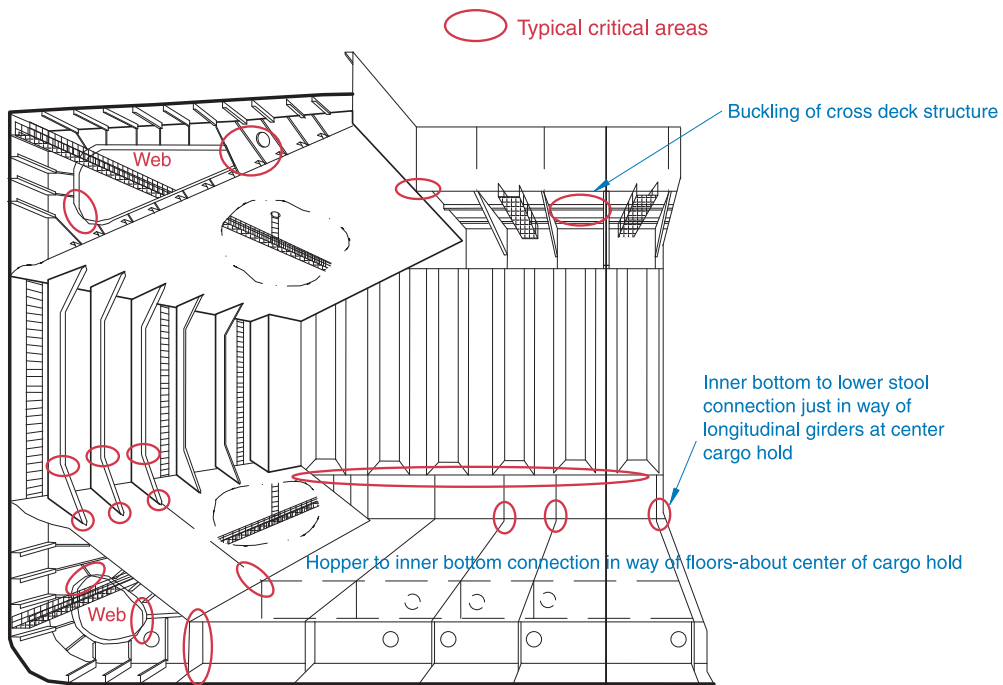


Figure 13-4. Typical areas critical for corrosion in a bulk carrier.

4 Assessment of existing surface coating systems in oil carriers, chemical carriers and double hull oil carriers

The protective coating system in the ballast tanks of oil carriers is required to be maintained in a GOOD coating condition in order to avoid annual re-examination of the ballast tanks. The definition of each grade is shown in Table 13-4 (IACS Rec. 87):

Rating / Condition	GOOD ⁽³⁾	FAIR	POOR
Breakdown of coating or area rusted ⁽¹⁾	<3%	3% - 20%	>20%
Area of hard rust scale ⁽¹⁾	–	<10%	≥10%
Local breakdown of coating or rust on edge or weld lines ⁽²⁾	<20%	20% - 50%	>50%
<p><i>Notes:</i></p> <p>(1) % is the percentage of the area under consideration <i>or</i> of the critical structural area</p> <p>(2) % is the percentage of edges or weld lines in the area under consideration <i>or</i> of the critical structural area</p> <p>(3) spot rusting i.e. rusting in spot without visible failure of coating</p>			

Table 13-4. Coating condition.

Coating Condition	Surveys (Internal Inspection)															
	S			I		S			I		S			I		S
GOOD	S			I		S			I		S			I		S
FAIR or POOR	S	A	A	I	A	S	A	A	I	A	S	A	A	I	A	S
Vessel Age	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
<p><i>S: Special Survey</i></p> <p><i>I: Intermediate Survey</i></p> <p><i>A: Annual Survey</i></p>																

Table 13-5. Sample of frequency of internal inspections for ballast tanks based on coating condition.

4.1 Ballast tanks

Recognizing that different areas in the tank experience different breakdown and corrosion patterns, it is recommended to divide a ballast tank into logical areas and grade each area separately. The coating grade of each area under consideration is to be reported separately. The area under consideration with the lowest rating within any category shall govern the final rating of the ballast tank. Special attention should be given to critical areas of the tank. Figures 13-5 to 13-10 indicate the 14 or 16 areas under consideration as defined in IACS Rec. 87 for tankers.

4.1.1 Single Hull tankers

- 1) Main deck plating and internals
- 2) Bottom plating in way of bilge and internals
- 3) Upper part shell plating and internals
- 4) Middle part shell plating and internals
- 5) Lower part shell plating and internals
- 6) Upper part side skin plating and internals
- 7) Middle part side skin and internals
- 8) Lower part side skin and internals
- 9) Forward Transverse Bulkhead upper part
- 10) Forward Transverse Bulkhead middle part
- 11) Forward Transverse Bulkhead lower part
- 12) Aft Transverse Bulkhead upper part
- 13) Aft Transverse Bulkhead middle part
- 14) Aft Transverse Bulkhead lower part

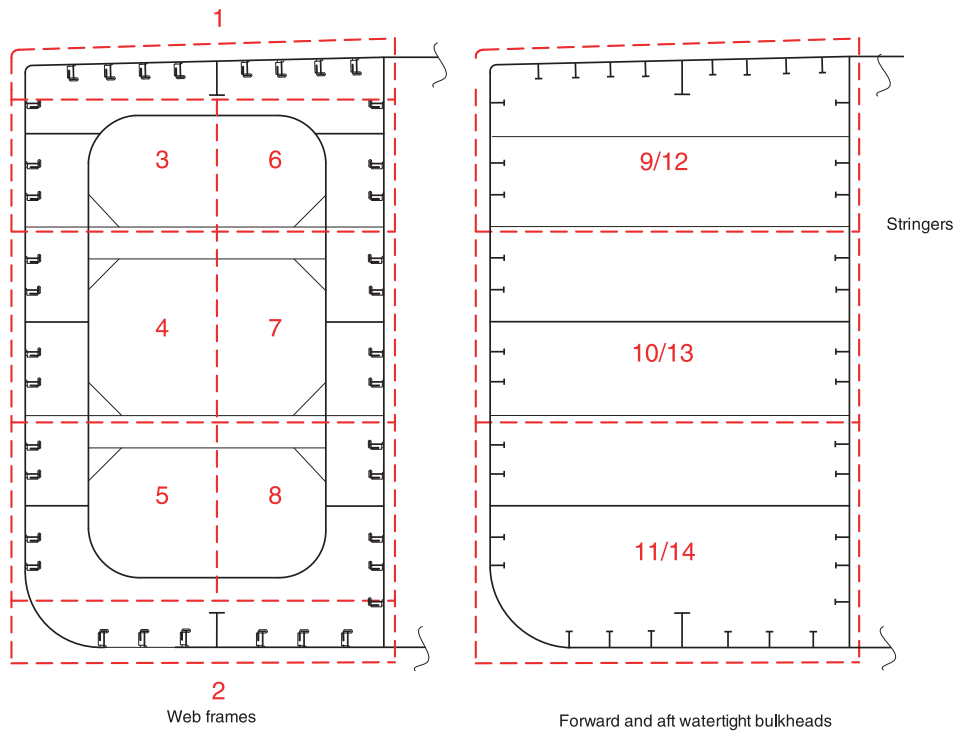


Figure 13-5. Areas of consideration for plating and internals in single hull tanker.

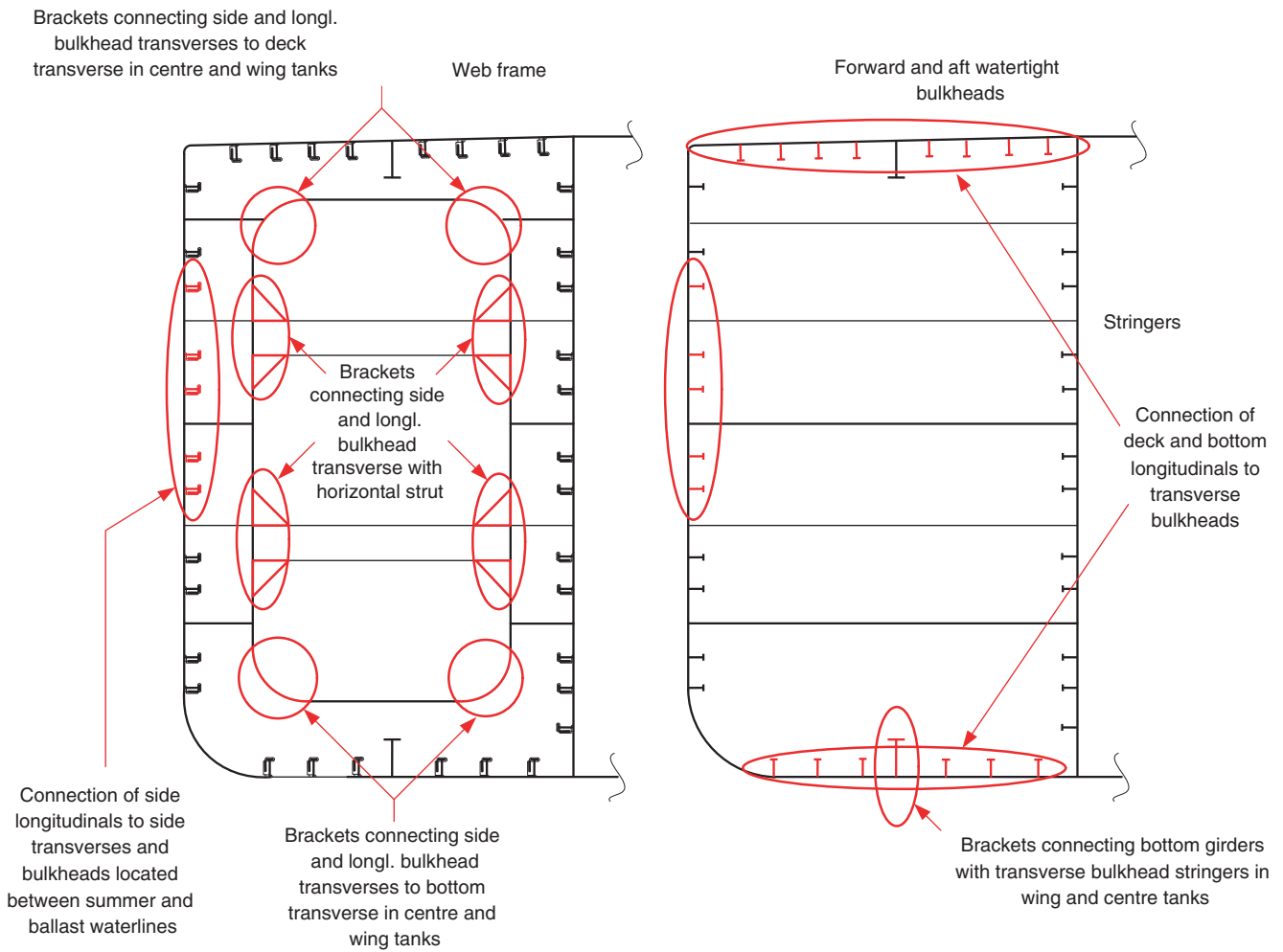


Figure 13-6. Critical areas for corrosion on single hull tankers.

4.2 Double hull tankers

- 1) Main deck plating and internals
- 2) Bottom plating in way of bilge and internals
- 3) Upper part shell plating and internals
- 4) Middle part shell plating and internals
- 5) Lower part shell plating and internals
- 6) Upper part side skin plating and internals
- 7) Middle part side skin and internals
- 8) Lower part side skin and internals
- 9) Forward Transverse Bulkhead upper part
- 10) Forward Transverse Bulkhead middle part
- 11) Forward Transverse Bulkhead lower part
- 12) Aft Transverse Bulkhead upper part
- 13) Aft Transverse Bulkhead middle part
- 14) Aft Transverse Bulkhead lower part
- 15) Inner bottom plating and internals
- 16) Bottom plating and internals

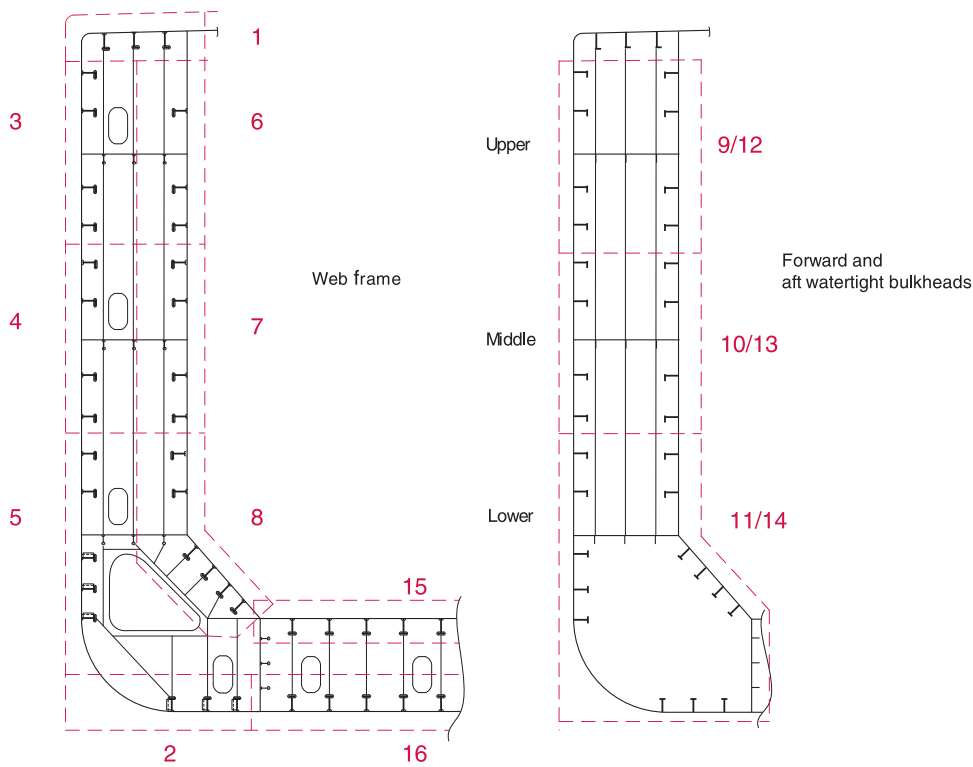


Figure 13-7. Areas under consideration for ballast tanks of a double hull tanker.

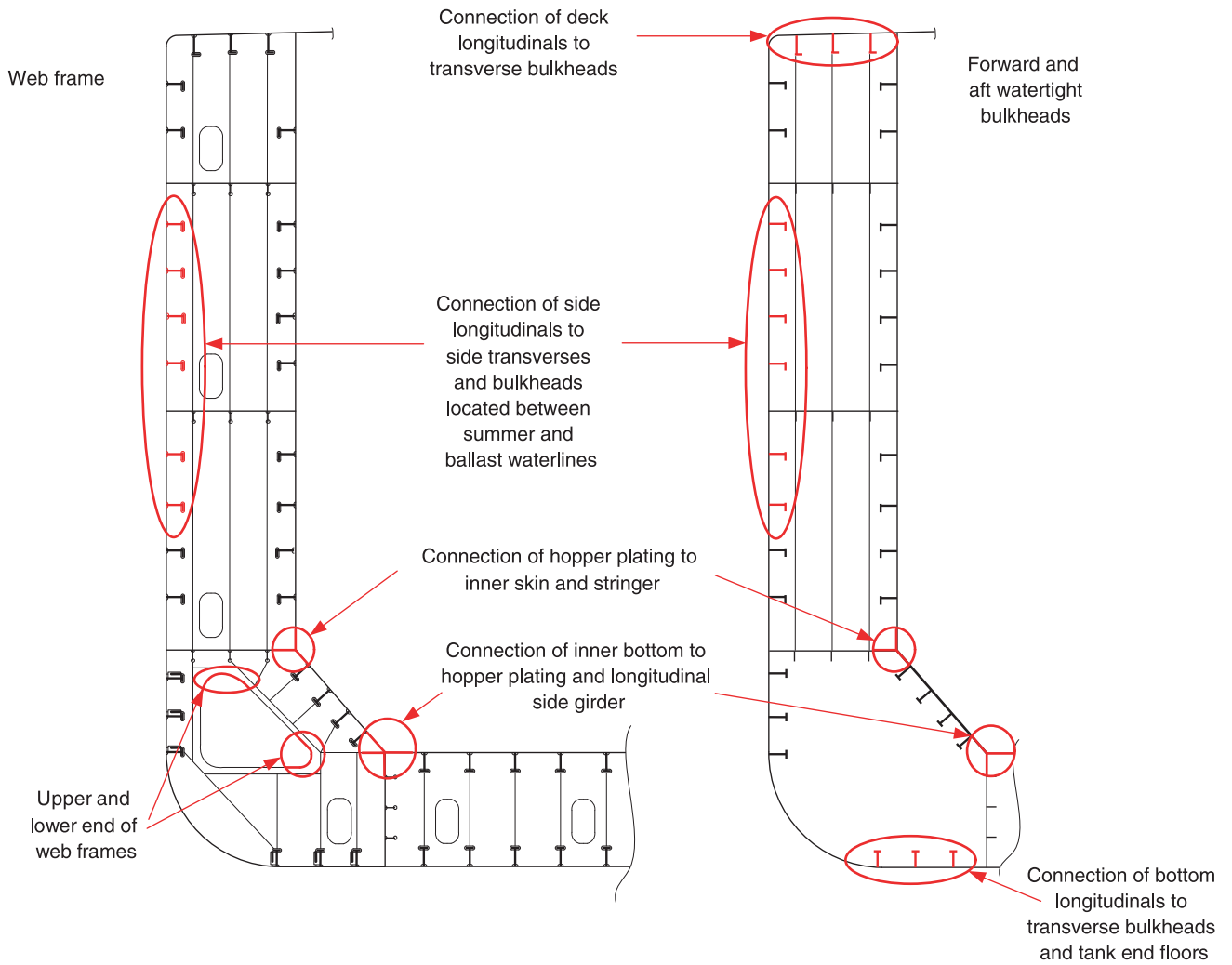


Figure 13-8. Critical areas for corrosion on double hull tankers.

4.3 Peak tanks

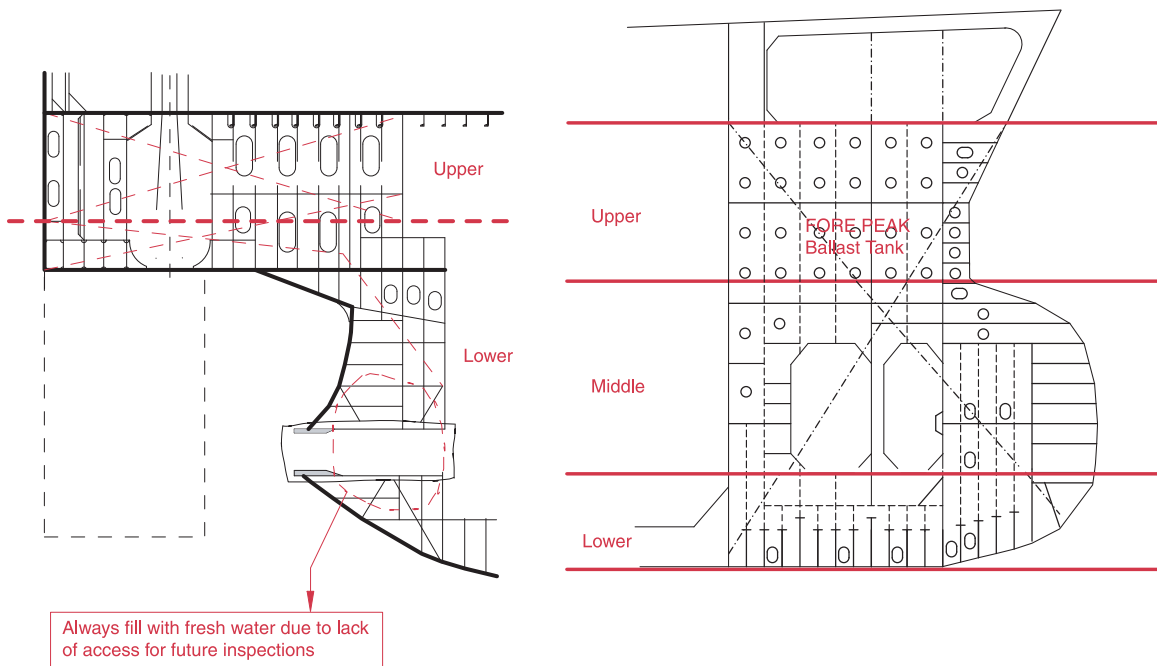


Figure 13-9. Typical areas under consideration in the after peak and fore peak ballast tank on a tanker.

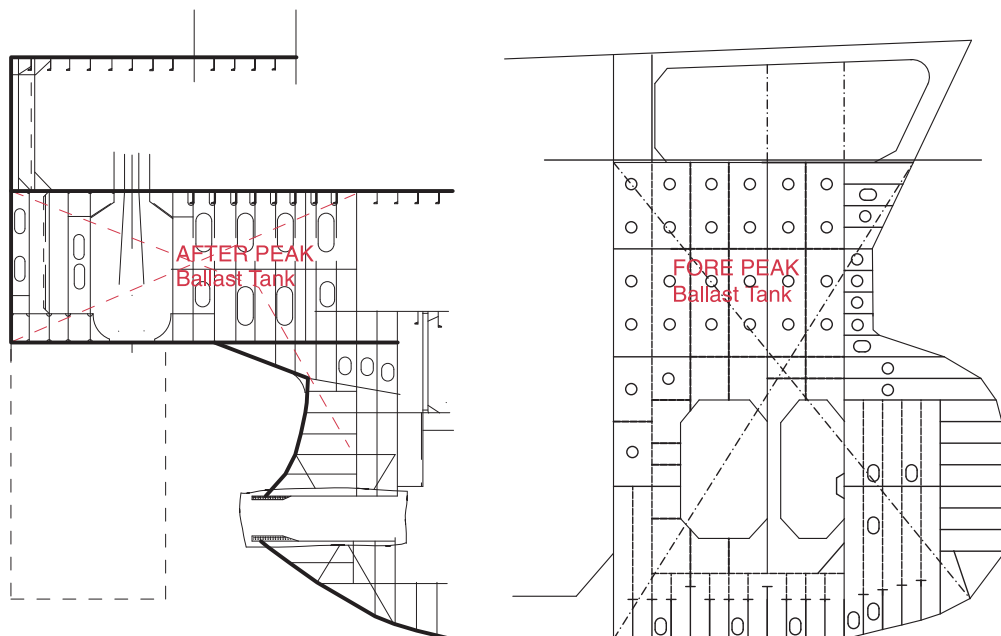


Figure 13-10. Typical areas under consideration in the after peak and fore peak ballast tank of a bulk carrier.

4.4 Assessment scales

In addition to the assessment scales for scattered coating failures and localized coating failures, there is a scale for linear coating failures for the assessment of the breakdown on edges. A combination of these diagrams helps to assess the coating condition of the area under consideration in accordance with the grading definitions.

4.4.1 Scattered coating failures assessment scale

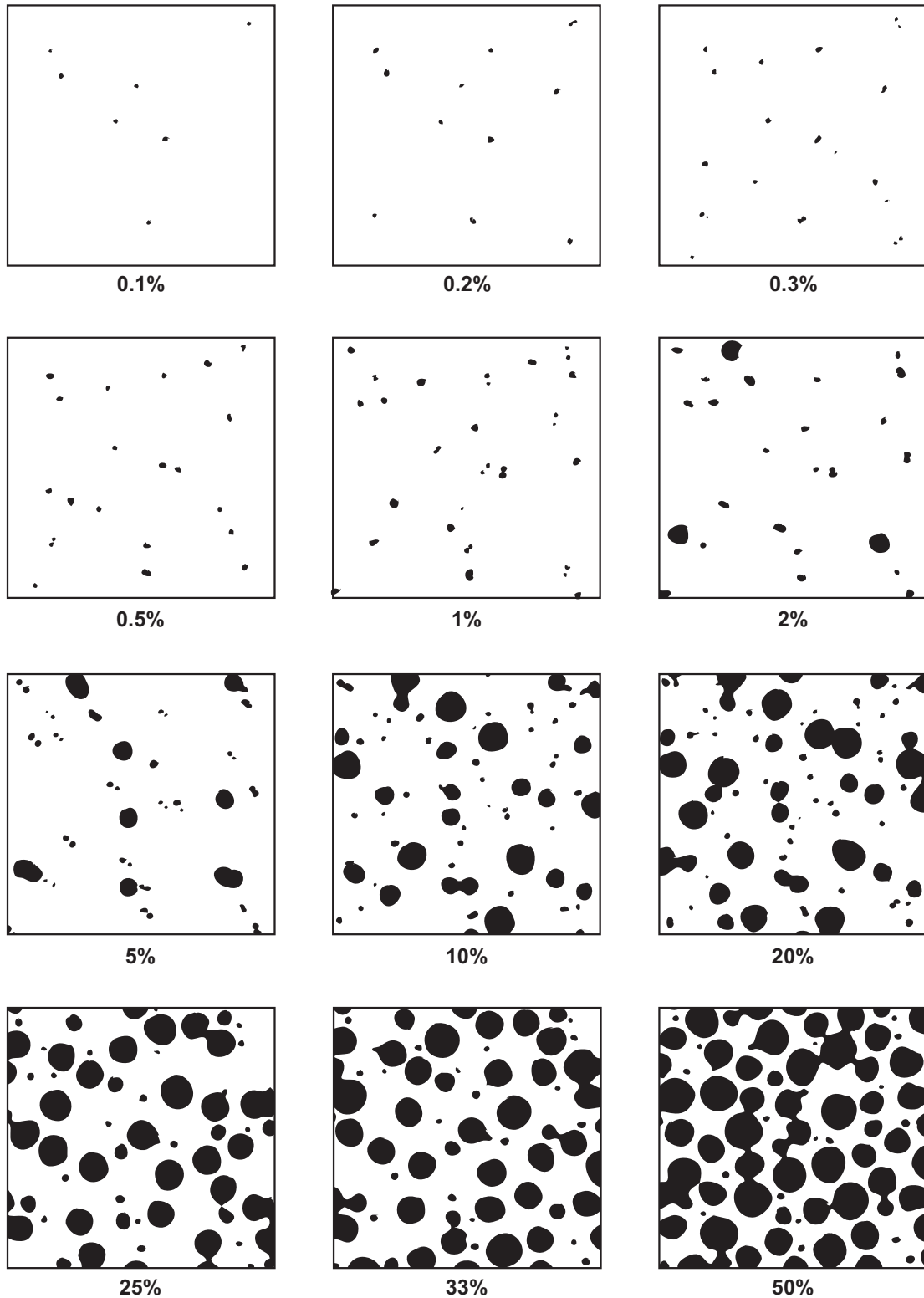


Figure 13-11. Original scatter diagrams for corrosion and coating breakdown assessment.

4.4.2 Localized and scattered coating failures assessment scale

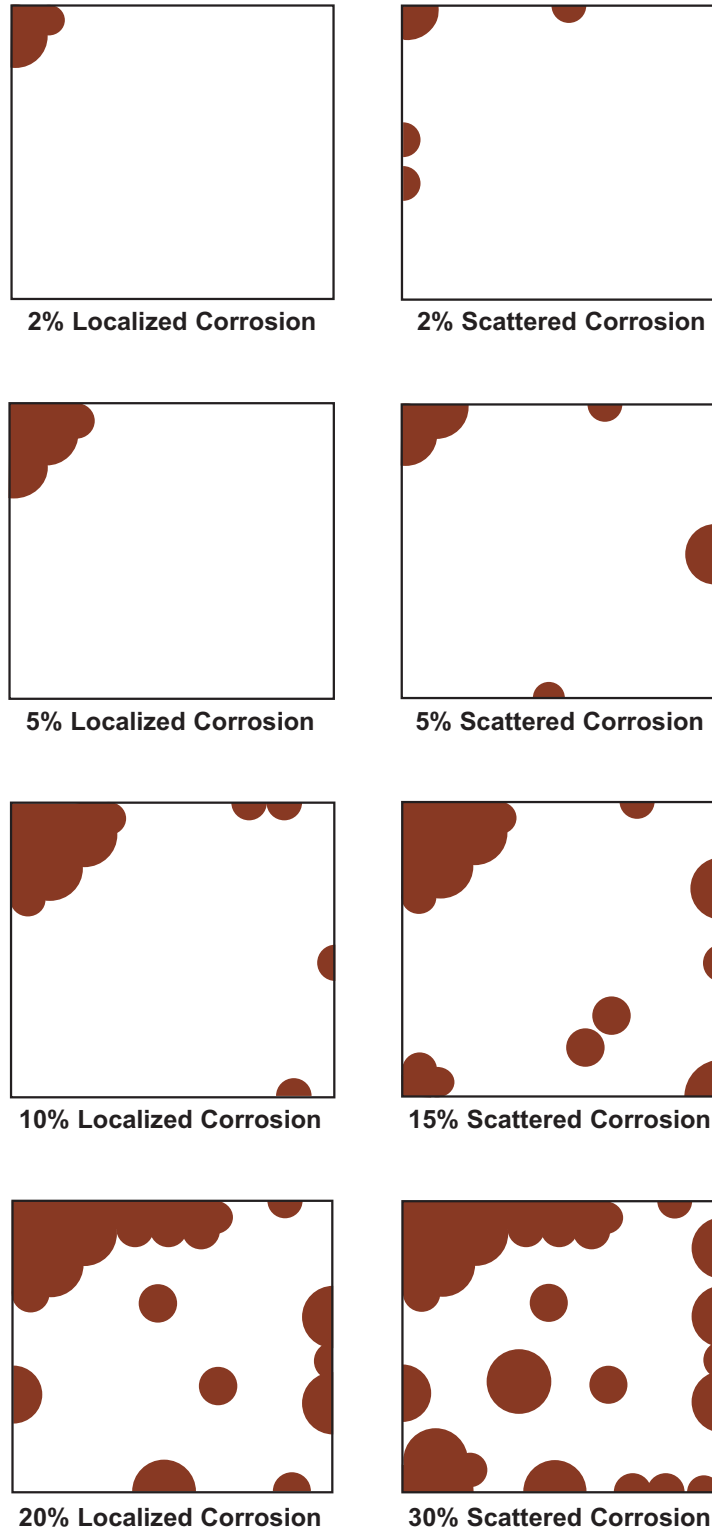
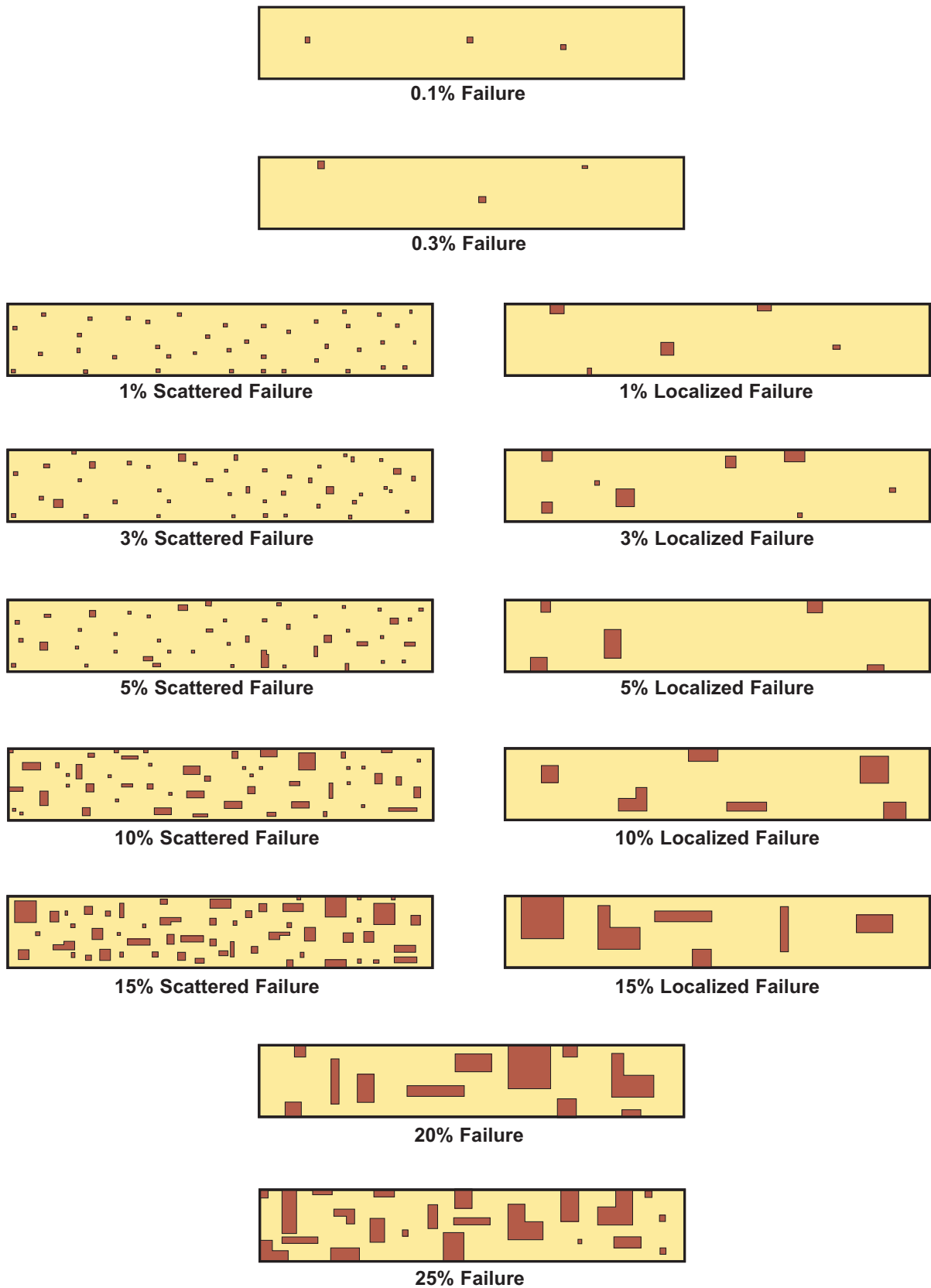


Figure 13-12. New corrosion extent diagrams for localized and scattered corrosion in corners.

4.4.3 Localized and scattered coating failures assessment scale (IACS Rec. 87)



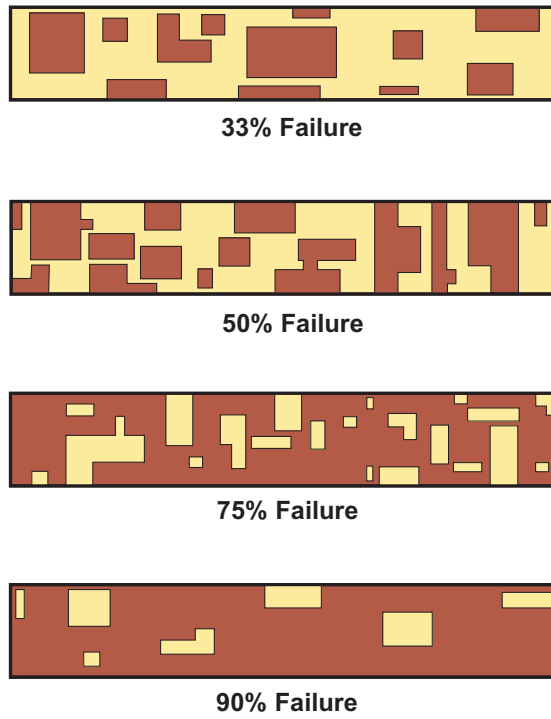


Figure 13-13. Assessment scale of failures IACS Rec. 87.

4.4.4 Linear coating failure assessment scale

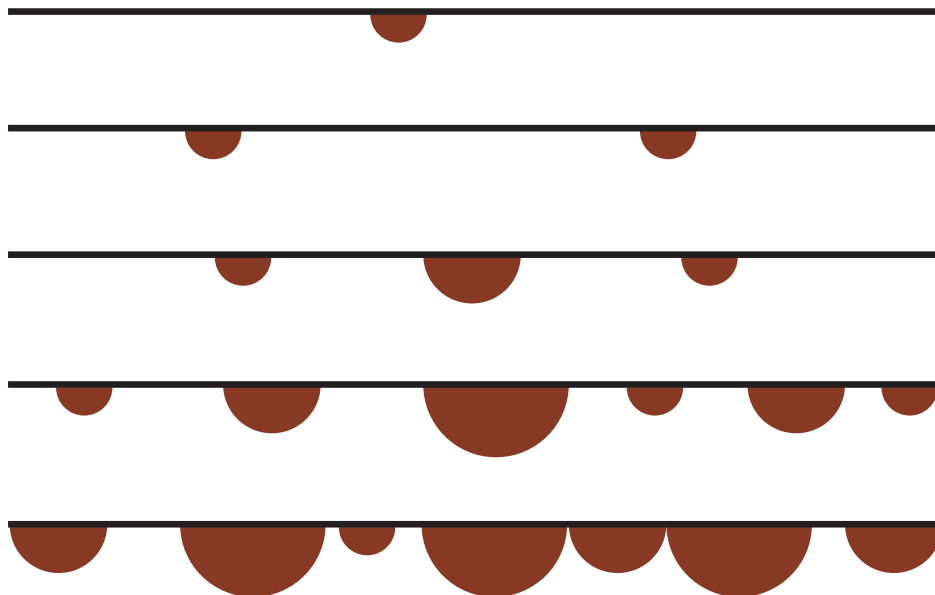


Figure 13-14. Linear extent diagrams.

It should be noted that the areas to be included in the assessment scale are those of actual corrosion and not areas of rust staining. These coating failure assessment scales are designed for use along stiffener edges and on welds. The corrosion may extend to both sides of the arbitrary line.

CHAPTER 14: Examples

This chapter shows photographs of tanks in various stages of coating breakdown. The original area assessment scales, the new linear and localized assessment scales and the Revision 87 charts are shown for comparison.

In many cases, a combination of the available charts allows the most accurate assessment of the overall coating condition.

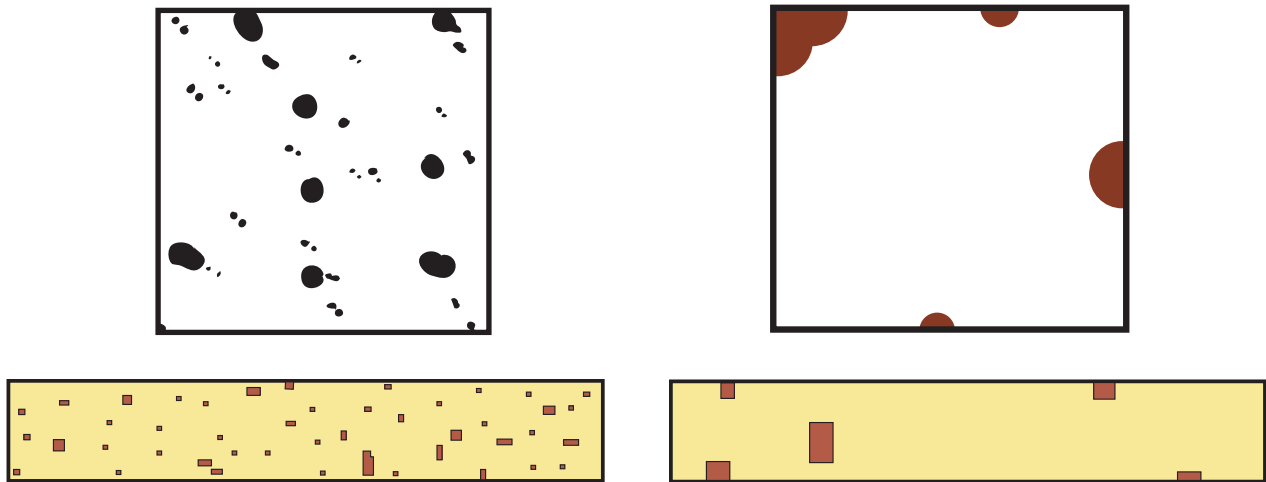


Figure 14-1. Sample assessment scales indicating 5% breakdown.

The linear coating failure assessment scales are to be used exclusively for stiffener edges and welds.



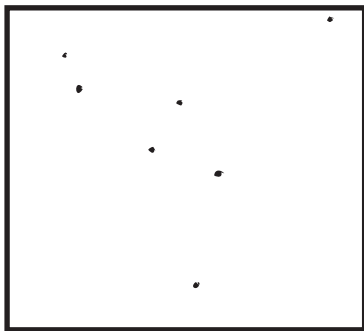
Figure 14-2. Sample linear coating assessment scales indicating 5% edge or weld breakdown

The coating conditions as defined by IMO Resolution A.744(18) are to be used for all vessels except tankers. For single and double hull tankers the coating condition as defined in IACS Recommendation 87 is to be used.

Both assessments in accordance with IMO Res. A.744(18) and IACS Rec. 87 are noted with photographic examples.

Cautionary note: Final assessment of these examples is based on the pictures only and **not** the overall area under consideration

1% Breakdown on Flat Area



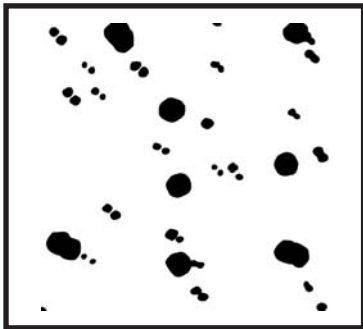
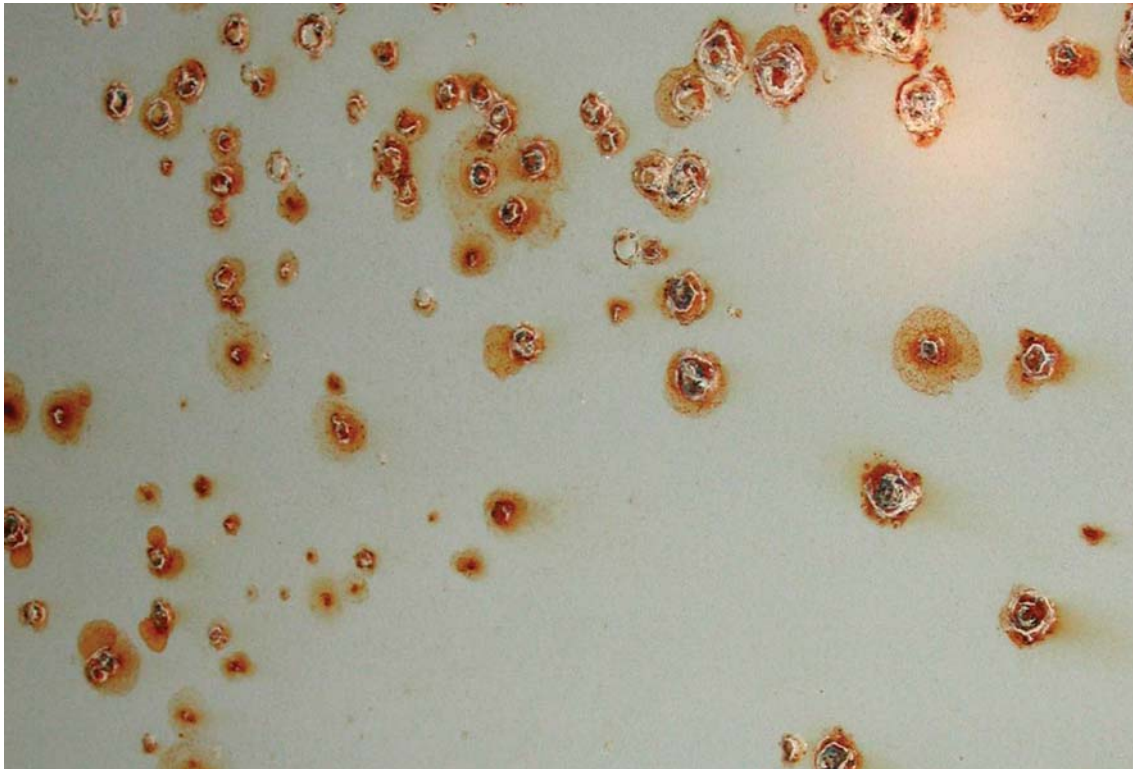
1%



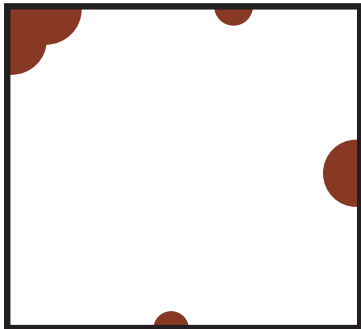
1% Scattered

Final Assessment	Comment
IMOGOOD IACS REC. 87GOOD	Corrosion on flat area: < 1%

5% Breakdown on Flat Area



5%



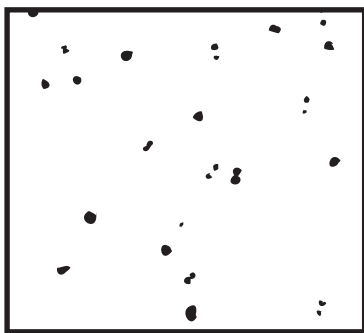
5% Scattered



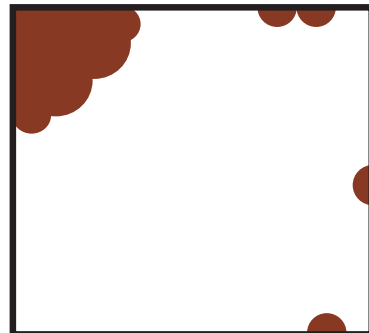
5% Scattered

Final Assessment	Comment
IMOGOOD IACS REC. 87FAIR	Note that the rust staining is not included in the corroded area assessment.

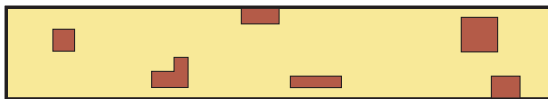
10% Breakdown on Flat Area



10%



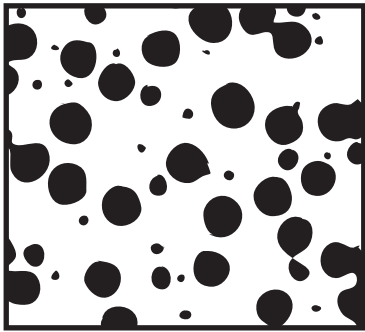
10% Localized



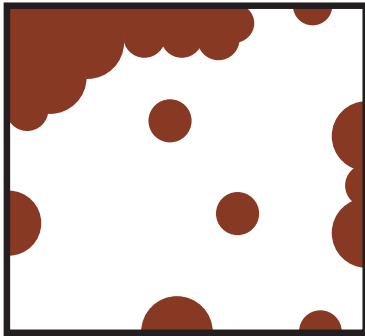
10% Localized

Final Assessment	Comment
IMOFAIR IACS REC. 87FAIR	Corrosion on flat areas: 10%

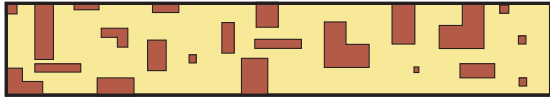
25% Breakdown on Flat Area



25%



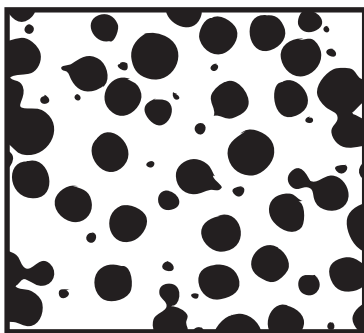
20% Scattered



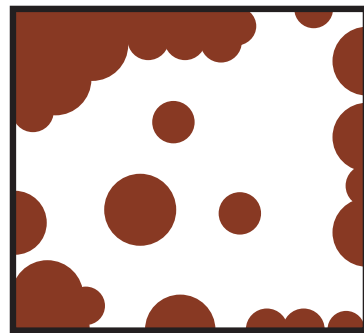
25% Failure

Final Assessment	Comment
IMOPOOR	Corrosion on flat areas: 25%
IACS REC. 87POOR	Hard scale on flat areas: < 10%

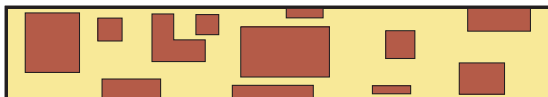
33% Breakdown on Flat Area



33%



30% Scattered



33% Failure

Final Assessment	Comment
IMOPOOR IACS REC. 87POOR	Corrosion on flat area: > 30%

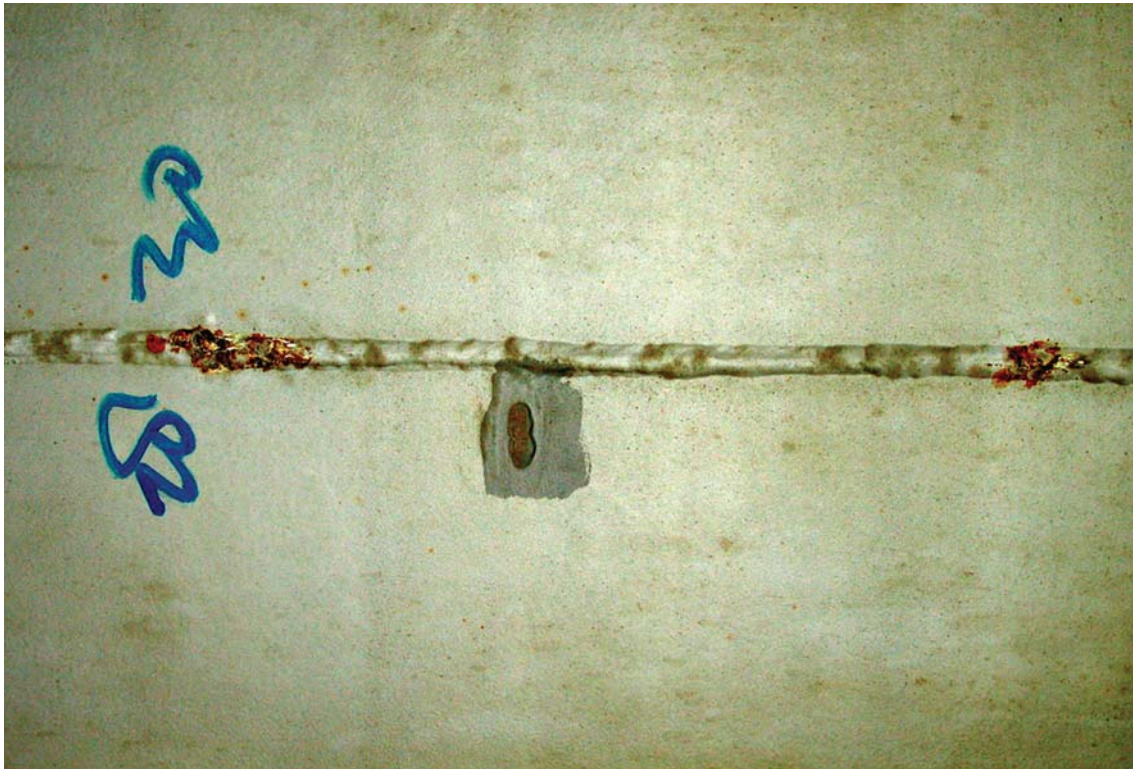
5% Breakdown on Edges / Welds Only



5%

Final Assessment	Comment
IMOGOOD IACS REC. 87GOOD	Corrosion on edges and welds: < 5%

10% Breakdown on Edges / Welds Only



10%

Final Assessment	Comment
IMOGOOD IACS REC. 87GOOD	Corrosion on edges and welds: < 10%

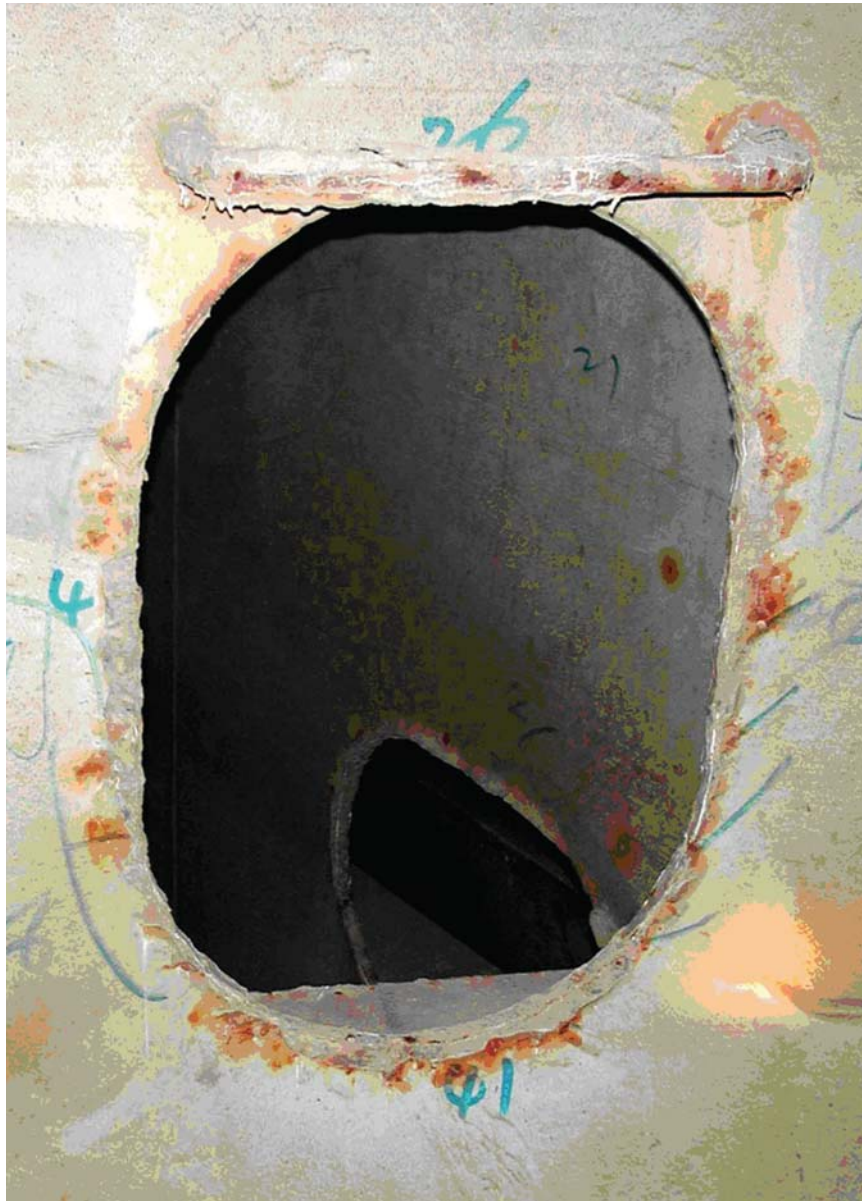
10% Breakdown on Edges / Welds Only



10%

Final Assessment	Comment
IMOGOOD IACS REC. 87GOOD	Corrosion on edges and welds: < 10%

50% Breakdown on Edges / Welds Only



50%

Final Assessment	Comment
IMOFAIR/POOR IACS REC. 87POOR	Corrosion on edges and welds: > 50% IMO Assessment of FAIR or POOR depends on the condition of flat surfaces It is the actual area of corrosion that is determined, not the extent of rust staining

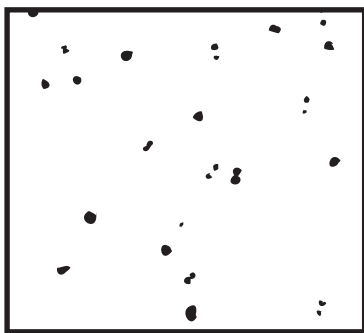
80% Breakdown on Edges / Welds Only



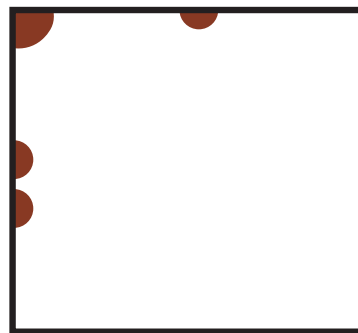
80%

Final Assessment	Comment
IMOFAIR/POOR IACS REC. 87POOR	Corrosion on edges and welds: > 50% IMO Assessment of FAIR or POOR depends on the condition of flat surfaces

Coal Tar Epoxy GOOD Condition



1%



2% Scattered



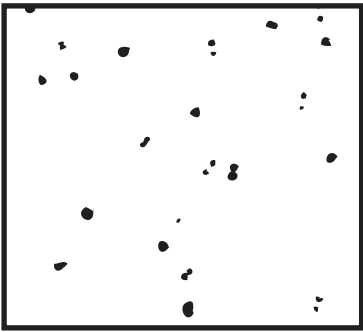
1% Scattered



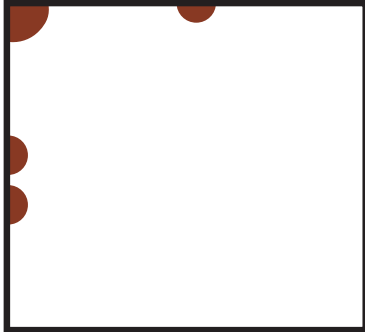
5%

Final Assessment	Comment
IMO PSPCGOOD	Corrosion on flat areas: < 1%
IACS REC. 87GOOD	Corrosion on edges and welds: < 5%

Coal Tar Epoxy Ballast Coating in GOOD Condition



1%



2% Scattered



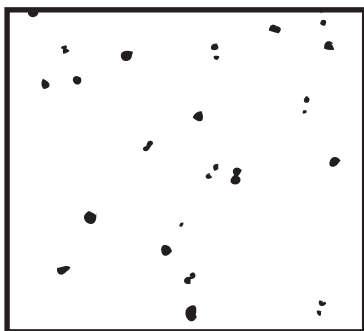
1% Scattered



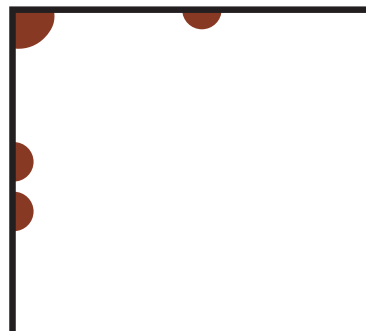
5%

Final Assessment	Comment
IMOGOOD	Corrosion on flat areas: < 1%
IACS REC. 87GOOD	Corrosion on edges and welds: < 5%

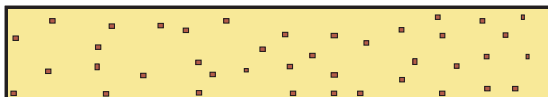
Coal Tar Epoxy Ballast Coating in GOOD Condition



1%



2% Scattered



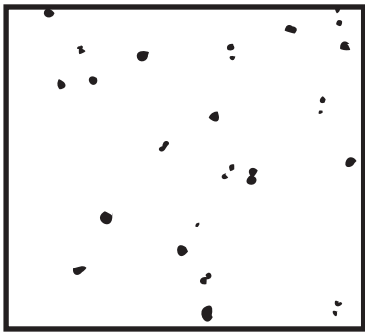
1% Scattered



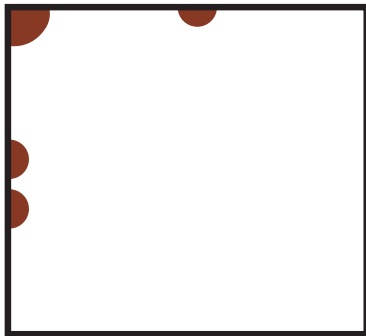
5%

Final Assessment	Comment
IMOGOOD	Corrosion on flat areas: < 1%
IACS REC. 87GOOD	Corrosion on edges and welds: < 5%

Coal Tar Epoxy – GOOD/FAIR Condition



1%



2% Scattered



1% Scattered



20%



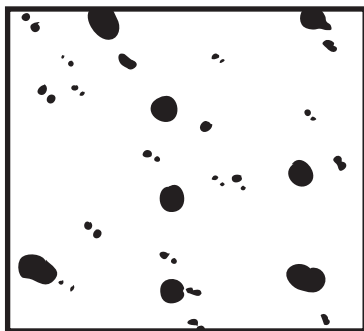
1% Localized



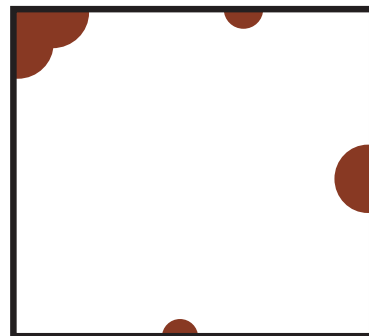
50%

Final Assessment	Comment
IMOGOOD	Corrosion on flat areas: < 1%
IACS REC. 87GOOD	Corrosion on edges and welds: 20% - 50%

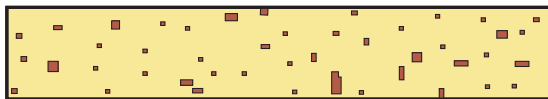
Coal Tar Epoxy in FAIR/POOR condition



5%



5% Scattered



5% Scattered



20%



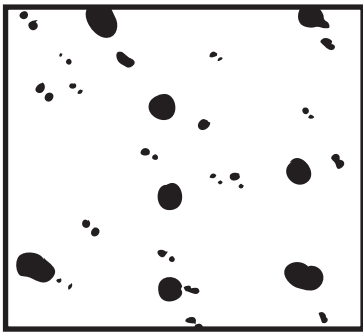
5% Localized



50%

Final Assessment	Comment
IMOFAIR	Corrosion on flat areas: > 5%
IACS REC. 87POOR	Corrosion on edges and welds: 40%

Coal Tar Epoxy Ballast Coating in FAIR Condition



5%



5% Localized



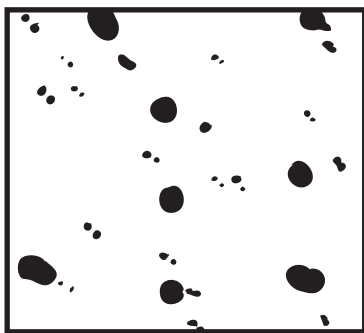
5% Localized



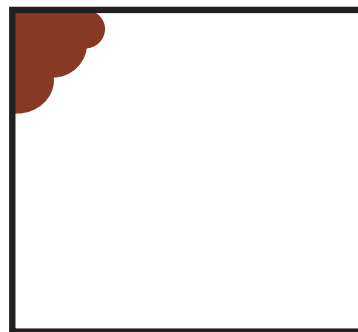
50%

Final Assessment	Comment
IMOFAIR	Corrosion on flat areas: 5%
IACS REC. 87FAIR	Corrosion on edges and welds: > 50%

Coal Tar Epoxy Ballast Coating in POOR Condition



5%



5% Localized



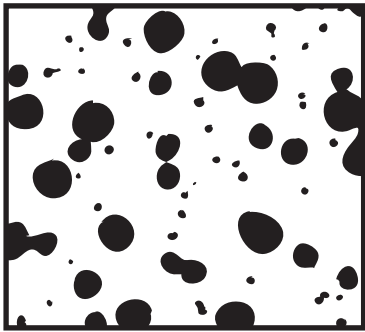
5% Localized



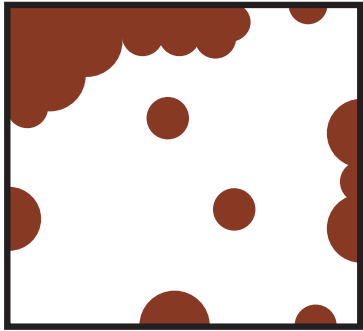
Edges and Welds 80%

Final Assessment	Comment
IMOPOOR IACS REC. 87POOR	Corrosion on flat areas: < 5% Corrosion on edges and welds: > 80%

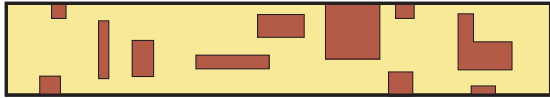
Coal Tar Epoxy in POOR Condition



20%



20% Scattered



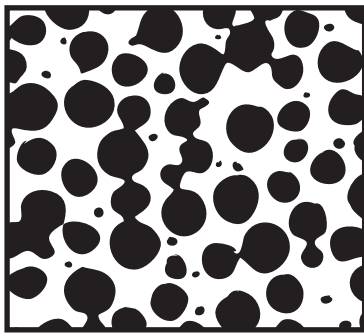
20% Scattered



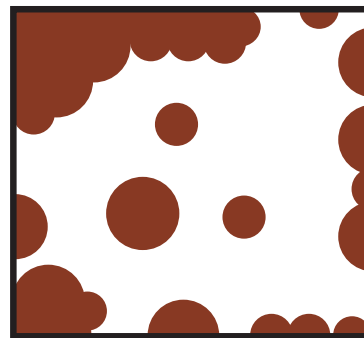
20%

Final Assessment	Comment
IMOPOOR	Corrosion on flat areas: 20%
IACS REC. 87POOR	Corrosion on edges and welds: 20%

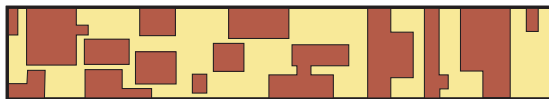
Coal Tar Epoxy in POOR Condition



50%



30% Scattered



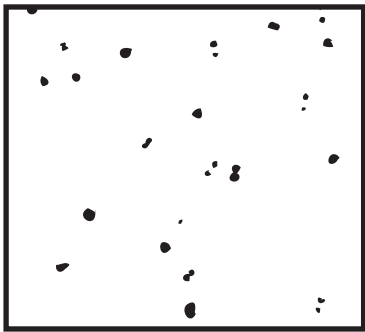
50% Scattered



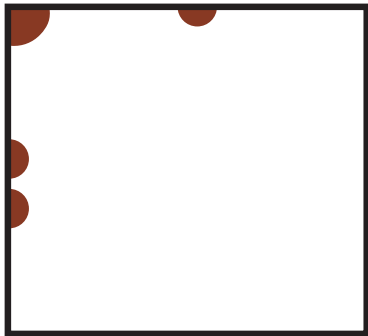
20%

Final Assessment	Comment
IMOPOOR	Corrosion on flat areas: > 50%
IACS REC. 87POOR	Corrosion on welds and edges: 20%

Light Colored Ballast Tank Coating in GOOD Condition



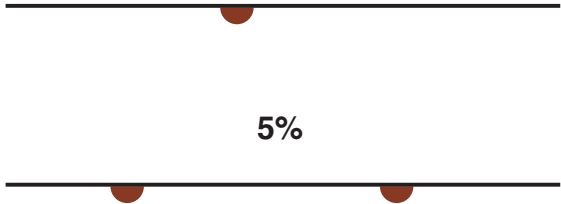
1%



2% Scattered



1% Scattered

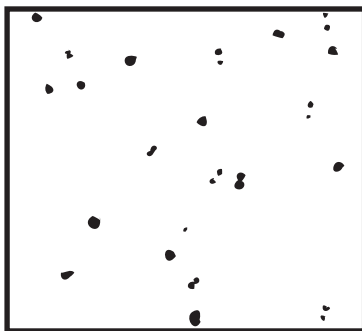


5%

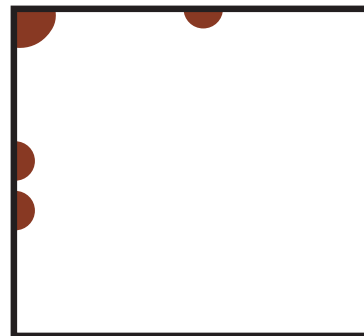
10%

Final Assessment	Comment
IMOGOOD	Corrosion on flat areas: < 1%
IACS REC. 87GOOD	Corrosion on edges and welds: 5% - 10%

Light Colored Ballast Tank Coating in GOOD/FAIR Condition



1%



2% Scattered



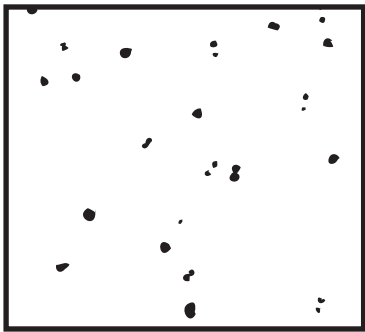
1% Localized



20%

Final Assessment	Comment
IMOGOOD	Corrosion on flat areas : < 1%
IACS REC. 87GOOD	Corrosion on edges and welds: < 20%

Light Colored Coating in GOOD Condition



1%



2% Localized



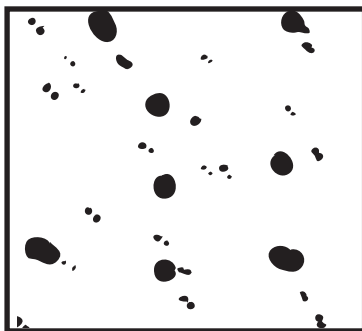
1% Scattered



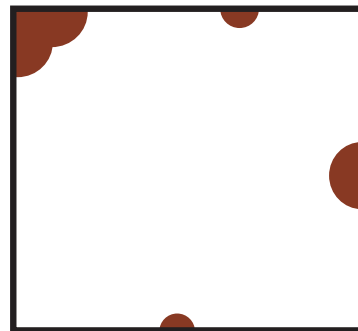
5%

Final Assessment	Comment
IMOGOOD IACS REC. 87GOOD	Corrosion on flat areas: < 1% Corrosion on edges and welds: < 5% Picture is of double hull WBT connection between transverse bulkhead and side shell with PMA

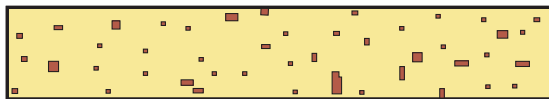
Light Colored Ballast Coating in GOOD / FAIR Condition



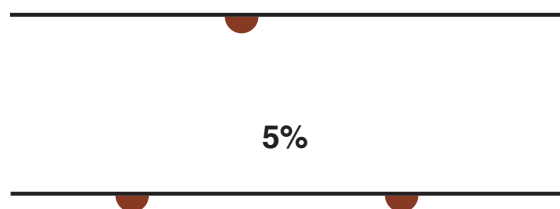
5%



5% Scattered



5% Scattered

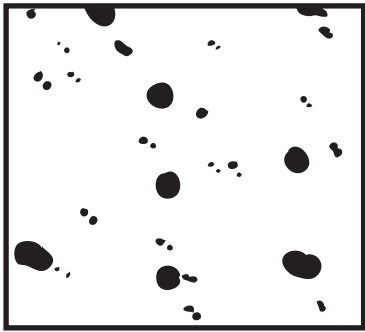


5%

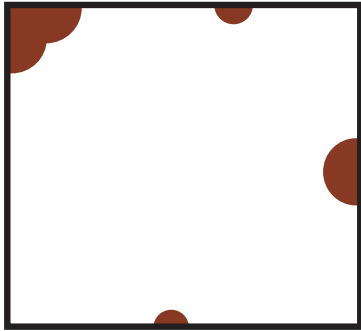
10%

Final Assessment	Comment
IMOGOOD	Corrosion on flat areas: < 3%
IACS REC. 87GOOD	Corrosion on edges and welds: < 10%

Light Colored Coating in FAIR Condition



1%



5% Scattered



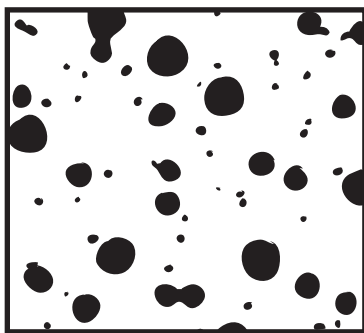
5% Localized



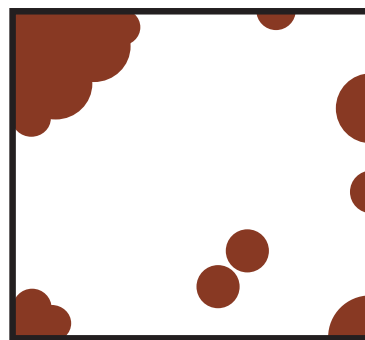
20%

Final Assessment	Comment
IMOFAIR IACS REC. 87FAIR	Corrosion on flat areas: < 5% Corrosion on edges and welds: < 20%

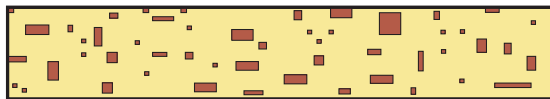
Light Colored Coating in POOR Condition



10%



15% Scattered



10% Scattered



50%

Final Assessment	Comment
IMOPOOR	Corrosion on flat areas: > 10%
IACS REC. 87POOR	Corrosion on edges and welds: > 50%

CHAPTER 15: Glossary and definitions

Air drying paints:	Paints which dry and form a film when exposed to air, without any external heat being applied.
Airless spray:	A method of paint spraying which does not use compressed air to atomise the paint. In this method, the paint is put under great pressure (up to 5000 psi - 360 kg/cm ²) by a compressed air driven pump and is atomised by being forced through a small nozzle. Airless spray is a very fast and efficient method of application since the paint is forced into the surface at very high speed, which assists in wetting the surface.
Alkyd:	A synthetic resin made by reacting two chemicals in the presence of a natural or processed oil. Because of the wide variety of possible constituents, alkyds can be 'tailor-made' to meet conditions found in practice.
Anode:	A piece of metal fixed to steel to provide cathodic protection. Anodes must be fixed so that they are in electrical contact with the steel they have to protect, and must not be greased or painted.
Antifouling:	For underwater use on hulls. Contains biocides which are released and which prevent the adhesion and growth of organisms on the hull. See also foul release coatings.
Binder:	The component in paint or varnish which binds the constituents to the surface. Paints are usually named after the binder type.
Bleached tar epoxy:	See modified epoxy.
Cathodic protection:	A method of controlling the corrosion of steel either by attaching a sacrificial anode or by the use of impressed current. Coatings used with cathodic protection systems must be resistant to alkali.
Coal tar epoxy:	A combination of epoxy resins, tar and a curing agent, which produces a very water resistant film.
CPS:	ABS notation given to a vessel when it complies with the <i>ABS Coating Performance Standard Guide (CPS)</i> .
CSR:	Common Structural Rules, refer to <i>ABS Rules for Building and Classing Steel Vessels, Part 5A (Double Hull Oil Tankers)</i> and <i>Part 5B (Bulk Carriers)</i> .
CTF:	Coating Technical File is a document that contains information on the coatings applied during new construction, inspection and maintenance of the coating.
Dew point:	The temperature at which air is saturated with moisture.
DFT:	The Dry Film Thickness is the thickness of the paint or coating system after it has cured.
Dust:	Loose particle matter on a surface prepared for painting which may arise from blast-cleaning or other surface preparation processes, or resulting from the action of the environment.
Edge grinding:	The treatment of edges before secondary surface preparation
Emulsion paints:	Paints in which the binder is dispersed in water e.g. polyvinyl acetate (PVA), acrylics, etc. Paints dry as soon as the water evaporates and the emulsified droplets of resin join together to form a solid film.
Epoxy:	Epoxy resins which are cured by chemically reacting with a curing agent such as amines, amine adducts and polyamides. Properties can be tailored to meet a wide range of needs.
Epoxy mastic:	Originally a high-build epoxy containing a high level of thixotropes. Also see modified epoxy.

Flashpoint:	The temperature at which the vapour of a material will be ignited by a spark or open flame. It is measured under standardised conditions.
Foul release coatings:	Antifouling paints which do not contain biocides and which have a low free energy surface unattractive to fouling organisms.
GOOD:	The coating condition with minor spot rusting as defined in resolution A.744(18). See also IACS Rec. 87.
Hard coatings:	A coating which chemically converts during its curing process, normally used for new construction, or non-convertible air drying coating which may be used for maintenance purposes. Hard coatings can be either inorganic or organic.
Induction time:	The period of time which must elapse between mixing the paint and its application, for some two pack materials.
Latex:	A resin used in emulsion paints.
Mix ratio:	For a two pack system, the mix ratio is the relative quantity of each pack.
Modified epoxy:	Also called epoxy mastic, tar free or bleached tar epoxy. An epoxy paint, containing non-epoxy polymers, which can be cross linked into the film. Non reactive polymers, either solid or liquid, may also be included to provide specific properties in the final film.
NDFT:	The Nominal Dry Film Thickness is the thickness of the paint coat after it has cured. A 90-10 practice means that 90 percent of all thickness measurements shall be greater than or equal to NDFT and none of the remaining 10 percent measurements shall be below 0.9 x NDFT.
Organotin compounds:	These are chemical compounds based on tin with hydrocarbon constituents. Triorganotins are very toxic. Depending on the organic groups, they can be powerful bactericides and fungicides. Tributyltins were used in marine anti-fouling paint, however now they cannot be applied to larger vessels.
Pigments:	Powders dispersed in resins which give the paint its color, finish and protective properties.
Polymer:	A high molecular weight material created from lower molecular weight constituents by chemical reaction. Polymers with resinous characteristics are frequently used in paints.
Polyurethane:	Paints based on polyurethane are usually two pack, are extremely hard wearing, and are generally resistant to chemicals. They may be formulated to be exceptionally color stable and weather resistant.
Pot life:	The time for which a two pack paint or varnish be applied by the method specified (usually spray) before it should be discarded. The paint should be used within this time, since the curing will be so far advanced by then that the paint will not behave in the normal manner. Paint must never be allowed to remain in spray equipment after the expiration of the pot life.
PR 34:	IACS Procedural Requirement No 34: Application of IMO Performance Standard for Protective Coatings (PSPC), Resolution MSC.215(82), under IACS Common Structural Rules for Bulk Carriers and Oil Tankers.
PSPC:	Performance Standard for Protective Coatings.
Pure epoxy:	A paint where the binder is based on epoxy polymers only.
PVA paint:	See emulsion paints.
Resin:	A material used as a binder constituent which forms a non-crystalline film when dried.

Semi-hard coating:	A coating which dries in such a way that it stays flexible, but still hard enough to touch and walk upon. These coatings do not appreciably erode with the usual ballast water movement. Since 1 July 1998 semi-hard coatings have not been applied to ballast tanks of new vessels.
Shop-primer:	A rust inhibiting primer designed to protect steel from general weathering immediately after plate fabrication. At new building yards the shop primer is applied to steel plates and profiles after blasting and before construction, often in automated plants. Shop primers can be welded and are used to protect the surface from corrosion during construction and until the final paint system is applied.
Soft coatings:	A coating that remains soft so that it is removed easily at low mechanical impact or when touched by hand, these coatings are generally used to give temporary protection to existing structures. Not applied to ballast tanks since 1 July 1998 unless this type of coating had been previously applied before that date.
Spreading rate:	The area which is covered by one liter of paint.
Stripe coating:	Painting method used before or after a general coat on positions (weld, back, edge, corner etc.) where it is not easy to achieve the final thickness with airless spray application.
Surface tolerant:	Coatings which are able to withstand a higher level of surface contamination. Manufacturers' data sheets will specify the type and maximum quantity of contamination.
Target useful life:	The target value, in years, of the durability for which the coating system is designed.
Tar epoxy:	See Coal Tar Epoxy.
Technical Data Sheet:	The paint manufacturer's Product Data Sheet which contains detailed technical information relevant to the coating and its application.
Thermoplastic paints:	Paints which dry by evaporation of solvent only. The binder is un-reactive.
Thixotropic paints:	A paint with a semi-solid or gel consistency when undisturbed but which will flow readily when stirred or shaken, or when being applied. The process is reversible, and a fluid paint reverts to a gel consistency when the disturbance ceases. When applied, thixotropic paints will flow easily as long as they are being worked, but quickly regain a gel consistency which assists in preventing runs and sags.
Two pack paints:	Used to describe paints which are supplied in two separate containers and which have to be mixed together before use.
Zinc phosphate:	A pigment with corrosion preventing properties.
Zinc silicate paints:	Zinc-filled paints based on an inorganic binder. Zinc silicates are commonly used as shop primers.
Zinc-rich paints:	Zinc filled paints based on a large proportion of metallic zinc in powder form. They usually contain (for example) more than 85 percent zinc in the dry film and provide very hard films which are resistant to solvents.

CHAPTER 16: Appendices

NOTE: The regulations included herein are current as of 1 August 2007. For the latest copies please refer to the websites:

IMO: www.imo.org

IACS: www.iacs.org.uk

Appendix A: IMO PSPC MSC.215(82)

Performance Standard for Protective Coating (PSPC) of dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers.

Appendix B: IACS PR 34

IACS Procedural Requirement on Application of the IMO PSPC, Resolution MSC.215(82), under IACS Common Structural Rules for Bulk Carriers and Oil Tankers.

Appendix C: IACS SC 122

Tank corrosion prevention in seawater ballast.

Appendix D: IACS SC 127

Paints, varnishes and other finishes.

Appendix E: IACS UR Z17

Procedural requirements for service suppliers

Appendix F: IACS UR Z9

Corrosion protection coatings for cargo hold spaces on bulk carriers.

Appendix A

IMO PSPC MSC.215(82)

Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks In All Types Of Ships And Double-Side Skin Spaces Of Bulk Carriers

1 Purpose

This Standard provides technical requirements for protective coatings in dedicated seawater ballast tanks of all type of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of 150 m in length and upwards¹ for which the building contract is placed, the keels of which are laid or which are delivered on or after the dates referred to in SOLAS regulation II-1/3-2 as adopted by resolution MSC.216(82).

2 Definitions

For the purpose of this Standard, the following definitions apply.

- 2.1 *Ballast tanks* are those as defined in the Guidelines for the selection, application and maintenance of corrosion prevention systems of dedicated seawater ballast tanks (resolution A.798(19)) and the Guidelines on the enhanced programme of inspections during surveys of bulk carriers and oil tankers (resolution A.744(18), as amended).
- 2.2 *Dew point* is the temperature at which air is saturated with moisture.
- 2.3 *DFT* is dry film thickness.
- 2.4 *Dust* is loose particle matter present on a surface prepared for painting, arising from blast-cleaning or other surface preparation processes, or resulting from the action of the environment.
- 2.5 *Edge grinding* is the treatment of edge before secondary surface preparation.
- 2.6 “*GOOD*” *condition* is the condition with minor spot rusting as defined in resolution A.744(18).
- 2.7 *Hard coating* is a coating that chemically converts during its curing process or a non-convertible air drying coating which may be used for maintenance purposes. It can be either inorganic or organic.
- 2.8 *NDFT* is the nominal dry film thickness. A 90/10 practice means that 90% of all thickness measurements shall be greater than, or equal to, NDFT and none of the remaining 10% measurements shall be below 0.9 x NDFT.
- 2.9 *Primer coat* is the first coat of the coating system applied in the shipyard after shop-primer application.
- 2.10 *Shop-primer* is the prefabrication primer coating applied to steel plates, often in automatic plants (and before the first coat of a coating system).
- 2.11 *Stripe coating* is painting of edges, welds, hard to reach areas, etc., to ensure good paint adhesion and proper paint thickness in critical areas.
- 2.12 *Target useful life* is the target value, in years, of the durability for which the coating system is designed.
- 2.13 *Technical Data Sheet* is paint manufacturers’ Product Data Sheet which contains detailed technical instruction and information relevant to the coating and its application.

¹ This Standard applies only to dedicated seawater ballast tanks in all types of ships and double-side skin spaces in bulk carriers which are constructed of steel.

3 General Principles

- 3.1 The ability of the coating system to reach its target useful life depends on the type of coating system, steel preparation, application and coating inspection and maintenance. All these aspects contribute to the good performance of the coating system.
- 3.2 Inspection of surface preparation and coating processes shall be agreed upon between the shipowner, the shipyard and the coating manufacturer and presented to the Administration² for review. The Administration may, if it so requires, participate in the agreement process. Clear evidence of these inspections shall be reported and be included in the Coating Technical File (CTF) (see 3.4).
- 3.3 When considering the Standard provided in section 4, the following is to be taken into account:
- 3.3.1 it is essential that specifications, procedures and the various different steps in the coating application process (including, but not limited to, surface preparation) are strictly applied by the shipbuilder in order to prevent premature decay and/or deterioration of the coating system;
- 3.3.2 the coating performance can be improved by adopting measures at the ship design stage such as reducing scallops, using rolled profiles, avoiding complex geometric configurations and ensuring that the structural configuration permits easy access for tools and to facilitate cleaning, drainage and drying of the space to be coated; and
- 3.3.3 the coating performance standard provided in this document is based on experience from manufacturers, shipyards and ship operators; it is not intended to exclude suitable alternative coating systems, providing a performance at least equivalent to that specified in this Standard is demonstrated. Acceptance criteria for alternative systems are provided in section 8.

3.4 Coating Technical File

- 3.4.1 Specification of the coating system applied to the dedicated seawater ballast tanks and double-side skin spaces, record of the shipyard's and shipowner's coating work, detailed criteria for coating selection, job specifications, inspection, maintenance and repair³ shall be documented in the Coating Technical File (CTF), and the Coating Technical File shall be reviewed by the Administration.
- 3.4.2 New construction stage
The Coating Technical File shall contain at least the following items relating to this Standard and shall be delivered by the shipyard at new ship construction stage:
- .1 copy of Statement of Compliance or Type Approval Certificate;
 - .2 copy of Technical Data Sheet, including:
 - .2.1 product name and identification mark and/or number;
 - .2.2 materials, components and composition of the coating system, colours;
 - .2.3 minimum and maximum dry film thickness;
 - .2.4 application methods, tools and/or machines;
 - .2.5 condition of surface to be coated (de-rusting grade, cleanness, profile, etc.); and
 - .2.6 environmental limitations (temperature and humidity);
 - .3 shipyard work records of coating application, including:
 - .3.1 applied actual space and area (in square metres) of each compartment;
 - .3.2 applied coating system;
 - .3.3 time of coating, thickness, number of layers, etc.;
 - .3.4 ambient condition during coating; and
 - .3.5 method of surface preparation;

² In accordance with SOLAS regulation I/6, for the purposes of this Standard, the Administration may entrust a recognized organization acting on its behalf to determine compliance with the provisions of this Standard.

³ Guidelines to be developed by the Organization

- .4 procedures for inspection and repair of coating system during ship construction;
- .5 coating log issued by the coating inspector, stating that the coating was applied in accordance with the specifications to the satisfaction of the coating supplier representative and specifying deviations from the specifications (example of daily log and non-conformity report (see annex 2));
- .6 shipyard's verified inspection report, including:
 - .6.1 completion date of inspection;
 - .6.2 result of inspection;
 - .6.3 remarks (if given); and
 - .6.4 inspector signature; and
- .7 procedures for in-service maintenance and repair of coating system.

3.4.3 **In-service maintenance, repair and partial re-coating**

In-service maintenance, repair and partial re-coating activities shall be recorded in the Coating Technical File in accordance with the relevant section of the Guidelines for coating maintenance and repair⁴.

3.4.4 **Re-coating**

If a full re-coating is carried out, the items specified in 3.4.2 shall be recorded in the Coating Technical File.

3.4.5 The Coating Technical File shall be kept on board and maintained throughout the life of the ship.

3.5 **Health and safety**

The shipyard is responsible for implementation of national regulations to ensure the health and safety of individuals and to minimize the risk of fire and explosion.

4 **Coating Standard**

4.1 **Performance standard**

This Standard is based on specifications and requirements which intend to provide a target useful coating life of 15 years, which is considered to be the time period, from initial application, over which the coating system is intended to remain in "GOOD" condition. The actual useful life will vary, depending on numerous variables including actual conditions encountered in service.

4.2 **Standard application**

Protective coatings for dedicated seawater ballast tanks of all ship types and double-side skin spaces arranged in bulk carriers of 150 m in length and upwards shall at least comply with the requirements in this Standard.

4.3 **Special application**

4.3.1 This Standard covers protective coating requirements for the ship's steel structure. It is noted that other independent items are fitted within the tanks to which coatings are applied to provide protection against corrosion.

4.3.2 It is recommended that this Standard is applied, to the extent possible, to those portions of permanent means of access provided for inspection not integral to the ship's structure, such as rails, independent platforms, ladders, etc. Other equivalent methods of providing corrosion protection for the non-integral items may also be used, provided they do not impair the performance of the coatings of the surrounding structure. Access arrangements that are integral to the ship structure, such as increased stiffener depths for walkways, stringers, etc., are to fully comply with this Standard.

4.3.3 It is also recommended that supports for piping, measuring devices, etc., be coated in accordance with the non-integral items indicated in 4.3.2.

⁴ Guidelines to be developed by the Organization

4.4 Basic coating requirements

- 4.4.1 The requirements for protective coating systems to be applied at ship construction for dedicated seawater ballast tanks of all ship types and double-side skin spaces arranged in bulk carriers of 150 m in length and upwards meeting the performance standard specified in 4.1 are listed in table 1.
- 4.4.2 Coating manufacturers shall provide a specification of the protective coating system to satisfy the requirements of table 1.
- 4.4.3 The Administration shall verify the Technical Data Sheet and Statement of Compliance or Type Approval Certificate for the protective coating system.
- 4.4.4 The shipyard shall apply the protective coating in accordance with the verified Technical Data Sheet and its own verified application procedures.

Table 1 – Basic coating system requirements for dedicated seawater ballast tanks of all type of ships and double-side skin spaces of bulk carriers of 150 m and upwards

	Characteristic/ Reference standards	Requirement
1. Design of coating		
.1	Selection of the coating system	<p>The selection of the coating system shall be considered by the parties involved with respect to the service conditions and planned maintenance. The following aspects, among other things shall be considered:</p> <ul style="list-style-type: none"> .1 location of space relative to heated surfaces; .2 frequency of ballasting and deballasting operations; .3 required surface conditions; .4 required surface cleanliness and dryness; and .5 supplementary cathodic protections, if any (where coating is supplemented by cathodic protection, the coating shall be compatible with the cathodic protection system). <p>Coating manufacturers shall have products with documented satisfactory performance records and technical data sheets. The manufacturers shall also be capable of rendering adequate technical assistance. Performance records, technical data sheet and technical assistance (if given) shall be recorded in the Coating Technical File.</p> <p>Coatings for application underneath sun-heated decks or on bulkheads forming boundaries of heated spaces shall be able to withstand repeated heating and/or cooling without becoming brittle.</p>
.2	Coating type	<p>Epoxy-based systems.</p> <p>Other coating systems with performance according to the test procedure in annex 1.</p> <p>A multi-coat system with each coat of contrasting colour is recommended.</p> <p>The top coat shall be of a light colour in order to facilitate in-service inspection.</p>

.3	Coating pre-qualification test	<p>Epoxy-based systems tested prior to the date of entry into force of this Standard in a laboratory by a method corresponding to the test procedure in annex 1 or equivalent, which as a minimum meets the requirements for rusting and blistering; or which have documented field exposure for 5 years with a final coating condition of not less than "GOOD" may be accepted.</p> <p>For all other systems, testing according to the procedure in annex 1, or equivalent, is required.</p>
.4	Job specification	<p>There shall be a minimum of two stripe coats and two spray coats, except that the second stripe coat, by way of welded seams only, may be reduced in scope where it is proven that the NDFT can be met by the coats applied, in order to avoid unnecessary over-thickness. Any reduction in scope of the second stripe coat shall be fully detailed in the CTF.</p> <p>Stripe coats shall be applied by brush or roller. Roller to be used for scallops, ratholes, etc., only.</p> <p>Each main coating layer shall be appropriately cured before application of the next coat, in accordance with coating manufacturer's recommendations. Surface contaminants such as rust, grease, dust, salt, oil, etc., shall be removed prior to painting with proper method according to the paint manufacturer's recommendation. Abrasive inclusions embedded in the coating shall be removed. Job specifications shall include the dry-to-recoat times and walk-on time given by the manufacturer.</p>
.5	NDFT (nominal total dry film thickness) ⁵	<p>NDFT 320 µm with 90/10 rule for epoxy-based coatings; other systems to coating manufacturer's specifications.</p> <p>Maximum total dry film thickness according to manufacturer's detailed specifications.</p> <p>Care shall be taken to avoid increasing the thickness in an exaggerated way. Wet film thickness shall be regularly checked during application. Thinner shall be limited to those types and quantities recommended by the manufacturer.</p>

⁵ Type of gauge and calibration in accordance with SSPC-PA2:2004. Paint Application Specification No.2.

2. PSP (Primary surface preparation)		
.1	Blasting and profile ^{6,7}	<p>Sa 2½; with profiles between 30-75 µm</p> <p>Blasting shall not be carried out when:</p> <ul style="list-style-type: none"> .1 the relative humidity is above 85%; or .2 the surface temperature of steel is less than 3°C above the dew point. <p>Checking of the steel surface cleanliness and roughness profile shall be carried out at the end of the surface preparation and before the application of the primer, in accordance with the manufacturer's recommendations.</p>
.2	Water soluble salt limit equivalent to NaCl ⁸	≤ 50 mg/m ² of sodium chloride.
.3	Shop primer	Zinc containing inhibitor free zinc silicate based or equivalent. Compatibility with main coating system shall be confirmed by the coating manufacturer.
3. Secondary surface preparation		
.1	Steel condition ⁹	<p>The steel surface shall be prepared so that the coating selected can achieve an even distribution at the required NDFT and have an adequate adhesion by removing sharp edges, grinding weld beads and removing weld spatter and any other surface contaminant.</p> <p>Edges shall be treated to a rounded radius of minimum 2 mm, or subjected to three pass grinding or at least equivalent process before painting.</p>
.2	Surface treatment ⁶	<p>Sa 2½ on damaged shop primer and welds.</p> <p>Sa 2 removing at least 70% of intact shop primer, which has not passed a pre qualification certified by test procedures in 1.3.</p> <p>If the complete coating system comprising epoxy-based main coating and shop primer has passed a pre-qualification certified by test procedures in 1.3, intact shop primer may be retained provided the same epoxy coating system is used. The retained shop primer shall be cleaned by sweep blasting, high-pressure water washing or equivalent method.</p> <p>If a zinc silicate shop primer has passed the pre-qualification test of 1.3 as part of an epoxy coating system, it may be used in combination with other epoxy coatings certified under 1.3, provided that the compatibility has been confirmed by the manufacturer by the test in accordance with 1.7 of appendix 1 to annex 1 without wave movement.</p>

⁶ Reference standard: ISO 8501-1:1988/Suppl:1994. Preparation of steel substrate before application of paints and related products – Visual assessment of surface cleanliness.

⁷ Reference standard: ISO 8503-1/2:1988. Preparation of steel substrate before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates.

⁸ Conductivity measured in accordance with ISO 8502-9:1998. Preparation of steel substrate before application of paints and related products – Test for the assessment of surface cleanliness.

⁹ Reference standard: ISO 8501-3:2001 (grade P2). Preparation of steel substrate before application of paints and related products – Visual assessment of surface cleanliness.

.3	Surface treatment after erection ⁶	Butts St 3 or better or Sa 2½ where practicable. Small damages up to 2% of total area: St 3. Contiguous damages over 25 m ² or over 2% of the total area of the tank, Sa 2½ shall be applied. Coating in overlap shall be feathered.
.4	Profile requirements ⁷	In case of full or partial blasting 30-75 µm, otherwise as recommended by the coating manufacturer.
.5	Dust ⁹	Dust quantity rating "1" for dust size class "3", "4" or "5". Lower dust size classes to be removed if visible on the surface to be coated without magnification.
.6	Water soluble salts limit equivalent to NaCl after blasting/grinding ⁸	≤ 50 mg/m ² of sodium chloride.
.7	Oil contamination	No oil contamination.
4. Miscellaneous		
.1	Ventilation	Adequate ventilation is necessary for the proper drying and curing of coating. Ventilation should be maintained throughout the application process and for a period after application is completed, as recommended by the coating manufacturer.
.2	Environmental conditions	Coating shall be applied under controlled humidity and surface conditions, in accordance with the manufacturer's specifications. In addition, coating shall not be applied when: .1 the relative humidity is above 85%; or .2 the surface temperature is less than 3°C above the dew point.
.3	Testing of coating ⁵	Destructive testing shall be avoided. Dry film thickness shall be measured after each coat for quality control purpose and the total dry film thickness shall be confirmed after completion of final coat, using appropriate thickness gauges (see annex 3).
.4	Repair	Any defective areas, e.g., pin-holes, bubbles, voids, etc., shall be marked up and appropriate repairs effected. All such repairs shall be re-checked and documented.

⁵ Type of gauge and calibration in accordance with SSPC-PA2:2004. Paint Application Specification No.2.

⁶ Reference standard: ISO 8501-1:1988/Suppl:1994. Preparation of steel substrate before application of paints and related products – Visual assessment of surface cleanliness.

⁷ Reference standard: ISO 8503-1/2:1988. Preparation of steel substrate before application of paints and related products – Surface roughness characteristics of blast-cleaned steel substrates.

⁸ Conductivity measured in accordance with ISO 8502-9:1998. Preparation of steel substrate before application of paints and related products – Test for the assessment of surface cleanliness.

⁹ Reference standard: ISO 8502-3:1993. Preparation of steel substrate before application of paints and related products – Test for the assessment of surface cleanliness.

5 Coating System Approval

Results from prequalification tests (table 1, paragraph 1.3) of the coating system shall be documented and a Statement of Compliance or Type Approval Certificate shall be issued if found satisfactory by a third party, independent of the coating manufacturer.

6 Coating Inspection Requirements

6.1 General

- 6.1.1 To ensure compliance with this Standard, the following shall be carried out by qualified coating inspectors certified to NACE Coating Inspector Level 2, FROSIO Inspector Level III or equivalent as verified by the Administration.
- 6.1.2 Coating inspectors shall inspect surface preparation and coating application during the coating process by carrying out, as a minimum, those inspection items identified in section 6.2 to ensure compliance with this Standard. Emphasis shall be placed on initiation of each stage of surface preparation and coatings application as improper work is extremely difficult to correct later in the coating progress. Representative structural members shall be non-destructively examined for coating thickness. The inspector shall verify that appropriate collective measures have been carried out.
- 6.1.3 Results from the inspection shall be recorded by the inspector and shall be included in the CTF (refer to annex 2 (Example of daily log and non-conformity report)).

6.2 Inspection items

Construction Stage		Inspection Items
Primary surface preparation	1	The surface temperature of steel, the relative humidity and the dew point shall be measured and recorded before the blasting process starts and at times of sudden changes in weather.
	2	The surface of steel plates shall be tested for soluble salt and checked for oil, grease and other contamination.
	3	The cleanliness of the steel surface shall be monitored in the shop-primer application process.
	4	The shop-primer material shall be confirmed to meet the requirements of 2.3 of table 1.
Thickness		If compatibility with the main coating system has been declared, then the thickness and curing of the zinc silicate shop primer to be confirmed to conform to the specified values.
Block assembly	1	After completing construction of the block and before secondary surface preparation starts, a visual inspection for steel surface treatment including edge treatment shall be carried out. Any oil, grease or other visible contamination shall be removed.
	2	After blasting/grinding/cleaning and prior to coating, a visual inspection of the prepared surface shall be carried out. On completion of blasting and cleaning and prior to the application of the first coat of the system, the steel surface shall be tested for levels of remaining soluble salts in at least one location per block.
	3	The surface temperature, the relative humidity and the dew point shall be monitored and recorded during the coating application and curing.
	4	Inspection shall be performed of the steps in the coating application process mentioned in table 1.
	5	DFT measurements shall be taken to prove that the coating has been applied to the thickness as specified and outlined in annex 3.

Construction Stage		Inspection Items
Erection	1	Visual inspection for steel surface condition, surface preparation and verification of conformance to other requirements in table 1, and the agreed specification shall be performed.
	2	The surface temperature, the relative humidity and the dew point shall be measured and recorded before coating starts and regularly during the coating process.
	3	Inspection shall be performed of the steps in the coating application process mentioned in table 1.

7 Verification Requirements

The following shall be carried out by the Administration prior to reviewing the Coating Technical File for the ship subject to this Standard:

- 7.1 check that the Technical Data Sheet and Statement of Compliance or Type Approval Certificate comply with this Standard;
- 7.2 check that the coating identification on representative containers is consistent with the coating identified in the Technical Data Sheet and Statement of Compliance or Type Approval Certificate;
- 7.3 check that the inspector is qualified in accordance with the qualification standards in paragraph 6.1.1;
- 7.4 check that the inspector's reports of surface preparation and the coating's application indicate compliance with the manufacturer's Technical Data Sheet and Statement of Compliance or Type Approval Certificate; and
- 7.5 monitor implementation of the coating inspection requirements.

8 Alternative Systems

- 8.1 All systems that are not an epoxy-based system applied according to table 1 of this Standard are defined as an alternative system.
- 8.2 This Standard is based on recognized and commonly used coating systems. It is not meant to exclude other, alternative, systems with proven equivalent performance, for example non epoxy-based systems.
- 8.3 Acceptance of alternative systems will be subject to documented evidence that they ensure a corrosion prevention performance at least equivalent to that indicated in this Standard.
- 8.4 As a minimum, the documented evidence shall consist of satisfactory performance corresponding to that of a coating system which conforms to the coating standard described in section 4, a target useful life of 15 years in either actual field exposure for 5 years with final coating condition not less than "GOOD" or laboratory testing. Laboratory test shall be conducted in accordance with the test procedure given in annex 1 to this Standard.

ANNEX 1

TEST PROCEDURES FOR COATING QUALIFICATION FOR DEDICATED SEAWATER BALLAST TANK OF ALL TYPES OF SHIPS AND DOUBLE-SIDE SKIN SPACES OF BULK CARRIERS

1 Scope

These Procedures provide details of the test procedure referred to in 5 and 8.3 of this Standard.

2 Definitions

Coating specification means the specification of coating systems which includes the type of coating system, steel preparation, surface preparation, surface cleanliness, environmental conditions, application procedure, acceptance criteria and inspection.

3 Testing

Coating specification shall be verified by the following tests. The test procedures shall comply with appendix 1 (Test on simulated ballast tank conditions) and appendix 2 (Condensation chamber tests) to this annex as follows:

- 3.1** for protective coatings for dedicated seawater ballast tanks, appendix 1 and appendix 2 shall apply; and
- 3.2** for protective coatings for double-side spaces of bulk carriers of 150 m in length and upwards other than dedicated seawater ballast tanks, appendix 2 shall apply.

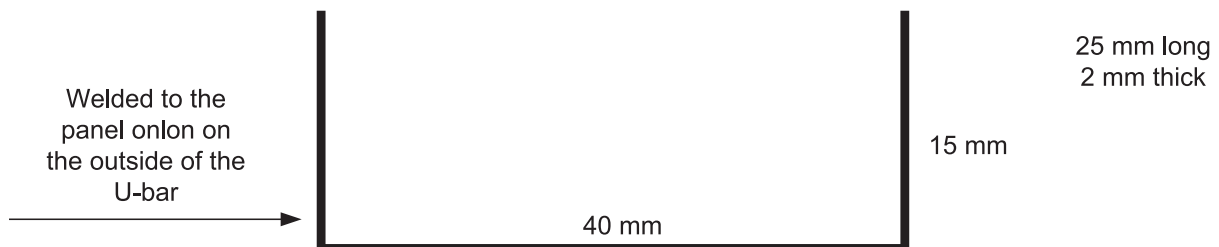
APPENDIX 1

TEST ON SIMULATED BALLAST TANK CONDITIONS 1

1 Test condition

Test on simulated ballast tank conditions shall satisfy each of the following conditions:

- 1.1 The test shall be carried out for 180 days.
- 1.2 There are to be 5 test panels.
- 1.3 The size of each test panel is 200 mm x 400 mm x 3 mm. Two of the panels (Panel 3 and 4 below) have a U-bar welded. The U-bar is welded to the panel in a 120 mm distance from one of the short sides and 80 mm from each of the long sides.



The panels are to be treated according to this Standard, table 1.1, 1.2 and 1.3, and coating system applied according to table 1, paragraphs 1.4 and 1.5. Shop primer to be weathered for at least 2 months and cleaned by low pressure washing or other mild method. Blast sweep or high pressure washing, or other primer removal methods not to be used. Weathering method and extent shall take into consideration that the primer is to be the foundation for a 15 year target useful life system. To facilitate innovation, alternative preparation, coating systems and dry film thicknesses may be used when clearly defined.

- 1.4 The reverse side of the test piece shall be painted appropriately, in order not to affect the test results.
- 1.5 As simulating the condition of actual ballast tank, the test cycle runs for two weeks with natural or artificial seawater and one week empty. The temperature of the seawater is to be kept at about 35°C.
- 1.6 Test panel 1: This panel is to be heated for 12 hours at 50°C and cooled for 12 hours at 20°C in order to simulate upper deck condition. The test panel is cyclically splashed with natural or artificial seawater in order to simulate a ship's pitching and rolling motion. The interval of splashing is 3 seconds or faster. The panel has a scribe line down to bare steel across width.
- 1.7 Test panel 2: This panel has a fixed sacrificial zinc anode in order to evaluate the effect of cathodic protection. A circular 8 mm artificial holiday down to bare steel is introduced on the test panel 100 mm from the anode in order to evaluate the effect of the cathodic protection. The test panel is cyclically immersed with natural or artificial seawater.
- 1.8 Test panel 3: This panel is to be cooled on the reverse side, in order to give a temperature gradient to simulate a cooled bulkhead in a ballast wing tank, and splashed with natural or artificial seawater in order to simulate a ship's pitching and rolling motion. The gradient of temperature is approximately 20°C, and the interval of splashing is 3 seconds or faster. The panel has a scribe line down to bare steel across width.
- 1.9 Test panel 4: This panel is to be cyclically splashed with natural or artificial seawater in order to simulate a ship's pitching and rolling motion. The interval of splashing is 3 seconds or faster. The panel has a scribe line down to bare steel across width.
- 1.10 Test panel 5: This panel is to be exposed to dry heat for 180 days at 70°C to simulate boundary plating between heated bunker tank and ballast tank in double bottom.

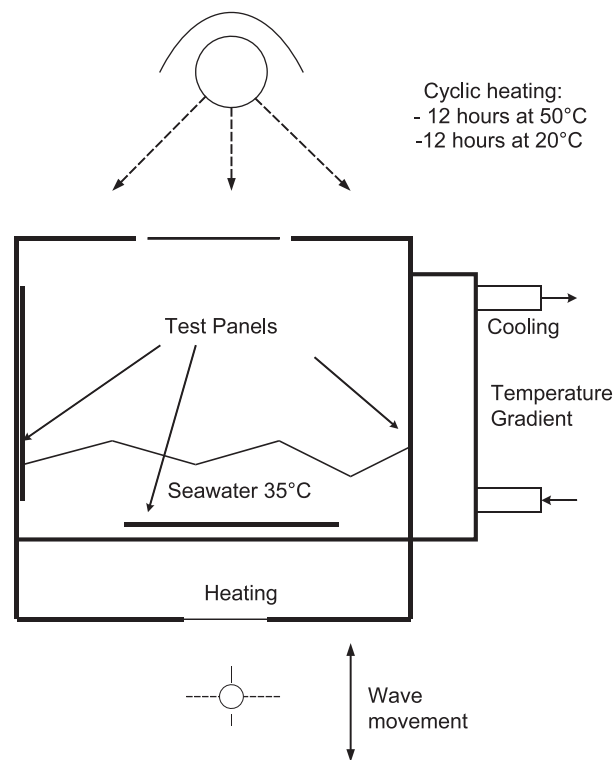


Figure 2: Wave tank for testing of ballast tank coatings.

2 Test results

2.1 Prior to the testing, the following measured data of the coating system shall be reported:

- 2.1.1 infrared (IR) identification of the base and hardener components of the coating;
- 2.1.2 specific gravity¹⁰ of the base and hardener components of the paint; and
- 2.1.3 number of pinholes, low voltage detector at 90 V.

2.2 After the testing, the following measured data shall be reported:

- 2.2.1 blisters and rust;¹¹
- 2.2.2 dry film thickness (DFT) (use of a template);¹²
- 2.2.3 adhesion value;¹³
- 2.2.4 flexibility¹⁴ modified according to panel thickness (3 mm steel, 300 µm coating, 150 mm cylindrical mandrel gives 2% elongation) for information only;
- 2.2.5 cathodic protection weight loss/current demand/disbondment from artificial holiday; and
- 2.2.6 undercutting from scribe. The undercutting along both sides of the scribe is measured and the maximum undercutting determined on each panel. The average of the three maximum records is used for the acceptance.

¹⁰ Reference standard: ISO 2811-1/4:1997. Paints and varnishes. Determination of density.

¹¹ Reference standards: ISO 4628/2:2003. Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 2. ISO 4628:2003. Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of common types of defect – Part 3: Designation of degree of rusting.

¹² Nine equally distributed measuring points are used on panel's size 150 mm x 150 mm or 15 equally distributed measuring points on panel's size 200 mm x 400 mm.

¹³ Reference standard: ISO 4624:2002. Pull-off test for adhesion.

¹⁴ Reference standards: ASTM D4145:1983. Standard Test Method for Coating Flexibility of Prepainted Sheet.

3 Acceptance criteria

3.1 The test results based on section 2 shall satisfy the following criteria:

Item	Acceptance criteria for epoxy-based systems applied according to table 1 of this standard	Acceptance criteria for alternative systems
Blisters on panel	No blisters	No blisters
Rust on panel	Ri 0 (0%)	Ri 0 (0%)
Number of pinholes	0	0
Adhesive failure	> 3.5 MPa Adhesive failure between substrate and coating or between coats for 60% or more of the areas.	> 5 MPa Adhesive failure between substrate and coating or between coats for 60% or more of the areas.
Cohesive failure	> 3 MPa Cohesive failure in coating for 40% or more of the area.	> 5 MPa Cohesive failure in coating for 40% or more of the area.
Cathodic protection current demand calculated from weight loss	< 5 mA/m ²	< 5 mA/m ²
Cathodic protection; disbondment from artificial holiday	< 8 mm	< 5 mm
Undercutting from scribe	< 8 mm	< 5 mm
U-bar	Any defects, cracking or detachment at the angle or weld will lead to system being failed.	Any defects, cracking or detachment at the angle or weld will lead to system being failed.

3.2 Epoxy-based systems tested prior to the date of entry into force of this Standard shall satisfy only the criteria for blistering and rust in the table above.

3.3 Epoxy-based systems tested when applied according to table 1 of this Standard shall satisfy the criteria for epoxy-based systems as indicated in the table above.

3.4 Alternative systems not necessarily epoxy-based and/or not necessarily applied according to table 1 of this Standard shall satisfy the criteria for alternative systems as indicated in the table above.

4 Test report

The test report shall include the following information:

- 4.1 name of the manufacturer;
- 4.2 date of tests;
- 4.3 product name/identification of both paint and primer;
- 4.4 batch number;
- 4.5 data of surface preparation on steel panels, including the following:
 - 4.5.1 surface treatment;
 - 4.5.2 water soluble salts limit;
 - 4.5.3 dust; and
 - 4.5.4 abrasive inclusions;
- 4.6 application data of coating system, including the following:
 - 4.6.1 shop primed;
 - 4.6.2 number of coats;
 - 4.6.3 recoat interval;¹⁵
 - 4.6.4 dry film thickness (DFT) prior to testing;¹⁵
 - 4.6.5 thinner;¹⁵
 - 4.6.6 humidity;¹⁵
 - 4.6.7 air temperature;¹⁵ and
 - 4.6.8 steel temperature;
- 4.7 test results according to section 2; and
- 4.8 judgment according to section 3.

¹⁵ Both of actual specimen data and manufacturer's requirement/recommendation.

APPENDIX 2

CONDENSATION CHAMBER TEST

1 Test condition

Condensation chamber test shall be conducted in accordance with applicable standards.¹⁶

- 1.1 The exposure time is 180 days.
- 1.2 There are to be 2 test panels.
- 1.3 The size of each test panel is 150 mm x 150 mm x 3 mm. The panels are to be treated according to the Performance Standard, table 1, paragraphs 1, 2 and 3 and coating system applied according to table 1, paragraphs 1.4 and 1.5. Shop primer to be weathered for at least 2 months and cleaned by low pressure washing or other mild method. Blast sweep or high pressure washing, or other primer removal methods not to be used. Weathering method and extent shall take into consideration that the primer is to be the foundation for a 15 year target life system. To facilitate innovation, alternative preparation, coating systems and dry film thicknesses may be used when clearly defined.
- 1.4 The reverse side of the test piece shall be painted appropriately, in order not to affect the test results.

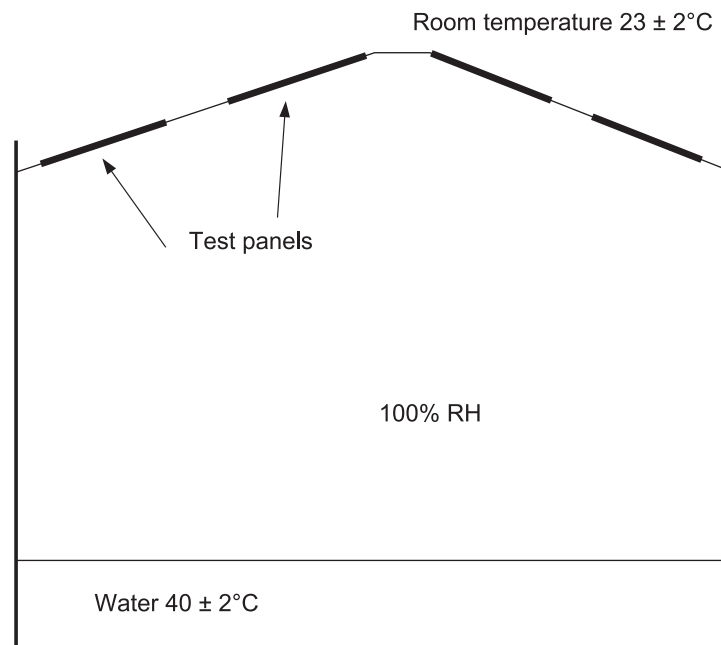


Figure 1: Condensation chamber

¹⁶Reference standard: ISO 6270-1:1998 Paints and varnishes - Determination of resistance to humidity - Part 1: Continuous condensation

2 Test results

According to section 2 (except for 2.2.5 and 2.2.6) of appendix 1.

3 Acceptance criteria

3.1 The test results based on section 2 shall satisfy the following criteria:

Item	Acceptance criteria for epoxy-based systems applied according to table 1 of this Standard	Acceptance criteria for alternative systems
Blisters on panel	No blisters	No blisters
Rust on panel	Ri 0 (0%)	Ri 0 (0%)
Number of pinholes	0	0
Adhesive failure	> 3.5 MPa Adhesive failure between substrate and coating or between coats for 60% or more of the areas.	> 5 MPa Adhesive failure between substrate and coating or between coats for 60% or more of the areas.
Cohesive failure	> 3 MPa Cohesive failure in coating for 40% or more of the area.	> 5 MPa Cohesive failure in coating for 40% or more of the area.

3.2 Epoxy-based systems tested prior to the date of entry into force of this Standard shall satisfy only the criteria for blistering and rust in the table above.

3.3 Epoxy-based systems tested when applied according to table 1 of this Standard shall satisfy the criteria for epoxy-based systems as indicated in the table above.

3.4 Alternative systems not necessarily epoxy-based and/or not necessarily applied according to table 1 of this Standard shall satisfy the criteria for alternative systems as indicated in the table above.

4 Test report

According to section 4 of Appendix 1.

ANNEX 2

EXAMPLE OF DAILY LOG AND NON-CONFORMITY REPORT DAILY

LOG

Sheet No:

Ship:	Tank/Hold No:	Database:							
Part of structure:									
SURFACE PREPARATION									
Method:		Area (m2):							
Abrasive:		Grain size:							
Surface temperature:		Air temperature:							
Relative humidity (max):		Dew point:							
Standard achieved:									
Rounding of edges:									
Comments:									
Job No.:	Date:	Signature:							
COATING APPLICATION:									
Method:									
Coat No.	System	Batch No.	Date	Air temp.	Surf temp.	RH%	Dew point	DFT Meas.*	Specified
*Measured minimum and maximum DFT. DFT readings to be attached to daily log									
Comments:									
Job No.:	Date:	Signature:							

NON-CONFORMITY REPORT

Sheet No:

Ship:	Tank/Hold No:	Database:
Part of structure:		
DESCRIPTION OF THE INSPECTION FINDINGS TO BE CORRECTED		
Description of findings:		
Reference document (daily log):		
Action taken:		
Job No.:	Date:	Signature:

ANNEX 3

DRY FILM THICKNESS MEASUREMENTS

1 Verification check points

The following verification check points of DFT are to be taken:

- 1.1 one gauge reading per 5 m² of flat surface areas;
- 1.2 one gauge reading at 2 to 3 m intervals and as close as possible to tank boundaries, but not further than 15 mm from edges of tank boundaries;
- 1.3 longitudinal and transverse stiffener members:
One set of gauge readings as shown below, taken at 2 to 3 m run and not less than two sets between primary support members;

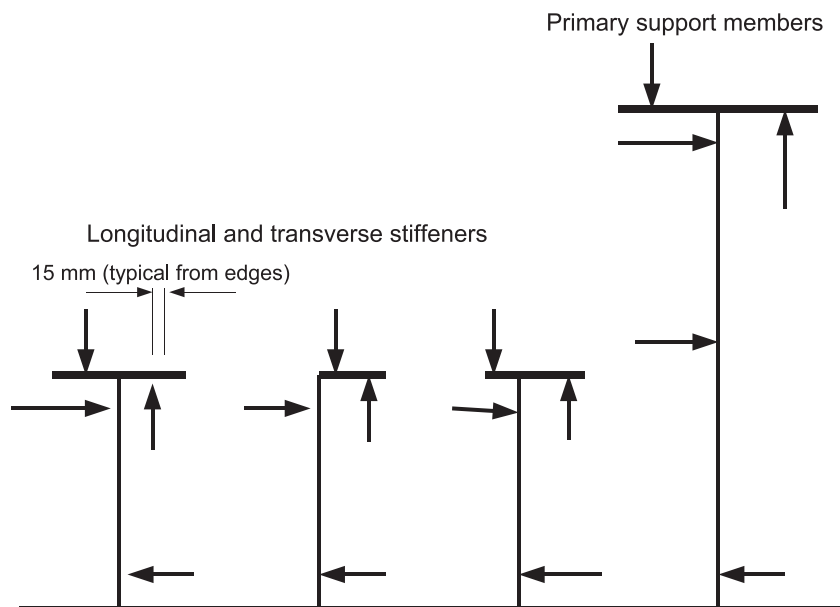


Figure 1: Arrows of diagram indicate critical areas and should be understood to mean indication for both sides.

- 1.4 3 gauge readings for each set of primary support members and 2 gauge readings for each set of other members as indicated by the arrows in the diagram;
- 1.5 for primary support members (girders and transverses) one set of gauge readings for 2 to 3 m run as shown in figure 3 above but not less than three sets;
- 1.6 around openings one gauge reading from each side of the opening;
- 1.7 five gauge readings per square metre (m²) but not less than three gauge readings taken at complex areas (i.e., large brackets of primary support members); and
- 1.8 additional spot checks are to be taken to verify coating thickness for any area considered necessary by the coating inspector.

Appendix B

No.34 IACS Procedural Requirement on Application of the IMO Performance Standard for Protective Coatings (PSPC), Resolution MSC.215(82), under IACS Common Structural Rules for Bulk Carriers and Oil Tankers (Dec 2006)

This IACS Procedural Requirement is to be read in conjunction with the IMO Performance Standard for Protective Coatings (PSPC), Resolution MSC.215(82). Application of the referenced international standards footnoted therein is mandatory under this Procedural Requirement.

1 IACS Procedure for Coating System Approval

Type Approval Certificate showing compliance with the PSPC section 5 shall be issued if the results of either method A+D, or B+D, or C+D are found satisfactory by the Society.

Method A: Laboratory Test

- 1.1 Coating pre-qualification test shall be carried out by the test laboratory which is recognized by the Society and meets the requirements set out in IACS UR Z17 paragraphs 4, 5, 6 and 7 (except for 4.6 & 5.3) as below.
- 1.2 Results from satisfactory pre-qualification tests (PSPC table 1, paragraph 1.3 of the PSPC) of the coating system shall be documented and submitted to the Society.

Method B: 5 years field exposure

- 1.3 Coating manufacturer's records are to be examined to confirm coating system has 5 years field exposure.
- 1.4 A joint (coating manufacturer/Society) survey of all ballast tanks of a selected vessel is to be carried out for the purpose of verification of compliance with the requirements of sections 1.3 and 1.7. The coating manufacturer's representative is to be qualified as defined in 2.2.
- 1.5 The selected vessel is to have ballast tanks in regular use, of which:
 - At least one tank approx 2000 m³
 - At least one tank shall be adjacent to heated tank and
 - At least one tank underdeck exposed to sun.
- 1.6 In the case that the selected vessel does not meet the requirements in 1.5 then the limitations shall be clearly stated on the type approval certificate. For example, the coating cannot be used in tanks adjacent to heated tanks or underdeck or tanks with volume greater than the size surveyed.
- 1.7 All ballast tanks are to be in "GOOD" condition, without touch up or repair in the prior 5 years.
 - 1.7.1 "Good" is defined as: *Condition with spot rusting on less than 3% of the area under consideration without visible failure of the coating. Rusting at edges or welds, must be on less than 20% of edges or welds in the area under consideration.*
 - 1.7.2 Examples of how to report coating conditions with respect to areas under consideration should be as those given in IACS Recommendation 87* Appendix 1.

Method C: Existing Marintek B1 Approvals.*

- 1.8 Epoxy Coatings Systems with existing satisfactory Marintek test reports minimum level B1 issued before 8 December 2006 can be accepted.
- 1.9 Such coatings are to be applied in accordance with Table 1 of the PSPC rather than the application conditions used during the approval test which may differ from the PSPC, unless these are more stringent than table 1 of the PSPC.

Note:

This Procedural Requirement is to be applied by IACS Societies to ships subject to the IACS CSR for Bulk Carriers and for Oil Tankers which are contracted for construction on or after 8 December 2006 and until the date of application referred to in para.1 of SOLAS Chapter II-1, Part A-1, Reg.3-2, as adopted by resolution MSC.216(82).

Method D: Coating Manufacturer

- 1.10 The coating manufacturer shall meet the requirements set out in IACS UR Z17 paragraphs 4, 5, 6 and 7, (except for 4.6), which is to be verified by the Society.
- 1.11 In the case that a manufacturer wishes to have products which are manufactured in different locations under the same name, then infrared (IR) identification and specific gravity shall be used to demonstrate that they are the same coating, or individual approval tests will be required for the paint manufactured in each location.

2 IACS Procedure for Assessment of Coating Inspectors' Qualifications

- 2.1 Coating inspectors required to carry out inspections in accordance with the IMO PSPC section 6 are to be qualified to NACE Coating Inspector Level 2, FROSIO Inspector Level III, or an equivalent qualification. Equivalent qualifications are described in 2.3 below.
- 2.2 However only coating inspectors with at least 2 years relevant coating inspector experience and qualified to NACE Coating Inspector Level 2 or FROSIO Inspector Level III, or with an equivalent qualification, can write and/or authorise procedures, or decide upon corrective actions to overcome non-compliances.
- 2.3 **Equivalent Qualification:** IACS Recommendation 87 is not mandatory.
- 2.3.1 Equivalent qualification is the successful completion, as determined by course tutor, of an approved course.
- 2.3.1.1 The course tutors shall be qualified with at least 2 years relevant experience and qualified to NACE Coating Inspector Level 2 or FROSIO Inspector Level III, or with an equivalent qualification.
- 2.3.1.2 Approved Course: A course that has a syllabus based on the issues associated with the PSPC including the following:
- Health Environment and Safety
 - Corrosion
 - Materials and design
 - International standards referenced in PSPC
 - Curing mechanisms
 - Role of inspector
 - Test instruments
 - Inspection Procedures
 - Coating specification
 - Application Procedures
 - Coating Failures
 - Pre-job conference
 - MSDS and product data sheet review
 - Coating technical file
 - Surface preparation
 - Dehumidification
 - Waterjetting
 - Coating types and inspection criteria
 - Specialized Application Equipment
 - Use of inspection procedures for destructive testing and non destructive testing instruments.
 - Inspection instruments and test methods
 - Coating inspection techniques
 - Cathodic protection
 - Practical exercises, case studies.

Examples of approved courses may be internal courses run by the coating manufacturers or shipyards etc.

2.3.1.3 Such a course shall have an acceptable measurement of performance, such as an examination with both theoretical and practical elements. The course and examination shall be approved by the Society.

2.3.2 Equivalent qualification arising from practical experience: An individual who: has a minimum of 5-years practical work experience as a coating inspector of ballast tanks during new construction within the last 10 years, and has successfully completed the examination given in 2.3.1.3.

3 IACS Procedure for Inspection Agreement (the PSPC 3.2)

3.1 The procedure for inspection of surface preparation and coating processes shall be agreed upon, between the shipowner, the shipyard and coating manufacturer. It should be presented by the shipyard to the Society for review and as a minimum shall comply with the PSPC. It is to be included in the Coating Technical File.

3.2 Any deviations in the procedure relative to the PSPC noted during the review shall be raised with the shipyard, which is responsible for identifying and implementing the corrective actions.

3.3 A class certificate is not to be issued until all required corrective actions have been closed out to the satisfaction of the Society.

4 IACS Procedure for Verification of Application of the PSPC

4.1 The verification requirements of section 7 of the PSPC are to be carried out by the Society.

4.1.1 Monitoring implementation of the coating inspection requirements, as called for in section 7.5 of the PSPC means checking, on a sampling basis, that the inspectors are using the correct equipment, techniques and reporting methods as described in the inspection procedures reviewed by the Society.

4.2 Any deviations found under 4.1.1 are to be raised initially with the coating inspector, who is responsible for identifying and implementing the corrective actions.

4.3 In the event that corrective actions are not acceptable to the Society or in the event that corrective actions are not closed out then the shipyard shall be informed.

4.4 A class certificate is not to be issued until all required corrective actions have been closed out to the satisfaction of the Society.

5 IACS Procedure for Coating Technical File Review

5.1 The shipyard is responsible for compiling the Coating Technical File (CTF) either in paper or electronic format, or a combination of the two.

5.2 The CTF is to contain all the information required by the PSPC section 3.4.

5.3 The CTF shall be reviewed for content in accordance with the PSPC section 3.4.2.

5.4 Any deviations found under 5.3 are to be raised with the shipyard, which is responsible for identifying and implementing the corrective actions.

5.5 A class certificate is not to be issued until all required corrective actions have been closed out to the satisfaction of the Society.

Appendix C

IACS SC122 - Corrosion Prevention in Seawater Ballast Tanks

(1998)

(v0.1, April 1998)

(Chapter II-1, Regulation 3-2)

The scheme for the selection, application and maintenance of the coating system should follow the requirements of IMO Resolution A.798(19) and contain, as a minimum, the following documentation:

- Owner's, coating manufacturer's and shipyard's explicit agreement to the scheme for coating selection, application and maintenance.
- List of seawater ballast tanks identifying the coating system for each tank, including coating color and whether coating system is a hard coating.
- Details of anodes, if used.
- Manufacturer's technical product data sheet for each product.
- Manufacturer's evidence of product quality and ability to meet owners requirements.
- Evidence of shipyard's and/or its subcontractor's experience in coating application.
- Surface preparation procedures and standards, including inspection points and methods.
- Application procedures and standards, including inspection points and methods.
- Format for inspection reports on surface preparation and coating application.
- Manufacturer's product safety data sheets for each product and owner's, coating manufacturer's and shipyard's explicit agreement to take all precautions to reduce health and other safety risks which are required by the authorities.
- Maintenance requirements for the coating system.

Coating of any color may be accepted, unless otherwise instructed by the Flag Administration. "Light color" coating is preferable, and includes colors which facilitate inspection or are easily distinguishable from rust.

Note:

This UI should be uniformly implemented by all Members and Associates not later than 1 July 1998.

Appendix D

IACS SC127 - Paints, varnishes and other finishes

(May, 1998) (Reg. II-2/6.2)

(Rev.1 July 2004)

(Rev.2 Nov 2005)

This regulation only applies to accommodation spaces, service spaces and control stations as well as stairway enclosures.

Note:

1. This Unified Interpretation is to be applied by all Members and Associates on ships contracted for construction on or after 1 January 2006.
2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No. 29.

Appendix E

IACS PR Z17 PROCEDURAL REQUIREMENTS FOR SERVICE SUPPLIERS

(1997)

(Rev.1 June 1999)

(Rev.2 November 1999)

(Rev.3 July 2002)

(Rev.4 July 2003)

(Rev.5 Feb 2004)

CONTENTS

1. General
2. Objective
3. Application
4. Procedure for Approval and Certification
5. Certification
6. Information of Alterations to the Certified Service Operation System
7. Cancellation of Approval
8. Existing Approvals

Annex I Special Requirements for Various Categories of Service Suppliers

Revision note, Rev.4: added in Annex, Section 10, 11 & 12, with reference in 3.1.2.

Rev.5 clarified applicability to thickness measurement companies in 3.1.1 and Annex 1, 1.1.

1 General

- 1.1 Firms providing services on behalf of the owner of a ship or a mobile offshore unit, such as measurements, tests or maintenance of safety systems and equipment, the results of which are used by Surveyors in making decisions affecting classification are subject to approval by the Society in accordance with the mandatory procedures in this unified requirement and its Annex¹.
- 1.2 Where such services are used by Surveyors in making decisions affecting statutory certifications, the firms are subject to approval by the Society where the Society is so authorised by the relevant flag Administration. For such services the Society may accept approvals done by:
- 1.2.1 the flag Administration itself,
 - 1.2.2 duly authorized organizations acting on behalf of the flag Administration, or
 - 1.2.3 other organizations that are acceptable to the flag Administration (e.g. other governments, etc.)

2 Objective

- 2.1 The objective of this procedure is to set basic standards for qualifying service suppliers.

3 Application

- 3.1 This procedure applies to the approval of the following categories of service suppliers:
- 3.1.1 Class services
 - Firms engaged in thickness measurements on ships except
 - (1) non-ESP ships less than 500 gross tonnage and
 - (2) all fishing vessels.
 - Firms engaged in tightness testing of hatches with ultrasonic equipment
 - Firms carrying out in-water survey of ships and mobile offshore units
 - Firms engaged in the examination of Ro-Ro ships bow, stern, side and inner doors.
 - 3.1.2 Statutory services
 - Firms engaged in surveys and maintenance of fire extinguishing equipment and systems
 - Firms engaged in service on inflatable liferafts, inflatable lifejackets, hydrostatic release units, inflatable rescue boats
 - Firms engaged in the servicing and testing of radio communication equipment
 - Firms engaged in inspection and testing of centralised gas welding and cutting equipment
 - Firms engaged in surveys and maintenance of self contained breathing apparatus
 - Firms engaged in annual performance testing of Voyage Data Recorders (VDR)
 - Firms engaged in surveys of low location lighting systems using photo luminescent materials
 - Firms engaged in sound pressure level measurements of public address and general alarm systems
- 3.2 In the following such firms are referred to as the supplier.
- 3.3 Detailed requirements specific to the various categories of suppliers are given in Annex I. National and/or international requirements may give additional requirements. Reference to such national and/or international requirements are given in Annex I.

¹After 10 December 2000, Societies shall only utilise service suppliers approved in accordance with this UR, except with respect to statutory work, where otherwise instructed by the relevant flag Administration.

4 Procedure for Approval and Certification

4.1 Submission of documents

- 4.1.1 The following documents are to be submitted to the Society for review. General requirements concerning suppliers are given in 4.2, and specific requirements as relevant, in Annex I.
- Outline of company, e.g. organisation and management structure, including subsidiaries to be included in the approval/certification
 - List of nominated agents
 - Experience of the company in the specific service area
 - List of operators/technicians/inspectors documenting training and experience within the relevant service area, and qualifications according to recognised national, international or industry standards, as relevant
 - Description of equipment used for the particular service for which approval is sought
 - A guide for operators of such equipment
 - Training programmes for operators/technicians/inspectors
 - Check lists and record formats for recording results of the services referred to in section 1
 - Quality Manual and/or documented procedures covering requirements in 4.5
 - Evidence of approval/acceptance by other bodies, if any
 - Information on the other activities which may present a conflict of interest
 - Record of customer claims and of corrective actions requested by certification bodies
 - Where relevant, list and documentation of licenses granted by equipment's manufacturer

4.2 General requirements:

- 4.2.1 Extent of Approval: The supplier shall demonstrate, as required by 4.2.2 – 4.2.9, that it has the competence and control needed to perform the services for which approval is sought.
- 4.2.2 Training of personnel – The supplier is responsible for the qualification and training of its personnel to a recognised national, international or industry standard as applicable. Where such standards do not exist, the supplier is to define standards for the training and qualification of its personnel relevant to the functions each is authorised to perform. The personnel shall also have an adequate experience and be familiar with the operation of any necessary equipment. Operators/technicians/inspectors shall have had a minimum of one (1) year tutored on-the-job training. Where it is not possible to perform internal training, a program of external training may be considered as acceptable.
- 4.2.3 Supervision – The supplier shall provide supervision for all services provided. The responsible supervisor shall have had minimum two (2) years experience as an operator/technician/inspector within the activity for which the supplier is approved. For a supplier consisting of one person, that person shall meet the requirements of a supervisor.
- 4.2.4 Personnel records – The supplier shall keep records of the approved operators/technicians/inspectors. The record shall contain information on age, formal education, training and experience for the services for which they are approved.
- 4.2.5 Equipment and facilities – The supplier shall have the necessary equipment and facilities for the service to be supplied. A record of the equipment used shall be kept. The record shall contain information on maintenance and calibration.
- 4.2.6 Procedures – The supplier shall have documented work procedures covering all services supplied.
- 4.2.7 Subcontractors – The supplier shall give information of agreements and arrangements if any parts of the services provided are subcontracted. Particular emphasis shall be given to quality management by the supplier in following-up of such subcontracts. Subcontractors providing anything other than subcontracted personnel or equipment shall also meet the requirements of sections 4.2 and 4.5.
- 4.2.8 Verification – The supplier shall verify that the services provided are carried out in accordance with approved procedures.
- 4.2.9 Reporting – The report shall be prepared in a form acceptable to the Society. Special guidelines may be given in Annex I. The report shall include a copy of the Certificate of Approval.

- 4.3 Auditing of the Supplier – Upon reviewing the submitted documents with satisfactory result, the supplier is audited in order to ascertain that the supplier is duly organised and managed in accordance with the submitted documents, and that it is considered capable of conducting the services for which approval/certification is sought.
- 4.4 Certification is conditional on a practical demonstration of the specific service performance as well as satisfactory reporting being carried out.
- 4.5 Quality Assurance System
- 4.5.1 The supplier shall have a documented system covering at least the following:
- code of conduct for the relevant activity
 - maintenance and calibration of equipment
 - training programmes for operators/technicians/inspectors
 - supervision and verification to ensure compliance with operational procedures
 - recording and reporting of information
 - quality management of subsidiaries and agents
 - job preparation
 - periodic review of work process procedures, complaints, corrective actions, and issuance, maintenance and control of documents
- 4.5.2 A documented Quality Assurance system complying with the ISO 9000 standard or equivalent and including the above items, would be considered acceptable.
- 4.6 Service Suppliers Relations with the Equipment Manufacturer
- 4.6.1 A company which works as a service station for manufacturer(s) of equipment (and as a service supplier in this field), shall be assessed by the manufacturer(s) and nominated as their agent. The manufacturer shall ensure that appropriate instruction manuals, material etc. are available for the agent as well as of proper training of the agent's technicians. Such suppliers shall be approved either on a case by case basis, or in accordance with 4.6.2.
- 4.6.2 If a manufacturer of equipment (and service supplier) applies to a Society for inclusion of his nominated agents and/or subsidiaries in the approval, then he must have implemented a quality assurance system certified in accordance with ISO 9000 series, with effective controls of his agents and/or subsidiaries, and when these agents/subsidiaries have an equally effective quality control system complying with ISO 9003. Such approvals shall be based upon an evaluation of the quality assurance system implemented by the parent company against minimum ISO 9002. The Society will follow-up the adherence to this quality assurance system by performing audits on such agents or subsidiaries against ISO 9003.

5 Certification

- 5.1 Upon satisfactory completion of both the audit of the supplier and the demonstration test, if required, the Society will issue a Certificate of Approval stating that the supplier's service operation system has been found to be satisfactory and that the results of services performed in accordance with that system may be accepted and utilised by the Society's Surveyors in making decisions affecting classification or statutory certification, as relevant. The Certificate shall clearly state that the type and scope of services and any limitations or restrictions imposed. The supplier will also be included in the Society's records of approved service suppliers.
- 5.2 Renewal or endorsement of the Certificate is to be made at intervals not exceeding five (5) years by verification through audits that approved conditions are maintained. Individual Societies may require renewal or endorsement of the Certificate at intervals shorter than five (5) years and may require intermediate audits. For firms engaged in thickness measurements, renewal/endorsement of the Certificate is to be made at intervals not exceeding 3 years by verification that original conditions are maintained.
- 5.3 Where several servicing stations are owned by a given company, each station is to be assessed and approved except as specified in 4.6.2.

6 Information of Alterations to the Certified Service Operation System

- 6.1 In case where any alteration to the certified service operation system of the supplier is made, such alteration is to be immediately informed to the Society. Re-audit may be required when deemed necessary by the Society.

7 Cancellation of Approval

- 7.1 Approval may be cancelled in the following cases:
- 7.1.1 Where the service was improperly carried out or the results were improperly reported.
 - 7.1.2 Where a Surveyor finds deficiencies in the approval service operation system of the supplier and appropriate corrective action is not taken
 - 7.1.3 Where the supplier fails to inform of any alteration as in 6 above to the Society
 - 7.1.4 Where intermediate audit, if requested as per 5.2, has not been carried out
 - 7.1.5 Where wilful acts or omissions are ascertained
- 7.2 The Society reserves the right to cancel the approval and to inform the IACS Members accordingly.
- 7.3 A supplier whose approval was cancelled, may apply for re-approval provided he has corrected the non-conformities which resulted in cancellation, and the Society is able to confirm he has effectively implemented the corrective action.

8 Existing Approvals

Approvals granted before the date of implementation of UR Z17 may remain valid as stated in the respective certificates for a period up to but not exceeding 3 years. Renewals of such certificates have to be carried out in accordance with UR Z17.

ANNEX 1

Special Requirements for Various Categories of Service Suppliers

1 Firms engaged in thickness measurements on ships

- 1.1 Extent of engagement – Thickness measurement of structural material of ships except
 - (1) non-ESP ships less than 500 gross tonnage and
 - (2) all fishing vessels.
- 1.2 Supervisor – The responsible supervisor shall be qualified according to a recognised national or international industrial NDT standard (e.g. EN 473 level II or ISO 9712 level II).
- 1.3 Operators – The operators carrying out the measurements shall be certified to a recognized national or international industrial standard (e.g. EN 473 level I or ISO 9712 level I) and shall have adequate knowledge of ship structures sufficient to elect a representative position for each measurements.
- 1.4 Equipment – On coated surfaces, instruments using pulsed echo technique (either with oscilloscope or digital instruments using multiple echo, single crystal technique) are required. Single echo instruments may be used on uncoated surfaces, which have been cleaned and grinded.
- 1.5 Procedures – Documented work procedures are at least to contain information on survey preparation, selection and identification of test locations, surface preparation, protective coating preservation, calibration checks, and report preparation and content.
- 1.6 Reporting – The report shall be based on the guidelines given in UR Z7.1, Z10.1, Z10.2, Z10.3, Z10.4 and Z10.5, as relevant.
- 1.7 Verification – The supplier must have the Surveyor's verification of each separate job, documented in the report by his signature.

2 Firms engaged in tightness testing of hatches with ultrasonic equipment

- 2.1 Extent of engagement – Ultrasonic tightness testing of hatches
- 2.2 Operators – The operator is to have the following qualifications:
 - Have knowledge of different hatch designs, their functioning and sealing features
 - Have experience with operation and maintenance of different hatch designs
 - Be able to document a theoretical and practical training onboard in using ultrasonic equipment specified
- 2.3 Equipment – The ultrasonic equipment to be used shall be type approved by the Society. It shall be demonstrated for the Surveyor that the equipment is fit for the purpose of detecting leakages in hatch covers.
- 2.4 Procedures – The supplier shall have documented work procedures which shall include the manual for the ultrasonic equipment specified, its adjustment, its maintenance, its operation and approval criteria.

3 Firms carrying out in-water survey of ships and mobile offshore units

- 3.1 Extent of engagement – In-water survey of ships and mobile offshore units.
- 3.2 Training of personnel – The supplier is responsible for the qualification of its divers and the diving equipment utilised when carrying out survey. Knowledge of the following shall be documented:
- Ship's underwater structure and appendages, tail shaft, propeller, rudder and its bearings, etc.
 - (void)
 - Under-water thickness gauging and non-destructive testing in accordance with a recognized national or international industrial NDT standard
 - Bearing clearance measurements on rudders and tail shaft
 - Under-water video monitoring with TV-monitors on deck, as well as still picture work
 - Operation of under-water communication system
 - Special equipment and tools like hull cleaners, grinders, cutters, etc.
- 3.3 A plan for training of personnel in the reporting system, minimum Rule requirements for relevant ship types, ship's underwater structure, measuring of bearing clearances, the recognition of corrosion damage, buckling and deteriorated coatings, etc. shall be included.
- 3.4 Supervisor – The supervisor shall be qualified according to the supplier's general requirements and shall have minimum two (2) years' experience as a diver carrying out survey.
- 3.5 Divers carrying out survey – The diver carrying out the survey shall have had at least one (1) year's experience as an assistant diver carrying out survey (minimum 10 different assignments).
- 3.6 Equipment – The following shall be available:
- Closed circuit colour television with sufficient illumination equipment
 - Two-way communication between diver and surface staff
 - Video recording device connected to the closed circuit television
 - Still photography camera
 - Equipment for carrying out thickness gauging, non-destructive testing and measurements, e.g. clearances, indents, etc., as relevant to the work to be performed.
 - Equipment for cleaning of the hull
- 3.7 Procedures and guidelines – The supplier shall have documented operational procedures and guidelines for how to carry out the survey and how to handle the equipment. These shall include:
- Two-way communication between diver and surface
 - Video recording and closed circuit television operation
 - Guidance of the diver along the hull to ensure complete coverage of the parts to be surveyed
- 3.8 Verification – The supplier must have the Surveyor's verification of each separate job, documented in the report by his signature.

4 Firms engaged in surveys and maintenance of fire extinguishing equipment and systems

Extent of engagement – The supplier shall have the professional knowledge of fire theory, fire fighting and fire extinguishing appliances sufficient to carry out the surveys and to make the necessary evaluations of the condition of the equipment.

5 Firms engaged in service of inflatable liferafts, inflatable lifejackets, hydrostatic release units, inflatable rescue boats

- 5.1 Extent of engagement – Servicing of inflatable liferafts, inflatable lifejackets, hydrostatic release units and/or inflatable rescue boats.
- 5.2 Equipment and premises – IMO Res. A.761(18) gives recommendations on conditions for the approval of servicing stations for inflatable liferafts which shall be observed as relevant.
- 5.3 Procedures and instructions – The supplier shall have documented procedures and instructions for how to carry out service of equipment. The procedures should include requirements to record the nature and extent of damages to and defects found in equipment during servicing and repair work. This data shall be made available to the Society upon request.
- 5.4 The supplier shall provide evidence that it has been authorised or licensed to service the particular makes and models of equipment for which approval is sought by the equipment's manufacturer.

6 Firms engaged in the servicing and testing of radio communication equipment

- 6.1 Extent of engagement – Inspection, testing, and/or measurement of radio equipment aboard ships or mobile offshore units for compliance with SOLAS regulations.
- 6.2 Reference documents – The supplier shall have access to SOLAS 1974 as amended, IMO Res. A.789(19): Specification on the survey and certification functions of recognized organizations acting on behalf of the administration, ITU Radio Regulations, and IMO Performance Standards as well as relevant parts, if any, of the Society's Rules and Guidelines.
- 6.3 Supervisor – The supervisor shall have minimum two (2) years education from a technical school and experience as an inspector, and should preferably hold a General Operator's Certificate (GOC).
- 6.4 Radio inspector – The inspector carrying out the inspection shall have passed the internal training of the supplier in Radiotelephony, GMDSS, and initial and renewal surveys, as applicable. The inspector shall also have at least one (1) year's technical school and at least one (1) year experience as an assistant radio inspector.
- 6.5 Equipment
- 6.5.1 The supplier shall have the major and auxiliary equipment required for correctly performing the inspection. A record of the equipment used shall be kept. The record shall contain information on manufacturer and type of equipment, and a log of maintenance and calibrations.
- 6.5.2 A standard which is relevant to the radio equipment to be tested shall be available for the equipment and shall be cited in the inspection report.
- 6.5.3 For equipment employing software in the conjunction with testing/examination, this software shall be fully described and verified.
- 6.6 Minimum required instruments –
- Equipment for measuring frequency, voltage, current and resistance
 - Equipment for measuring output and reflect effect on VHF and MF/HF
 - Equipment for measuring modulation on MF/HF and VHF (AM, FM, PM)
 - Acid tester for checking specific gravity of lead batteries
 - Tester for checking of correct output from Free-Float Satellite EPIRB
- 6.7 Procedures and instructions – The supplier shall have documented procedures and instructions for how to carry out testing and examination of radio equipment. Procedures and instructions for operating of each item of the testing/inspection equipment shall also be kept and be available at all times.

7 Firms engaged in inspection and testing of centralised gas welding and cutting equipment

The supplier shall document and demonstrate that it has knowledge of gas welding, of associated central gas installation systems and of current safety requirements applicable to such equipment by national administrations, sufficient to carry out the inspection and testing and to make the necessary evaluations of the state of the equipment.

8 Firms engaged in surveys and maintenance of self contained breathing apparatus

The supplier shall document and demonstrate that it has knowledge of the equipment and systems sufficient to carry out the inspections and testing of self-contained breathing apparatus to identified standards and to make the necessary evaluation of the condition of the equipment.

9 Firms engaged in the examination of Ro-Ro ships bow, stern, side and inner doors

- 9.1 Extent of engagement - inspection of securing and locking devices, hydraulic operating system, electric control system for the hydraulics, electric indicator systems, and supporting, securing and locking devices and tightness testing.
- 9.2 The supplier is to be certified to ISO 9002.
- 9.3 Reference documents - The supplier shall have access to SOLAS 1974 as amended and IACS Guidelines No. 8 - Check-list for Surveyors of Ro-Ro Ships Shell and Inner Doors Guidelines for Surveyors, or its equivalent, by the relevant class society.
- 9.4 In addition to 4.2.3 of Z17, the Senior Service Engineer (Supervisor) shall have a minimum two (2) years education from a technical school.
- 9.5 Required Equipment
 - 9.5.1 For Inspection of Supporting Securing and Locking Devices, Hinges and Bearings
 - Equipment for measuring clearances (i.e. feeler gauges, vernier calipers, micrometers).
 - Non-destructive examination (i.e. dye penetrant, magnetic particle inspection)
 - 9.5.2 For Tightness Testing
 - Ultrasonic leak detector or equivalent
 - 9.5.3 For Inspection of Hydraulic Operating System
 - Pressure gauges
 - Particle counter for analysing the quality of hydraulic fluid
 - 9.5.4 For Inspection of Electric Control System and Indication System
 - Digital multi-meter
 - Earth fault detector
- 9.6 Procedures and Instructions
 - 9.6.1 The supplier shall have access to drawings and documents, including the Operating and Inspection Manual.
 - 9.6.2 The supplier shall have access to the service history of the doors.
 - 9.6.3 The supplier should use, complete and sign a checklist which has been found acceptable by the classification society.

10 Firms engaged in annual performance testing of Voyage Data Recorders (VDR)

- 10.1 Extent of engagement – Testing and servicing of Voyage Data Recorders (VDR) in accordance with SOLAS Chapter V Regulation 18.8.
- 10.2 The supplier shall provide evidence that he has been authorised or licensed by the equipment's manufacturer to service the particular makes and models of equipment for which approval is sought.
- 10.3 Documentation and Equipment – The supplier shall have access to IMO Resolution A.861(20) and applicable industry performance standard (e.g., IEC 61996), and have documented procedures and instructions. In addition the supplier shall have documentation and equipment as specified in the authorisation or license from the equipment manufacturer.
- 10.4 Test Report - The supplier shall issue a certificate of compliance as specified in SOLAS Chapter V Regulation 18.8.

11 Firms engaged in surveys of low location lighting systems using photo luminescent materials

- 11.1 Extent of engagement – Luminance measurements on board ships of low location lighting systems using photo luminescent materials.
- 11.2 Operators – The operator is to have the following qualifications:
- Have adequate knowledge of the applicable international requirements (namely SOLAS reg. II- 2/13.3.2.5, IMO Res. A.752(18), ISO 15370-2001, FSSS Code Chapter 11)
 - Be able to document a theoretical and practical training onboard in using equipment specified
- 11.3 Equipment – The measuring instrument shall incorporate a fast-response photometer head with CIE (International Commission on Illumination) photopic correction and have a measurement range of at least 10⁻⁴ cd/m² to 10 cd/m².
- 11.4 Procedures – Documented work procedures are at least to contain information on survey preparation, selection and identification of test locations.
- 11.5 Reporting – The report shall conform to Annex C of ISO 15370-2001.
- 11.6 Verification – The supplier must have the Surveyor's verification of each separate job, documented in the report by his signature.

12 Firms engaged in sound pressure level measurements of public address or general alarm systems on board ships

- 12.1 Extent of engagement – Sound pressure level measurements of public address and general alarm systems on board ships.
- 12.2 Operators – The operator is to have the following qualifications:
- Have adequate knowledge of the applicable international requirements (SOLAS Reg. III/4 and III/6, LSA CODE Chapter VII/7.2, IMO Code on alarms and indicators, 1995)
 - Be able to document a theoretical and practical training onboard in using equipment specified
- 12.3 Equipment – The measuring instrument shall be an integrating sound level meter with frequency analyser capabilities complying with IEC (International Electrotechnical Commission) 60651 and IEC 60804, type 1 precision class with, at least an A-weighting frequency response curve and 1/3 octave and 1 octave band filters, complying to IEC 61260, as appropriate for the measurements to be carried out. In addition microphones shall be of the random incidence type, complying to IEC 60651.
- 12.4 Procedures – Documented work procedures are at least to contain information on survey preparation, calibration, selection and identification of test locations.
- 12.5 Reporting – The report shall describe, as a minimum, the environmental conditions of the tests and, for each test location, the ambient noise level or the speech interference level, as appropriate for the measurements to be carried out. The report shall conform to any other specific requirement of the Society.
- 12.6 Verification – The supplier must have the Surveyor's verification of each separate job, documented in the report by his signature.

Appendix F

IACS Z9 Corrosion Protection Coatings for Cargo Hold Spaces on Bulk Carriers

1992

(Rev 1

1995)

(Rev 2

1996)

Corr. 1997

At the time of new construction, all internal and external surfaces of hatch coamings and hatch covers, and all internal surfaces of the cargo holds, excluding the flat tank top areas and the hopper tanks sloping plating approximately 300 mm below the side shell frame and brackets, are to have an efficient protective coating (epoxy coating or equivalent) applied in accordance with the manufacturer's recommendation. In the selection of coating due consideration is to be given by the owner to intended cargo conditions expected in service.

For existing bulk carriers, where Owners may elect to coat or recoat cargo holds as noted above, consideration may be given to the extent of the close-up and thickness measurement surveys. Prior to the coating of cargo holds of existing vessels, scantlings are to be ascertained in the presence of a Surveyor.

Note: Revision 2, 1996 of Unified Requirements Z9 has been approved by Council for application to new ships for which the request for class is received on or after 1 July 1998.

ABS WORLD HEADQUARTERS

ABS Plaza
16855 Northchase Drive
Houston, TX 77060 USA
Tel: 1-281-877-5800
Fax: 1-281-877-5803
Email: abs-worldhq@eagle.org

ABS EUROPE DIVISION

ABS House
No. 1 Frying Pan Alley
London E1 7HR, UK
Tel: 44-20-7247-3255
Fax: 44-20-7377-2453
Email: abs-eur@eagle.org

ABS PACIFIC DIVISION

438 Alexandra Road #10-00
Alexandra Point
Singapore 119958
Republic of Singapore
Mail: PSA Building, P.O. Box 0496
Singapore 911147
Tel: 65-6276-8700
Fax: 65-6276-8711
Email: abs-pac@eagle.org

ABS AMERICAS DIVISION

ABS Plaza
16855 Northchase Drive
Houston, TX 77060 USA
Tel: 1-281-877-6000
Fax: 1-281-877-6001
Email: abs-amer@eagle.org

WEBSITE:

<http://www.eagle.org>



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