National Technical University of Athens
School of Naval Architecture & Marine Engineering
Shipbuilding Technology Laboratory

"Coating, Application & Performance"

ΔΙΠΛΩΜΑΤΙΚΗ ΕΡΓΑΣΙΑ
Της
ΜΑΡΙΑΣ ΣΤΑΡΑΤΖΗ

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Abstract

Paints have troubled industries for quite a long time, and shipping industry specifically over the last decades. These troubles set the absolute target for coating systems optimization, in terms of application as well as performance. This diploma thesis explores the vital aspects of the coating system for ship's life. Foundational knowledge of paints basic components and pre-treatment are considered essential for comprehending crucial methods of surface preparation prior coating application. Deep concertation on coating maintenance reasons and brief illustration of coating particularities for each different vessel structure are of equal importance. Water ballast tanks are a separate section which is extendedly explicated due to vagaries displayed within these areas. Regulatory frameworks and standards from international bodies are recorded and common coating defects with visual aids for easier identification are examined and health hazards associated with painting processes are highlighted. Supplementary, is analyzed economic aspects of painting systems on and at its conclusion are offered future research directions for environmentally friendly paints.

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Contents

List of Abbreviations

A: Area

e: electron

H: Hydrogen

H2O: Water

HCl: Hydrochloric Acid

IACS UR Z17: IACS Procedural Requirements for Service Suppliers

IACS: International Association of Classification Societies

ICCP: Impressed Current Cathodic Protection

IMO PSPC COT: The "Performance Standard for Protective Coatings for cargo oil tanks of crude oil tankers", adopted on 14 May 2010 by IMO Maritime Safety Committee under Resolution MSC.288(87).

IMO PSPC VSP: The "Performance Standard for Protective Coatings for void spaces on bulk carriers and oil tankers", adopted on October 2007 by IMO Maritime Safety Committee under Resolution MSC.244(83).

IMO PSPC WBT: The "Performance Standard for Protective Coatings for dedicated seawater ballast tanks", in all types of ships and double-side skin spaces of bulk carriers, adopted on 8 December 2006 by IMO Maritime Safety Committee under Resolution MSC.215(82).

IMO PSPC: IMO Resolution – Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks in All Types of Ships and Double Side Spaces of Bulk Carriers

IMO: International Maritime Organisation

IR: Infrared

LCC: Life Cycle Costing

LF: Loss Factor

MSDS: Material Safety Data Sheet

NaCl: Sodium Chloride

NDFT: Nominal total Dry Film Thickness

O2: Oxygen

PMS: Performance Maintenance System

PSPC: Performance Standard for Protective Coatings

PVC: Pigment Volume Concentration

Q: Volume of Paint

SG: Specific Gravity

SIS: Swedish Standards Institute

SoC: Statement of Compliance

TA-Cert: Type Approval Certification

TBT: Tributyltin

TDS: Technical Data Sheet

UV: Ultraviolet

VOC: Volatile Organic Compounds

VS: Volume of Solids

Zn: Zinc

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Chapter 1: Introduction

1.1 About Paints and Maintenance - Surface Preparation

A correct and systematic choice of paint system for a new building and subsequent maintenance of the system is, in the long run, one of the most decisive factors for the vessel's economy. Given that, painting on-board should be taken seriously.

Maintenance of paint work is mainly based on two requirements. The first one is to keep the ship as clean and tidy as possible, making it a pleasant place to work for the crew and also a proud representative of its countries and owner's flags, when it is sailing in foreign waters. Secondly, it is to prevent corrosion and fouling, maintaining maximum efficacy and value. Nowadays, the second aim of painting is probably the one with paramount importance, as counteracting corrosion and fouling should be the principal consideration when choosing paint systems and planning maintenance of paintwork.

Rust is an insidious enemy (see Figure 1) and costs the merchant fleet of the world enormous sums every year, but by using modern painting, it can be fought effectively. The primary objective of painting is to attack in time and choose the right method and paint system. If preventive measures are taken immediately when signs of rust are detected or when one suspects the formation of rust below the surface, it will be possible to save both work and money. In case of waiting till rust has ravaged the ship to such an extent that her appearance is marred, then most possible will be required a lot of time work and double cost in comparison with the pro-active measurements. In order for the best result to be obtained, it is of vital importance to know the way under which paint is working and also what is demanded of paint and preparation. At the work "preparation" are included the appeared rust removal, mill-scale, salt, grease, dirt and loose of paint, that is the main importance single factor in deciding how long the paintwork is to last, apart from the quality of the paint. First-class preparation may increase the life of the paint work tenfold (European Society for Marine Biotechnology, 2015).

Figure 1: Extended levels of rust on a shipwreck, located in New Zealand, (Jotun Coating Manual, Athens, 2018)

Paint can never be applied on top of rust with the best results. Besides preparation being the most important part of all paintwork at sea, it is also usually the most time-consuming. First of all, it should be made sure that the work is planned so that the priming coat can be applied immediately after preparation has been completed. If this coat is to provide full protection, then it must penetrate all indentations and irregularities in the surface. This is best done by using a brush or an airless spray. If a roller is used, air and moisture can be trapped in minute hollows in the surface and rust will quickly form. Given the above, it is recommended not to use a roller when applying the first coat of primer.

Paintwork should always be planned so that the paint can be applied in dry weather, since it is forbidden to start preparation in a damp atmosphere. Also, if it is possible, painting should be avoided in cold weather for best results. Commonly, rust under painting will appear on surfaces which have been painted when the temperatures were at freezing point or below it. At such temperatures, there is always a chance of invisible condensation. *Using light colors in dark areas can assist painting application and inspection (Figure 2)*

Figure 2: Light colors in dark areas assist application and inspection, (PST Photo Gallery, 2015)

1.2 Avoid Thinning the Paint

Modern paints are most of the times, ready to be used upon their on-board delivery. To be added any thinner or other additives other than those that may be prescribed for the paint in question, will only lead to inferior paintwork by reducing the solids content of the paint. The wet film thickness must therefore be increased to obtain the specific dry film thickness. If the paint is to be thinned, which may occur either by spaying or when applied at cold weather conditions, only small amounts of thinner should be added. Special attention should be paid for using the correct thinner, and thus the given instructions at the paint's tin should always be read either for the vessel's crew or by the technicians.

1.3 The Durability of Paint Film is Dependent on its Paint Thickness

Independent of the used paint's type, the specific film thickness is of course necessary for obtaining the optimum steel's protection. The ability of the paint film to resist wear caused by the wind, sea and mechanical stress is completely dependent on this film. Commonly, when standard paints are used and applied either by brush or roller, then at least 4 coats should be applied at the steel surface and of them, two (2) or three (3) should be rust –preventing primer.

On the other hand, if a high-build paint is to be used and it is to be applied by an airless spray, the number of coats can then be reduced. The relevant painting instructions should be strictly adhered to. Upon painting application completion, an instrument should be used for measuring the paint's film thickness, but also checking and ensuring that the whole work is completed smoothly.

At this point, it should be underlined that it is the total thickness of all the film layers that count and not only the primers. In general, valid below figures for paint films (1 micron= 1/1000 mm):

- On under-water surfaces, there should be at least 200 microns of corrosion preventing primers
- On boot toping, topsides and decks surfaces at least 150 microns
- On superstructures at least 125 microns

An approximate depiction of the variations of the paint thickness is shown on Figure 1.3.1.

Since the heaviest pigments tend to sink at the bottom of the tin, after some time has passed, the composition of paint will differ at various levels in the tin. Therefore, if the paint is used without being thoroughly stirred, then the initial promised quality will be deteriorated and, possibly, the color shades can also be changed. Based on all the above, it should always be remembered to stir the paint well and with a suitable tool.

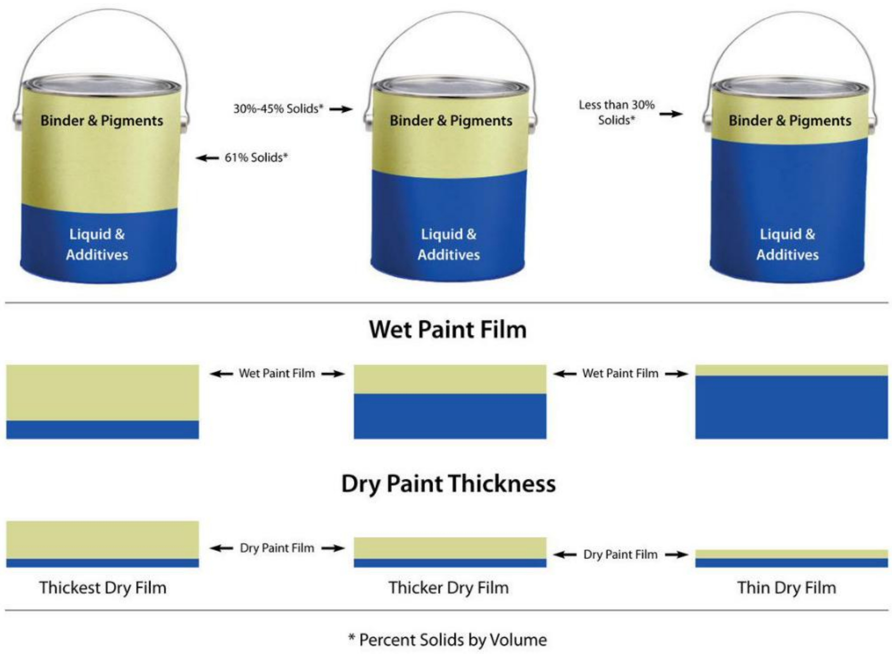

Figure 3: An approximate depiction of the variations of the paint thickness mentioned above (along with additional information on different possible compositions of paints), (PPG Basic Marine Coating and Terminology, 2013)

Additionally, cleanliness is also essential for good work-clean surface and clean tools. Very often, the appearance of a large area is damaged by streaks of rust which have originated from small penetrations of rust at corners and in places where generally the steel surface is very rough and uneven. This roughness should be removed and corners be rounded, in order for a more even thickness of the film to be achieved and thus, reduce the likelihood of rust penetrations. At that point, the used disc grinder for the rust removal should be carefully chosen, as it is important to be of the correct degree of fineness and be avoided the surface's polishing. Alternatively, if wire brushes are used, they should indeed be made of coarse wire with twisted bristles, so that they do not bend too easily in use.

1.4 Pre - Treatment

In order to judge the different methods of the surface preparation and also different types of equipment along with their use, we should be aware of what actually a surface preparation requires.

Paint work, intended to protect against corrosion, demands quite a different pre-treatment of the surface than what a touch-up job would, which is merely intended to reinstate colour and gloss.

1.4.1 Painting on the Top of Intact Paint

In the event that painting will be applied on the top of an old intact paint that is not too heavily contaminated, the surface must firstly be washed with fresh water, and if necessary, with the addition of a synthetic detergent. Then, the surface should be washed down thoroughly with fresh water. Painting over salt does not gives satisfactory results and trying to save water is just poor economy. Modern high-pressure equipment also gives excellent results in removing trace of salt.

The surface should be absolutely dry before paint is applied, but not too much time must have passed, since salts quickly form on the steel surface again. When painting on top of old, intact and glossy paint, a flat undercoat is normally required. This, however, is not necessary when repainting is referring to chlorinated rubber and vinyl paints.

Areas which are heavily contaminated by oil should be cleaned in the following mentioned manner, on the assumption that chlorinated rubber, vinyl or bituminous paints have not previously been used on those surfaces. Very dirty surfaces should be treated with a water-soluble detergent. After the cleaning agent has been allowed to work for a time period of approximately 10 minutes, then the surface should be washed down with fresh water. In case that this procedure do not give the required results, then the same treatment should be repeated.

1.4.2 Areas Damaged With Rust

Rust and mill-scale, as well as loose paint and paint under which rust has started, must be thoroughly removed. All rust preventing paints give the best results when applied to bare steel or over intact paint.

Several methods can be used for the rust removal and contamination on steel. Rust chipping with subsequent hand-scraping and wire-brushing is the most usual and commonly preferred method, but unfortunately rust said to be unsatisfactory when considering today’s exacting demands. Essentially, the use of the rotating wire-brush (Figure 4) gives better results than manual wire-brushing. Consequently, the choice of the correct implement is of paramount importance for the final results.

Other methods that can also give goods results are mechanical grinding, mechanical wire-brushing, mechanical chiseling and needle hammering. Descaling, either with ordinary or mechanical scaling hammers, is not to be recommended as they can easily chip the surface and should therefore not be used if it is not necessary. A combination of all the above-mentioned methods is often advantageous (American Iron and Steel Institute, 2020).

Figure 4: A wire-brush, one of the methods of dealing with rust, as mentioned above (PST Photo Gallery, 2015)

Blast cleaning, however, is the best method for removing rust, mill-scale, loose old paint and will undoubtedly in the future be common also in connection with maintenance on-board work (Figure 5)-. In connection to ordinary blast-cleaning, following rules are of paramount importance:

- Efficient air pressure should be ensured. Correct air pressure when blasting in blast-cleaning is approximate 7-7,5 kg/sq. cm. In case that this air pressure for some reasons has to be reduced to 5 kg/sq. cm, then it may have to be used twice as much abrasive in order to achieve the same results with those of used air pressure at 7-7,5 kg/sq.
- Small areas at a time should be blasted and protect the blasted surface with shop-primer or wash-primer as soon as possible after blasting.
- Efficient dust removal should be provided, either by compressed air that will be free of oil and water or with vacuum cleaner, of course prior to the primer application.
- Firstly, rust and loose paint could be removed by chipping or scrapping, prior blast cleaning, since most of the times they result in a great saving in time and abrasive consumption.

In general, the efficiency of blast-cleaning measured in sq. meters per working hour is many times greater with a good and conventional pre-treatment. Moreover, it should be taken into account that the durability of any chosen paint system will be greatly increased when applied to a blast-cleaned surface in comparison with application on a surface treated in the best possible manner but only with conventional tools. It should be also underlined at this point that a number of sophisticated paint systems require a blast-cleaned surface to give a good result.

Figure 5:Example of the blast-cleaning method depicted (Hempel, Guideline for Corrosion Protection, 2019)

Blast-cleaning should be also carried out by means of vacuum blasting apparatus. The sand, grit or small steel shot that are used, are under that way circulated in a closed system so that dust is completely avoided. This apparatus has a relatively small capacity but is well suited for treating smaller areas such as welding seems or burn damage.

1.4.3 Aluminum and Galvanized Steel

Untreated aluminum, other light metal and galvanized steel are surfaces that are considered quite difficult to be painted on and ordinary primers do not adhere. Therefore, special pre-treatment procedure is recommended as described below:

1. Thoroughly decrease with a strong solvent
2. One coat of wash-primer should be applied after which the desired paint system should be applied.
3. In case of using 2-pack epoxy paints, then the wash-primer should be omitted.
4. Substrate should be rubbed with emery paper or lightly blast-clean and then ply-amide cured epoxy should be applied direct.

Not all types of primer are suitable for application on aluminum and galvanized steel surfaces.

1.4.4 Recommended Tools and Equipment

For the daily maintenance, work is carried out on board, following simple tools and equipment recommended and commonly used for pre-treatment purposes, such as:

1. Larger, mobile blast-cleaning equipment
2. Vacuum-blasting equipment
3. Air-driven grinding equipment
4. Rotary wire-brushes (can be easily been combined with the latter two)
5. Needle gun
6. Air-driven descaler
7. Manual scraper with exchangeable hard-metal edge
8. Hand wire-brushes of various sizes

The main reason for tank-coating is to provide effective corrosion control of the internal cargo compartments designed to carry a wide range of liquid cargoes, and also to protect the cargoes transported against contamination. Furthermore, the lining of the tanks ensures easier cleaning and gas freeing.

For a successful treatment, the design and accessibility to the entire surface of the cargo tank is the most important factor.

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For a successful treatment, the design and accessibility to the entire surface of the cargo tank is the most important factor (See Figure 6).

Figure 6: A diagram of the most important stages and factors affecting tank-coating (many of which will be examined furthermore afterwards) (Hyundai Painting Specification, 2016)

Chapter 2: Paints

2.1 Introduction

Paint may be described as a liquid composition, with a viscosity adjusted for application by spray equipment, brush, roller etc. and which drying/ curing process transforms to a solid, strong, protecting and decorative coating.

Modern paints are complicated in their composition. The chief constituents are as follows (Figures 7-9):

- Binder
- Pigment
- Extender
- Organic Solvents or water
- Additives (driers, anti-skinning agents, rheological agents, air release agents, leveling agents etc)

The materials used are carefully selected and tested, and the relative amounts employed in the paint are of paramount importance for the final properties of the paint. Generally speaking, formulating modern paints is a specialized profession, and small variations in the relative amount of the paint constituents may lead to great variations in the final properties of the paint (See Figure 10).

Thus, adding oils that are not recommended by the manufacturer, invariably lead to inferior results.

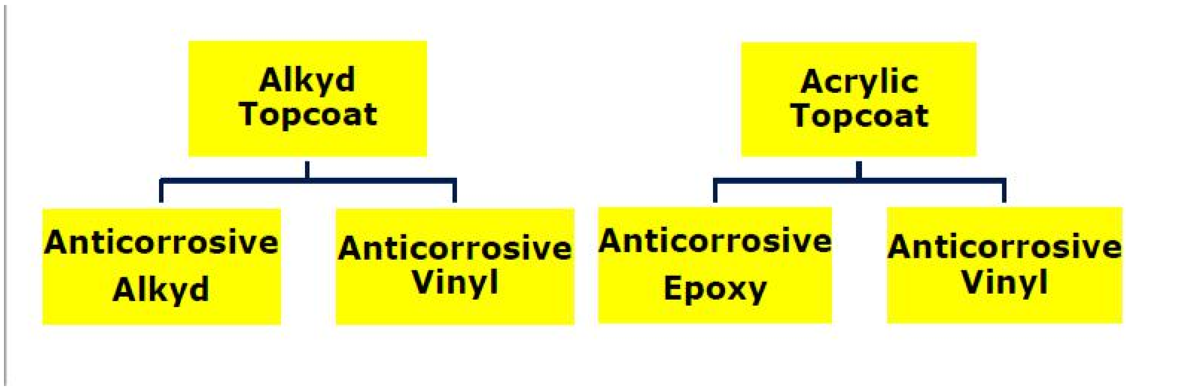

Figure 7: Paint systems (Compatibility of Generic Types) (1) (ABS Coating Performance Standards, 2019)

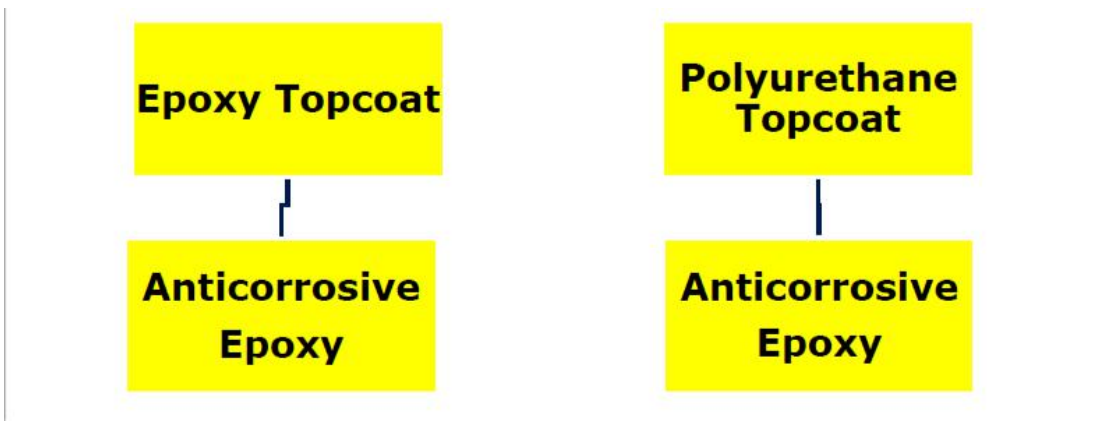

Figure 8: Paint systems (Compatibility of Generic Types) (2) (ABS Coating Performance Standards, 2019)

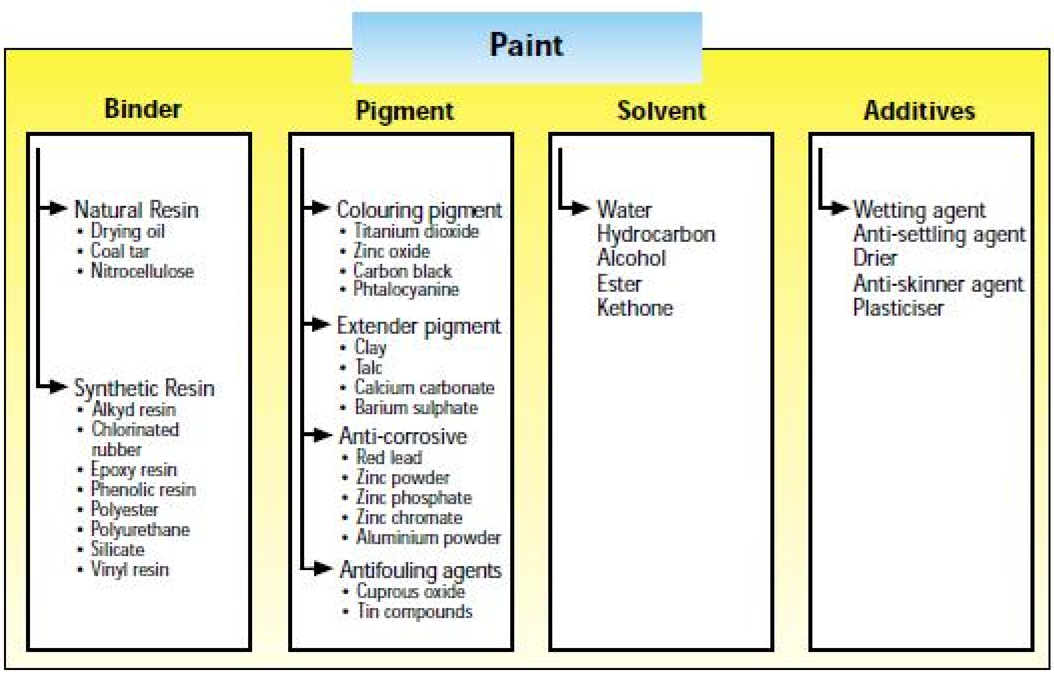

Figure 9: A summary table of the most important ingredients of a paint (Jotun Coating Manual, 2018)

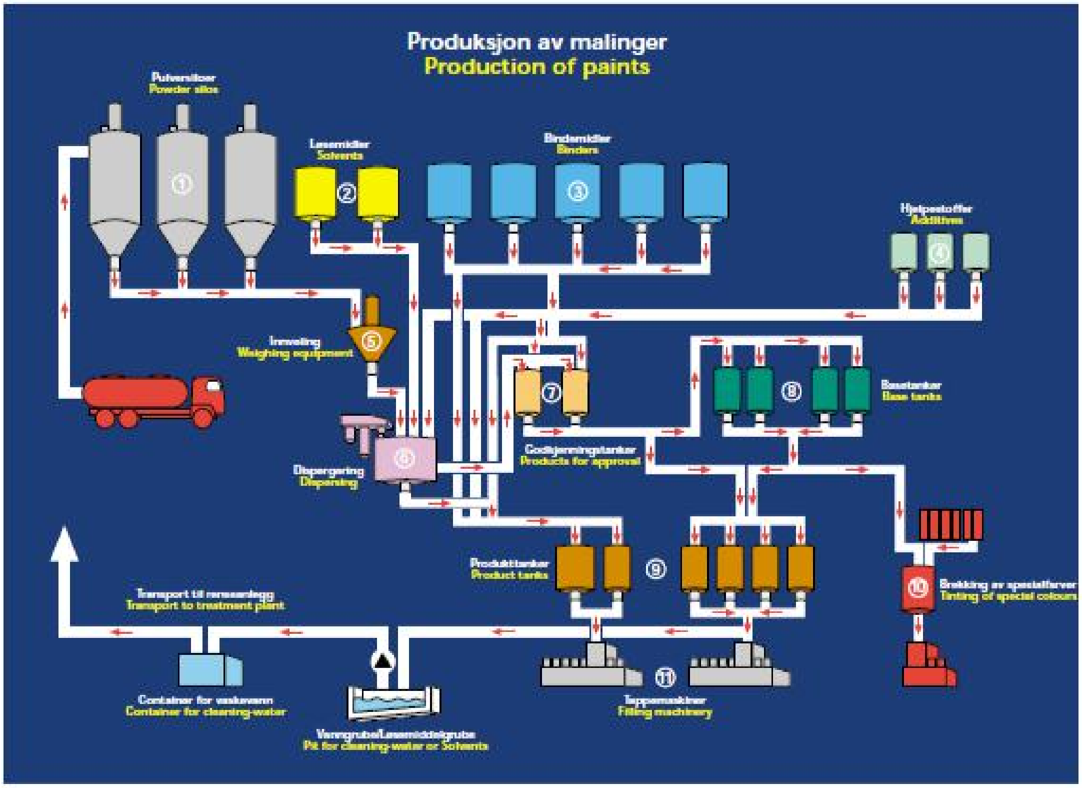

Figure 10: A summary of the production stage of paint (Jotun Coating Manual, 2018)

2.2 Useful Terminology

It is important to get accustomed to some terms that are often used among people who produce or apply paints. Below, the most frequently used, as well as some that may not be understandable on a first glimpse, are presented:

- **Theoretical Spreading Rate:** It is used to refer to the area that is expected to be covered with one liter of paint, at a certain Dry Film Thickness (DFT). It is measured in [m^2/liter] (Figure 11).

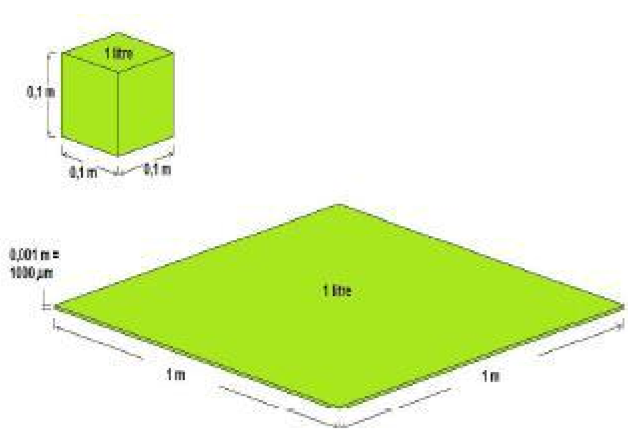

Figure 11: Spreading Rate (Recommended Procedures and Guidelines, ITTC, 2011)

- **Loss Factor**: It is percentage of the technological waste in the application process, which can even vary up to 85% on complex structures.

- **Practical Spreading Rate**: It is the actual area that can be covered with 1 liter of paint, at a specific DFT, which is calculated after taking into consideration the Loss Factor mentioned above. Thus, it is measured in [m^2/liter].
- **Dead Volume**: It is a term that is mostly used to refer to the primers. It is basically the volume of micro surface roughness which needs to be filled in, prior to build the specified Wet Film Thickness or/and Dry Film Thickness. It should be underlined that it does not contribute to the effective, measurable Wet Film Thickness and Dry Film Thickness (Figure 12).
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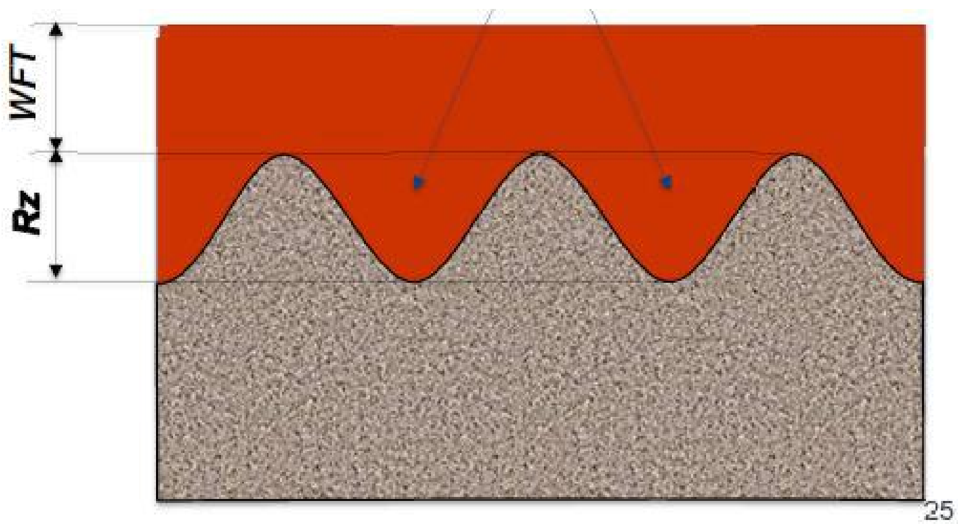


Figure 12: The "valleys", which the arrows point to, are the Dead Volume mentioned above (Jotun Coating Manual, 2018)

- **Paint Volume Estimation:** It is more of a formula, essentially, which is able to provide satisfying results, regarding the volume of paint needed for a certain area.

  $_{(10 * A * DFT)}\ ^{Q=}VS*(100-LF)$

  in which, A= Area to be coated [m^2]

  DFT= Dry Film Thickness [microns] VS=
  Volume of Solids [%]
  LF= Loss Factor [%]

  and the expected result Q=Volume of Paint needed is calculated in liters
- **Mass Density:** It is Weight-to-Volume Ratio [Kg/Liter] and is quite important for packaging, Transporting Storing and Handling. In daily exchanges, a Mixing Ratio could be measured in Volume/Volume or Weight/Weight.
- **Relative Humidity:** The actual amount of water-vapor in the air, as a percentage of the maximum possible water-vapor the air can contain at a certain T^o and pressure, before saturation (Figure 2.2.3).
- **Dew Point:** The temperature at which the water-vapor in the air starts condensing on hard surfaces (Figure 13).

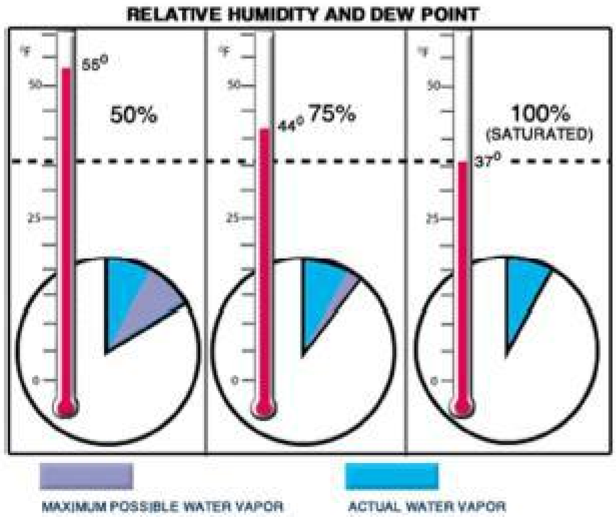


Figure 13: Schematic presentation of Relative Humidity and Dew Point (Jotun Coating Manual, 2018)

2.3 Pigment

Those components are small particle side solid materials which are finely dispersed in the paint. The primary functions of the pigments are to give the paint its color and hiding power and to protect the binder against degradation by the UV rays in sunlight.

Some pigments such as zinc phosphate have anticorrosive properties. Some others as zinc oxide, copper suboxide etc have biocidal effects and protect against moulds and fouling organisms.

There is a wide variation of pigments in terms of colours and types (See Figures 14-15).

Figure 14: A sample of different variations of pigments (Coating Performance Standards, ABS, 2019)

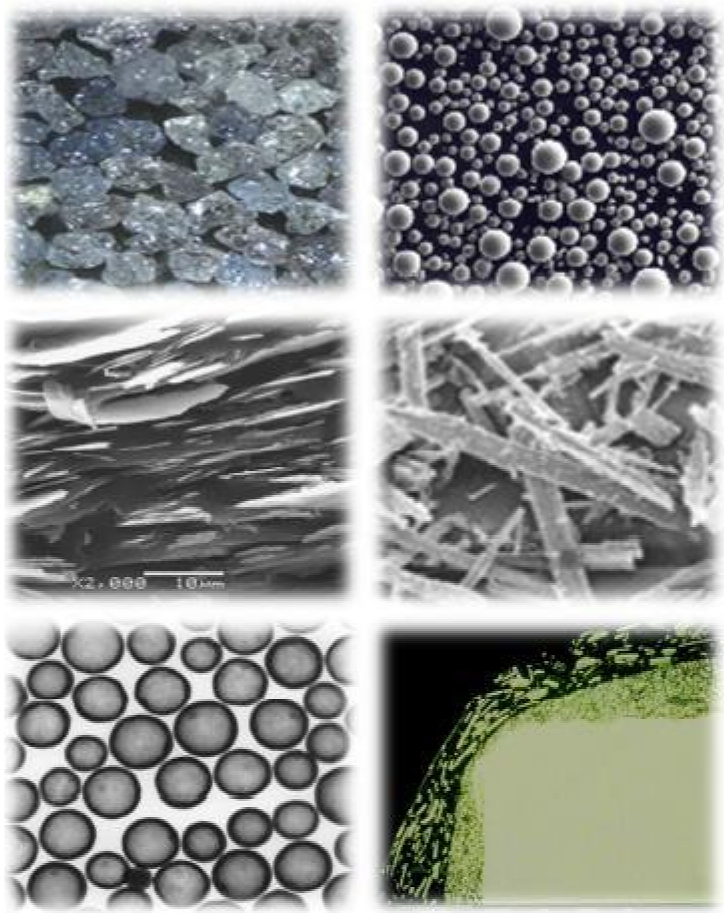


Figure 15: Different types of pigments (Coating Performance Standards, ABS, 2019)

2.4 Extender

Extenders are naturally occurring or synthetic minerals like talc's, clays, dolomite, calcite etc., finely divided and dispersed in the paint. They have different particle size and shape, spherical, laminar, and fibrous and are with smooth or rugged surface. Extenders have vital functions in the paint.

They must be carefully chosen and blended in the correct relative amounts in order to achieve the best possible quality of the paint. Their primary function is to reinforce the paint film and to give the correct gloss (Figure 16). However, they also have great influence on application and anticorrosive properties.

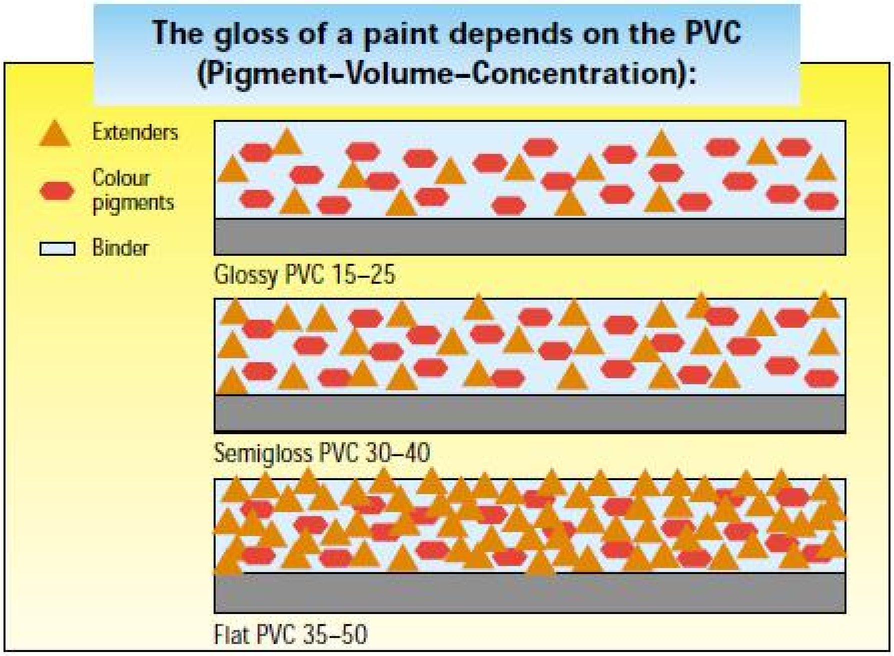


Figure 16: The gloss of a paint depends on the PVC (Basic Paint Technology & Terminology, PPG, 2013)

2.5 Binder

The binder is the continuous phase of the paint film, wherein pigments and extenders are dispersed. In most cases the binder also represents the largest volume share of the film (See Figure 17) and is the single component having the largest influence on the paints properties as to drying/curing characteristics, adhesion, hardness, strength, chemical resistance etc.

Therefore, the type of binder is normally used to describe generic types of paints (alkyd paints, epoxy paints, chlorinated rubber paints)

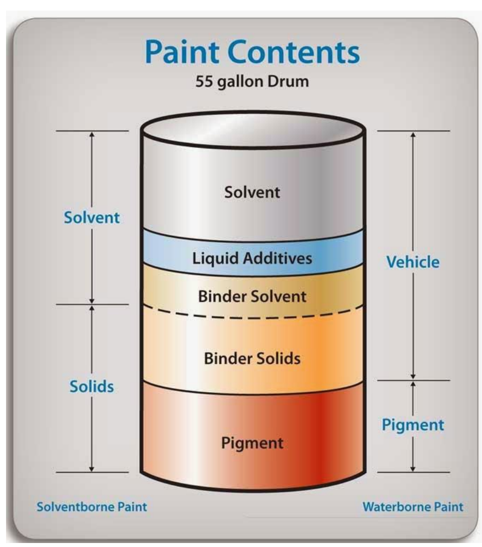


Figure 17: A typical allocation of paint contents (Basic Paint Technology & Terminology, PPG, 2013)

In the old days binder for paints were mainly naturally occurring materials like linseed oil, bitumen, coal tar, various hard resins etc. On the contrary, today's paints binders are developed by polymer chemists, reacting together carefully selected raw linseed oils still play an important role as building blocks in some of the modern binders (See Figure 19).

The paint chemists of the day have a large variety of binders at their disposal, which enables tailor making paints for specific purposes as well as development of general-purpose paints of high quality. A summary of the different types of binders and their effects is shown in Figure 18.

Binder drying/curing Mechanism	Binder Generic Type	Component 1		Component 2	Wet Paint Thickness WFT	Drying / Curing By:	Dry Film Thickness DFT
Physically Drying	Acrylics, Vinyl's, Chlorinated-Rubbers					Solvent Evaporation	
Oxidative Curing	Alkyds		+	O_2 Oxygen from the Air		Solvent Evaporation + Reaction with Oxygen	
Moisture Curing	Silicates, Silicones		+	H_2O Moisture from the Air		Solvent Evaporation + Reaction with Water	
Chemically Curing	Epoxies, Polyurethanes		+			(Solvent Evaporation) + Reaction between Components	

Figure 18: A summary of different types of binders and their effects (Basic Paints Technology & Terminology, PPG, 2013)

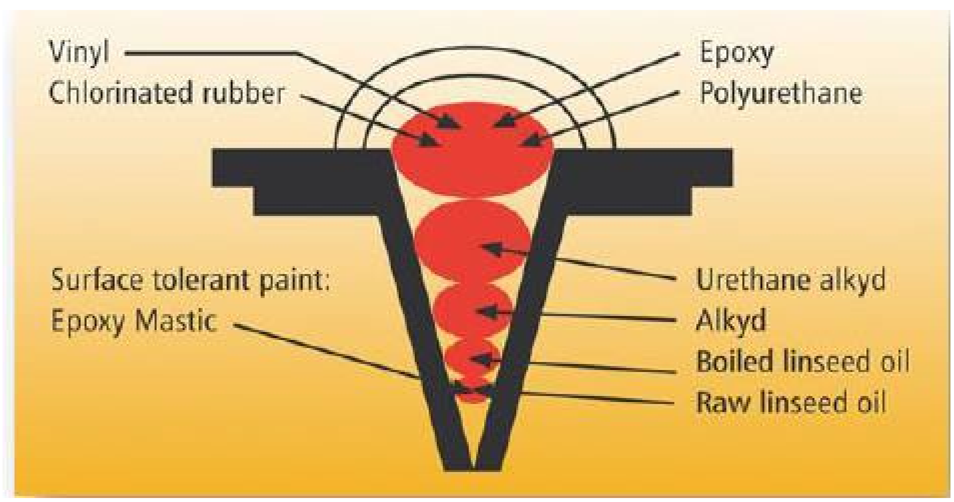


Figure 19: Pigmented epoxy binder which has been enhanced with hydrocarbon resin and cured with an amine based curing agent (Basic Paint Technology & Terminology, PPG, 2013)

2.6 Types of Paints

Paints may be classified in many ways, such as the general type of the binder or by function (primer/topcoat, protective/decorative). In most cases, however, they are categorized according to their drying/curing mechanisms.

All materials are composed of molecules. The type and size of the molecules and the natural attractive and repulsive forces acting between them, determine the physical and chemical characteristics of the material.

Molecules are the smallest single particles materials may be divided into. All molecules are very, very small, that even what we will call very large molecules are so small that single molecules cannot be distinguished by the strongest microscopes.

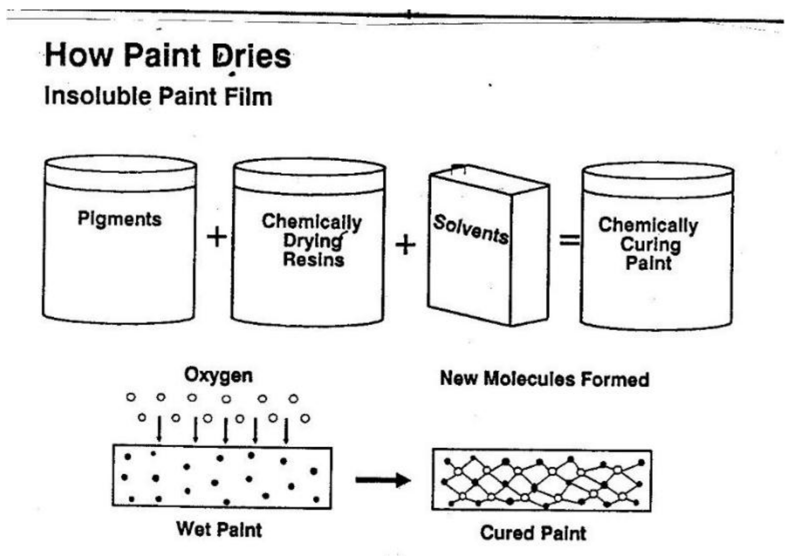


Figure 20: A very simple explanation of the process (Coating Manual, Jotun, 2018)

A chemical reaction means to change the molecules in some ways, making them smaller or bigger or changing their structure. By changing the molecules, the material will automatically change and thus, broadly speaking, we may say that gases consist of small molecules, liquids of small to medium sized and solids from medium to very large sized molecules.

Solid materials, consisting of large sized molecules, may however be bought into the liquid state by mixing with materials of smaller molecules, i.e. dissolving resins/ polymers in solvents.

On the other hand, liquid materials may be bought into the solid state by chemical reaction, i.e. increasing the molecules size by linking smaller sized molecules together with chemical bonds.

By drying/ curing the paint films, physical and/or chemical reactions are taking place, whereby small sized molecules (solvents, water) are leaving the film by evaporation, and the binder left either consists of premade very large molecules or of smaller sized molecules being linked together by chemical reactions in the film (See Figures 20-22). Based on that drying/ curing mechanism, paints could be classified in three main groups, as below mentioned:

1. **Oxidative Paints**
2. **Physically Drying**
3. **Chemically Curing, two components' paints**

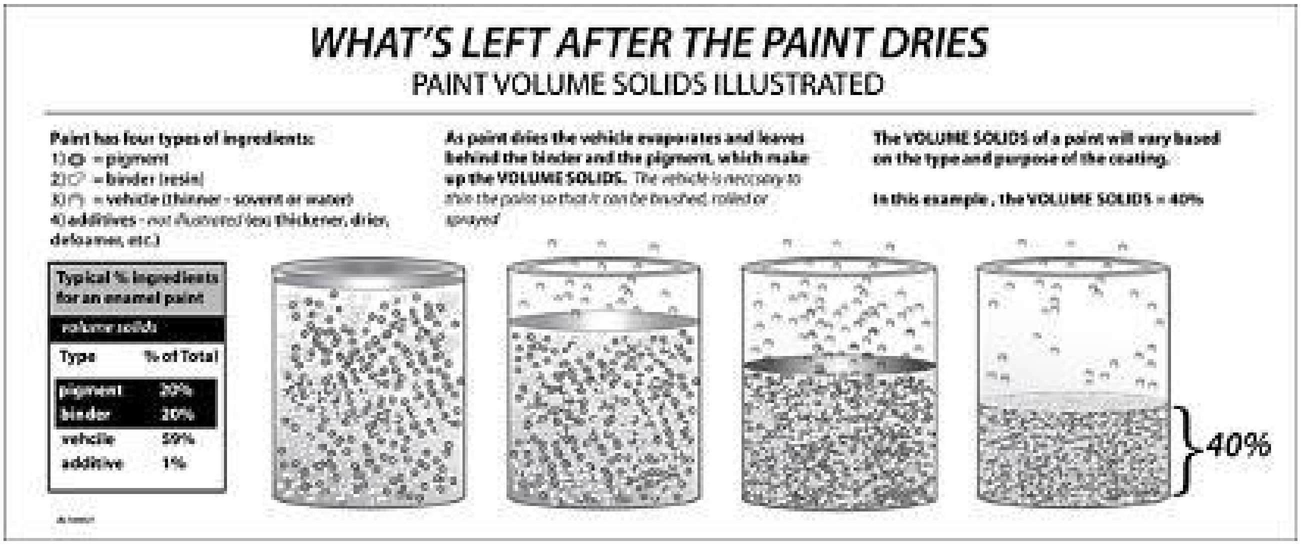


Figure 21: An illustration of the remaining paint volume after the drying process (Hyundai Painting Specification, 2006)

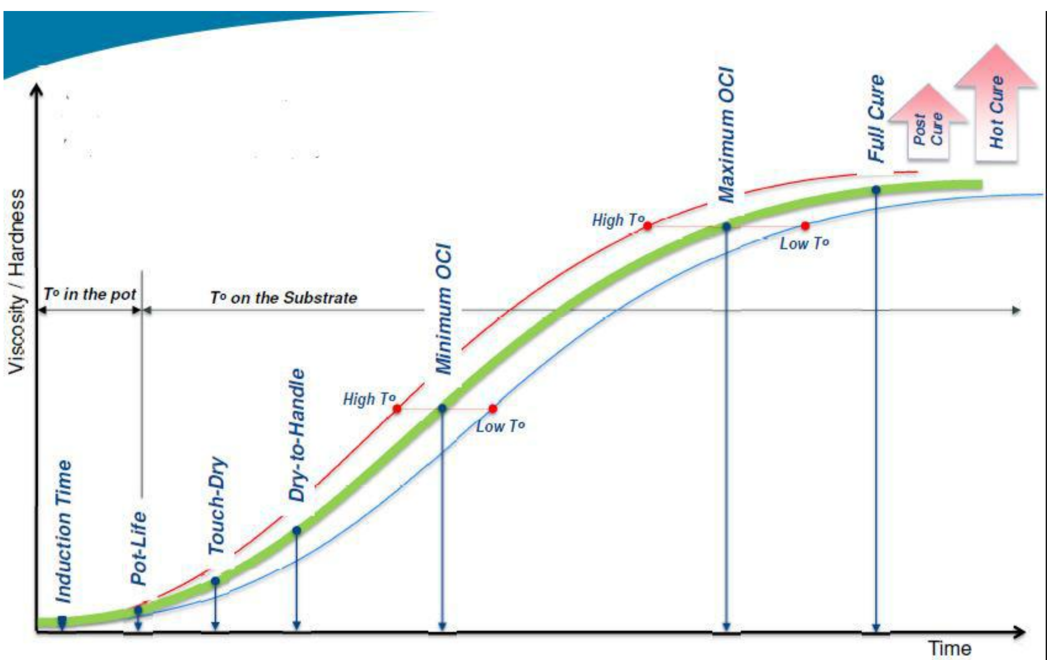


Figure 22: Viscosity of Paint according to Time (Hyundai Painting Specification, 2006)

2.6.1 Oxidative Drying Paints

Binders, used in the old paints were natural oils, such as linseed oil and wood oil, and consisted of medium sized molecules. In oil molecules there are a number of fields of reaction which are called "double bonds". When they get in contact with the oxygen in the air, a chemical reaction binds the oil molecules together (See Figure 23). The oil molecules are of medium size and therefore, a quite large number of the binder reactions ought to take place in order to attain the size of molecule that is needed for a stronger, harder film. In this way, the drying time is extended.

In order to reduce the time needed, natural oil is modified. This takes place, in resin plants, by reacting the oil with different chemicals. This results in materials with large molecules. Alkyds are the best-known examples of chemically modified oils.

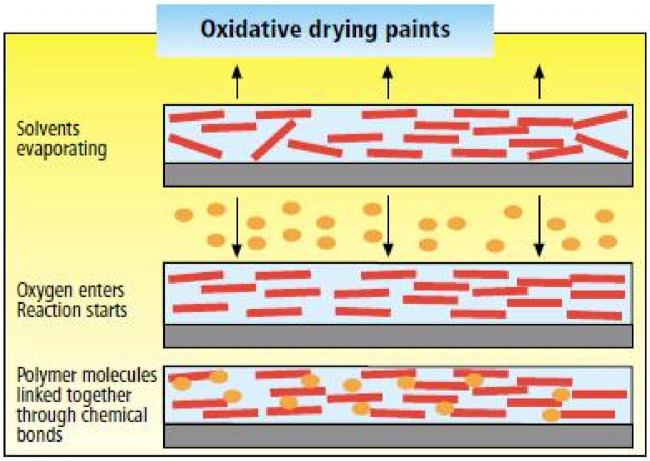


Figure 23: Simple schematic representation of the mechanism (Coating Performance Standards, DNV, 2020)

Oxygen is the first substance to contact the surface of the paint film. If an oxidative drying paint is applied too thick a film, a "skin" will form on top of the paint, but the paint under the film will remain in liquid form. This so-called skin reduces the movement of oxygen to the lower layers, which results in a long curing time. Therefore, it is imperative that the film thickness will be controlled during application.

If oils and modified chemicals are chosen wisely, as well as the relative quantities of components, it is possible to produce alkyds with a wide range of characteristics, so as to make it easier to produce alkyds paints for specific purposes. Examples of oxidative drying paints are oil paints, alkyd paints, epoxy ester paints and urethane oil paints.

2.6.1.1 Alkyd Paints

Alkyd paints include many different types. They have different properties, but they are mostly used for decorative purposes and for protection of steel, when exposed to relatively mild environments. It is useful to know that the word "alkyd" is derived from the English word "alcid", which in turn is originated from the word "alcohol" and "acid". Alkyds are namely produced from alcohols and acid, with the addition of fatty acids, vegetable or animal oils. Alkyd paints in corrosion protective paints have managed to keep a certain position in competition with products based on newer, more "advanced" binders.

They are used above water, and never beneath its surface, as the water resistance of the alkyds is not sufficient for continuous exposure to high humidity or water. Also, it should be noted that they should not be used on zinc primers or galvanised steel due to possible zinc soaps formation and loss of adhesion. Since they are esters, they will saponify when in contact with the alkalis. They are widely used in varnishes, both for indoor and outdoor use, and they are quite easy to maintain.

When they are high in oil, they are usually used on corrosion protective coatings. Medium oil alkyds are recommended mainly for decorative purposes, as well as for floors.

They contain anticorrosive pigments, e.g. zinc phosphate which, by dissociation, prevents the steel from rusting. Furthermore, they have good penetrating properties and pre-treatment to the standards St 2 to St 3 is normally sufficient in dry interior areas. However, in exterior areas, (or when exposed to more severe conditions), blast cleaning of welded seams and damaged shop primer is preferred (Naval Sea Systems Command, 2005).

Below, a table of the primary benefits and limitations of the alkyds can be found:

Table 1: Benefits and Limitations of alkyd products (Coating Manual, Jotun, 2018)

Benefits	**Limitations**
Easy application, both with airless spray, roller and brush.	Poor resistance to chemicals, especially to alkalis.
Good wetting properties.	Limited water resistance; Can usually tolerate ordinary outdoor humidity.
Good adhesion to the surface, and good penetration properties.	Limited resistance to solvents; Can swell under the influence of strong solvents, such as xylene, ketones, alcohols and chlorinated hydrocarbons.
Good weather resistance; Good gloss and colour stability.	Cannot be used on zinc primers (Saponification).
One-pack product (Easier to use than two-pack products).	The film thickness per coat is limited, usually 30-50 microns, up to 80 microns for special types.
Easy to repair "details" in the paint	Must not be over-coated by paints
film during application.	containing strong solvents.
Good levelling properties.	

2.6.2 Physically Drying Paints

These types of paints do not require a chemical reaction whilst the film is forming; only evaporation of solvents is needed. The ready-made binders consist mainly of very large molecules –polymers – formed in chains. The binder molecules are so large that the attraction between the molecules is sufficient to give strong paint films without further chemical reaction. Large quantities of strong solvents are necessary in order to keep the polymer molecules liquid and to produce paint with a viscosity suitable for application.

When a physically drying paint has been used to coat a substrate, the solvent will immediately begin to evaporate. The molecules in the binder will gradually draw closer together, attract each other, join together and become immobile. A solid material is therefore achieved (See Figure 24).

A paint film can be dissolved in the same type of solvent used in the original paint, because no chemical reaction has taken place in the original binder. The drying process can therefore be reversed, something which has certain advantages.

The problems that occur when a glossy, chemically cured paint film is over-painted with a topcoat, are well known. If the old paint used is a physically drying type, then the following may occur:

- There will be a hard, glossy film of the physically drying paint.
- A new coat of the same type is used to recoat the previous film.
- Solvents in the newly applied paint will penetrate, become distributed in the existing paint film and dissolve it. The molecules in the two paint films will blend and make a homogeneous interface.

If the old paint is clean, there will be good adhesion between the old and the new films. "Clean" means that there is no oil or other pollution on the surface of the old paint, which could reduce contact between the two films.

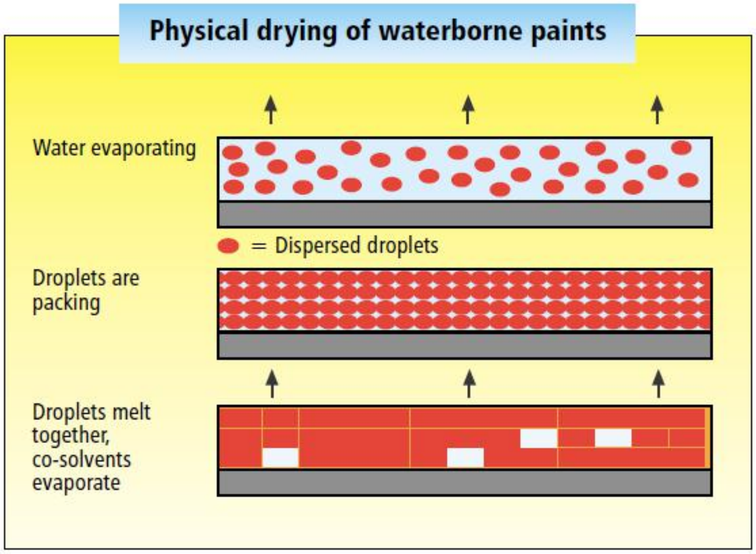


Figure 24: Physical drying of waterborne paints (Coating Manual, Jotun, 2018)

This type of paint has another advantage as well: It is not sensitive to temperature during the drying process. The paint could actually be applied and dry satisfactorily whatever the temperature, as long as it is not extreme. The only thing that varies, depending on the temperature conditions, is the drying rate; the higher the temperature, the faster the paint will dry. In each case, the end result remains the same, as well as the properties. Sufficient air circulation, which is necessary to remove the evaporated solvents from the surface, is more important than the temperature.

Film thickness is limited, due to the quite high proportion of solvents. The most common physically drying coatings are:

- Vinyl
- Chlorinated Rubber
- Acrylic
- Antifouling

Even though they have been used for many years in the marine industry, in recent years, people have been displaying an interest in health and environmental aspects in general. In this sense, Volatile Organic Compounds (VOC – emission of solvents) restrictions have become more and more important and thus, there has been a tendency to use lower molecular weight resins. The binder in physically drying coating consists of long chained molecules, resulting in high content of VOC. As it seems, the regulations, that continue to become stricter, will cause these coatings to disappear from the market (except maybe for some specialized uses).

The physical drying coatings provide moderate high film thickness by normal applications.

2.6.2.1 Vinyl

Vinyl paints have been widely used as industrial coatings in chemical plants, refineries and tank farms, bridges and on ships.

They have generally similar properties as chlorinated rubber, meaning they have adequate chemical resistance, good exterior durability and good abrasion and impact resistance. In addition, they have excellent moisture and oxygen barrier properties, excellent water resistance and very good acid and alkali resistance. They are single-pack paints (like alkyd paints), and they are easy to apply by airless spray, brush and roller. The physically drying paints are resoluble and this is the reason why they provide excellent re-coatability, even after years of exposure. Another benefit is that they dry fast, even at low temperatures (ITTC, 2011).

However, a certain drawback is the lack of substrate tolerance. They are composed of large, highly cohesive molecules, that tend to have great attraction for each other, large amounts of strong solvents are necessary in order to keep the paint in a liquid state and to have a viscosity of the paint suitable for application. Because of limited wetting properties, blast cleaning to the standard Sa 2 1⁄2 is the required surface preparation.

Also, application of vinyl on zinc silicate primers represents a problem as pinholes or popping can develop.

This can be avoided by applying a special tie-coat or by using the so-called “mist coat – full coat” technique.

The tie-coat should be applied at a dry film thickness of approximately 20-30 microns.

Furthermore, they have a limitation in firm build-up. If a coat is applied too thick, there is a risk of having entrapped air in the paint film. It is important to follow the recommendations given by the technical data sheet regarding dry and wet film thickness.

Finally, it is generally not recommended that the vinyl paints are subject to long time exposure at temperatures exceeding 78-80^{O} C. Decomposition would then take place and lead to yellowing and the development of a brittle paint film.

2.6.2.2 Chlorinated Rubber (CR)

Chlorinate Rubber coatings have been widely used on ships (both above and below the waterline) and other marine structures. They have similar properties to those of vinyl paints, such as being a strong barrier, having great durability etc. The process of physical drying for CR paints is shown in Figure 25.

As with all physically drying paints, the CR products are resoluble. This property can be perceived both as a positive aspect and as a negative one. In most cases, it can be viewed as a benefit, since it gives flexible, over-coating periods, with basically no danger of flaking between coats. The negative side here would be that, in some cases, the CR-based products are not resistant to most solvents. In other words, strong solvents have a great chance of destroying the paint film, but also there is a danger of solvents being entrapped in the paint film. This happens especially during over-coating a thick CR-system at low temperatures.

To add to the advantages, CR has a very good resistance to water. The paint is also quite resistant to acids and alkalines and to most corrosive chemicals. However, the resistance to both animal as well as vegetable oils is poor.

CR paints display the cohesion of the previously mentioned vinyl paints. Due to limited wetting properties, application should only take place on a blast cleaned surface (Sa 2 1⁄2) or, alternatively, directly on intact shopprimer.

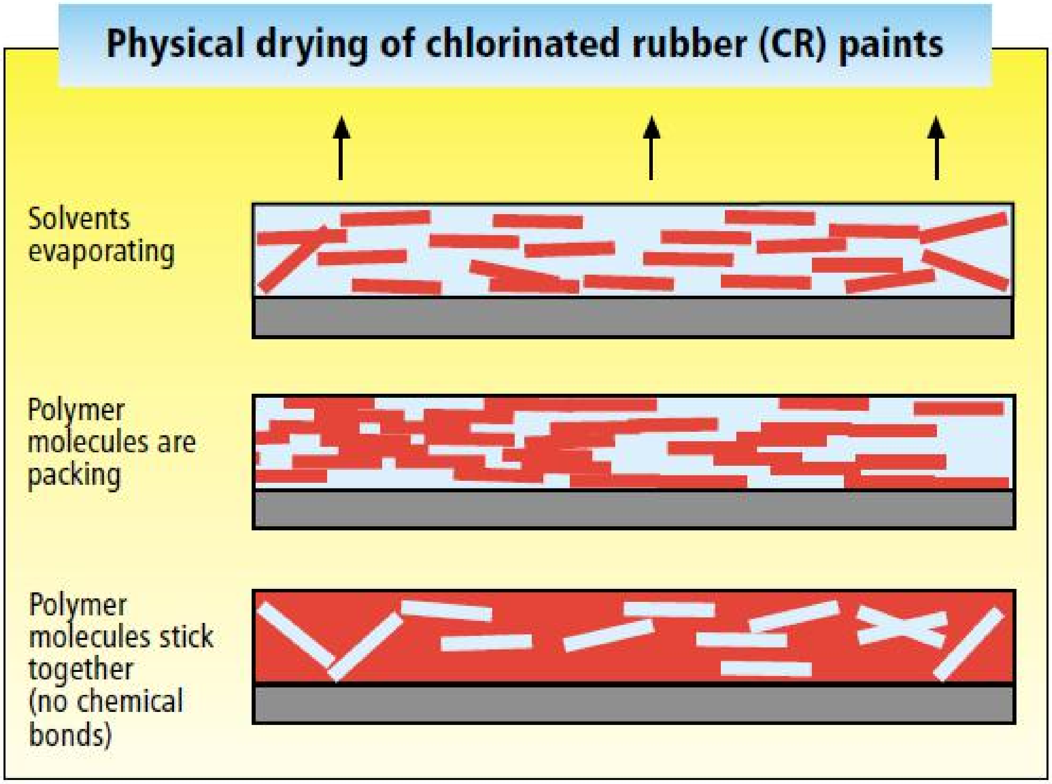


Figure 25: Physical drying of chlorinated rubber paints (Coating Manual, Jotun, 2018)

They present certain temperatures limitations. They are not recommended on objects that have a constant temperature of more than 70^{0} C. Above that temperature limit, there is a tendency toward chemical decomposition of the binder with the evolution of hydrochloric acid (HCl) as one of the reaction products.
They usually protect the steel through the barrier effect, so no rust preventing pigments are normally included in the paint. CR paints are often pigmented with aluminium to increase the barrier effect. They are normally applied in 60-80 microns dry film thickness (DFT) per coat. Three coats of CR coating will usually be sufficient to give a satisfactory barrier, and thereby good corrosion protection. If the coat is applied thicker than recommended, there is the risk of air being entrapped in the paint film, which may result in blistering.

2.6.2.3 Acrylic

Acrylic resins are primarily characterised by their water-white colour, their resistance to change in colour over time and their perfect transparency. They are widely used as topcoats on vinyl and CR paint systems, and are applied to a film thickness of approximately 50 microns.

2.6.2.4 Antifouling

They have been used as the primary method of protecting structures submerged in seawater against marine fouling for many years. Their main purpose is to prevent or reduce marine growth and to avoid growth penetration through the coatings and thus extend corrosion protection.
In their simplest form, antifoulings comprise a binder, pigments and solvents. Their binder type determines the nature of antifouling. Pigments include antifouling agents or biocides and various fillers. The solvents provide a workable body.

The biocide is a chemical substance that is released at very low rates and inhibits the growth of marine fouling. One of the most commonly used is the cuprous oxide. From the late 1970s onward, organotin compounds started being used as part of a copolymer.

In very basic terms, there are three main types of antifoulings:

- **Conventional antifoulings**

  These paints, also known as "soluble matrix" paints, have a natural product – resin – as a binder, which slowly dissolves in seawater (Figure 26).

  When the coating is immersed in seawater, the biocide leaches out of the paint. The release rate, however, soon falls to a level below which the fouling can be controlled. Effective life is, in general, short, approximately 12 months.

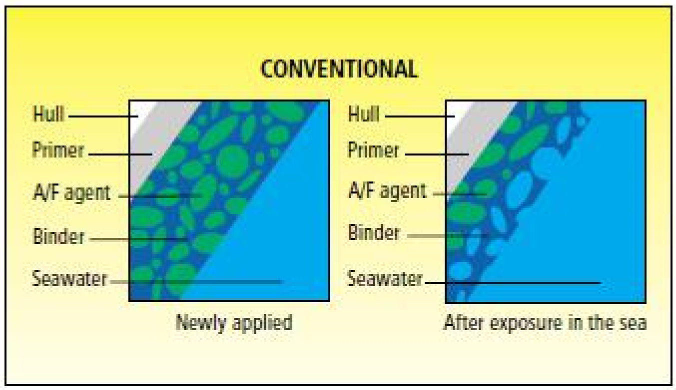


Figure 26: Conventional antifouling (How to select the right paint System, Hempel, 2019)

- **Longlife antifouling**

  The binder is insoluble in seawater. As only biocides are released, the paint film is left as a porous skeleton. As the porous layer increases, the rate of biocides release reduces. Eventually, no biocide can be released, antifouling performance drops dramatically and the layer becomes clogged with fouling (Figure 27).

  Effective life is up to 24 months, where a relative porous layer remains. This porous film leaves a very weak substrate for any new coatings in case of repainting.

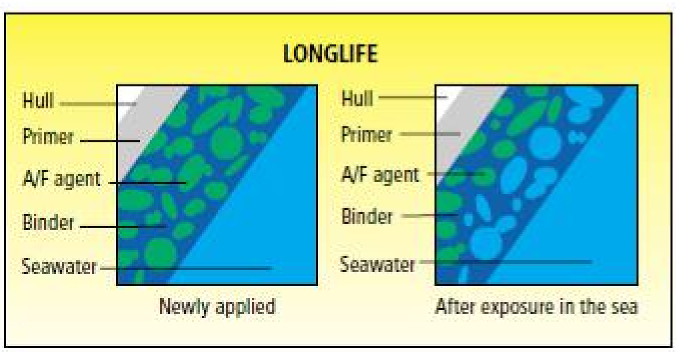


Figure 27: Longlife antifouling (How to select the right paint system, Hempel, 2019)

- **Self-polishing antifoulings** (containing TBT and tin free)

  Containing TBT

  Self-polishing antifoulings were firstly introduced in the 1970s. They developed rapidly leading to predictable performance and better control. It became possible to plan material purchase and the expected lifetime of the antifouling system.

  These antifoulings contain chemically bound organotin that is released, following hydrolysis in seawater. Once organotin is released, the remaining polymer backbone is soluble and is released from the surface (Etzkorn & Allan, 2006).

  Layer after layer of the antifouling provides the same performance until the paint is polished away. Selective erosion occurs because the turbulence on the surface peaks is greater. The peaks erode at a faster rate than the general paint film and lead to a polishing of the surface (Figure 28)..

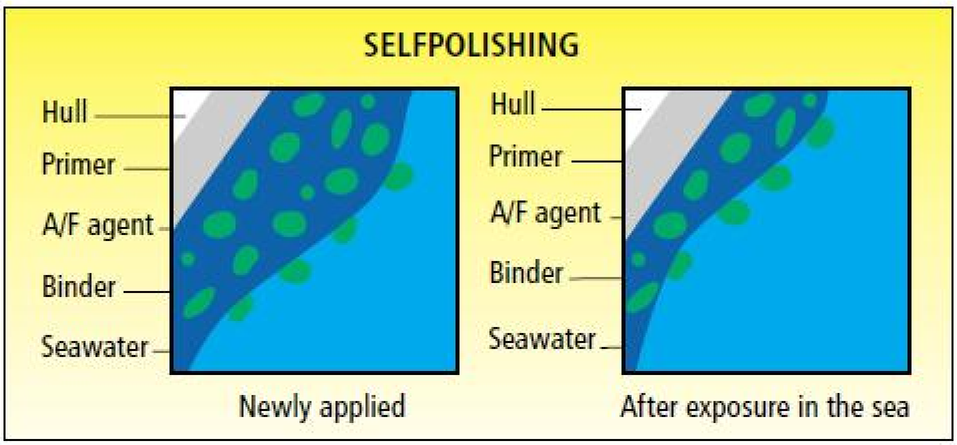


Figure 28: Self-polishing antifouling (How to select the right Paint System, Hempel, 2019)

  Tin free

  With tin free compositions, a different mechanism takes place. Manufacturers use various blends of water-soluble and water-sensitive binders. The polishing effect is similar to those containing organotin, but non identical in performance. This is mainly due to a different reaction with the seawater and to the absence of the organotin.

  - The use of antifoulings containing organotin compounds has been a subject for serious discussions for a long time. Nowadays, IMO has released a TBT worldwide ban. The aim is to find alternate solutions of equal quality and performance.

2.6.3 Chemically Curing Paints

Chemically curing two-components (or more) paints are supplied in two separate cans. One contains the base – Component A, and the other contains the curing agent – Component B. It must be kept in mind that if these components are used separately, they are not able to provide a sufficient paint film. To be more precise, applying only Component A would result in a tacky, soft film without any protective qualities. Each component contains reactive molecules that are relatively small or medium sized but which are also different types. Left alone, these reactive molecules can usually be kept for an unlimited period. When mixed, however, they begin to react chemically and build larger and larger molecules to form the binder in the paint film (Figure 29).

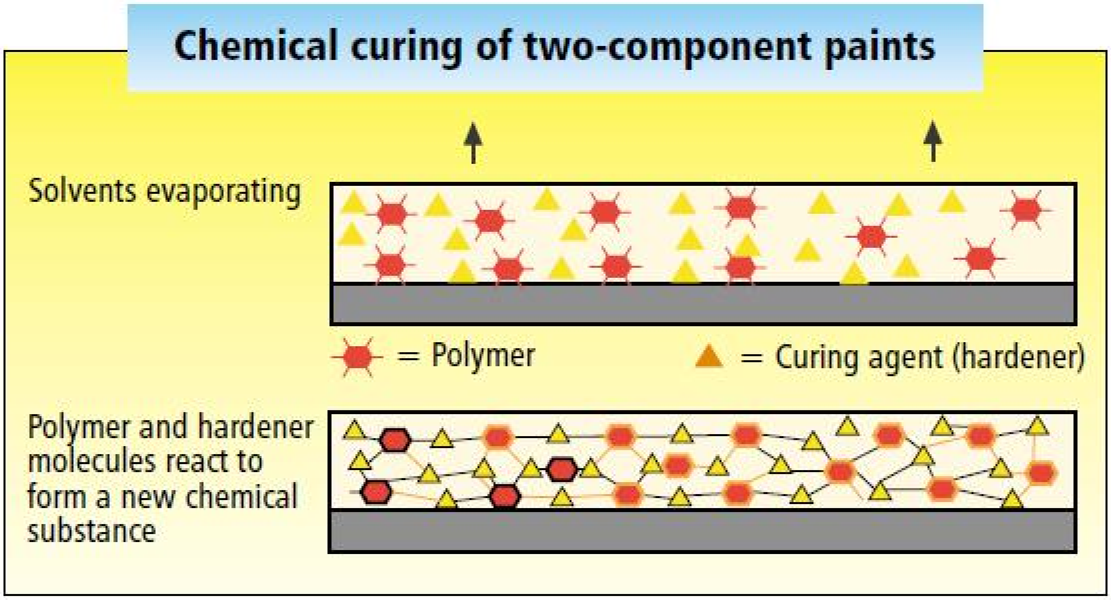


Figure 29: Chemical curing of two-component paints (Coating Manual, Jotun, 2018)

There are different components available to paint researchers, for making two-component curing paints. The characteristics of the finished paints can vary within quite wide limits e.g. they can be resistant to UV rays, be flexible etc.

In order to obtain the maximum advantages from the chemical curing reaction, it is very important for the components to be well mixed in the correct relative amounts before application.

An example of a product, provided by PPG, with the commercial label "PPG SIGMAPRIME", is given below (PPG, 2019):

The ratio by volume - base to hardener=80:20- is given in the product's information. The following instructions are provided:

If the mixing ratio is 78:22, every 10 cm (approx. 4 inches) of can height should consist of 7.8 cm (approx. 3 inches) of base material and 2.2 cm (approx. 0.8 inches) of hardener. Mark a measuring stick to the correct proportions (Figure 30).

Put the stick in an empty, clean tin and fill this with base material, to the first mark (make sure the base material is premixed). Then fill the second part with hardener. Mix the two components together and add thinner if necessary.

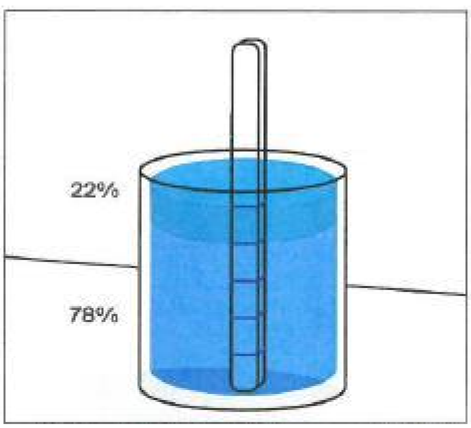


Figure 30: Mixing ratio of 78:22 (Coating Manual, Jotun, 2018)

During curing, the binder will form a continuous structure which may be compared with steel structures, where steel girders are welded or riveted in a certain pattern to give maximum strength.

Two-component paints can be very hard and extremely resistant to wear. Three-dimensional network is formed during curing, and great physical force is needed to break down the structure. Unlike physically drying paints, this structure is impossible to dissolve with solvents, which can be both an advantage and a disadvantage.

When a two-component paint is repainted, the solvents in the new coat do not penetrate and dissolve the previous, cured paint film. This can result in reduced adhesion between coats, so that when a glossy, chemically hardened paint is to be given a new coat, it may be necessary first to roughen the surface by sand paper or a light blast cleaning (see Chapter 4).

A further disadvantage is the influence of temperature on the curing rate. All chemical reactions are, to a certain degree, dependent upon the temperature to continue curing at a satisfactory rate. However, modern research has widened the temperature gap considerably, and today, many chemical curing paints may be used well below freezing point. Generally, two-component products should not be applied at temperatures below those recommended without consulting the manufacturer.

For example, if a tank needs to be painted during winter, the air inside it should be heated, or air in the desirable temperature should be brought in. In these occasions, the sides of the tank will obviously be colder than the air in the tank, making it possible that condensation will form on the surface and reduce adhesion of the paint film. Also, the paint may cure more quickly on the paint surface, and more slowly at the surface of the steel, causing solvents to be encapsulated within the paint film. A better solution is to slightly raise the temperature of the steel by heating the adjacent tanks.

Chemically curing paints include epoxy paints, tar-epoxy paints, epoxy mastic paints, polyurethane paints and two-component acrylic paints (PPG Protective & Marine Coatings, 2013).

2.6.3.1 Epoxy paint

There are a number of different epoxy paints, each one of them made to meet certain requirements during service, while they maintain many common properties, belonging in the same family. Below (Table 2), there are the variations of epoxy paints and the areas they are most used in.

Table 2: Types of epoxy paints and areas of implementation (How to select the right Paint System, Hempel, 2019)

Epoxy paint	Common areas of use
Epoxy Mastic	Very versatile coatings: Industry, ships and offshore. Below and above water (Topcoat required when exposed to UV-light). On most substrates due to good penetration and adhesion properties.
Pure Epoxy	Chemical tanks, potable water tanks and as an all-round coating system on ships and industrial plants. Require blast cleaning to minimum Sa 2½.
Phenolic Epoxy	Chemical tanks. Even better properties than pure epoxy. Require blast cleaning to minimum Sa 2½.
Coal Tar Epoxy	Ships. Under water, particularly water ballast tanks.
Solvent Free Epoxy	Drinking water tanks and where environmental restrictions are decisive.
Waterborne Epoxy	Industry where conditions can be controlled (humidity and temperature).

As it was mentioned above, there are some common properties among the epoxy paints as shown in Table 3:

Table 3: Benefits and limitations of epoxy paint systems (Coating Manual, Jotun, 2018)

Benefits	**Limitations**
Good water resistance	Poor resistance to UV rays; chalks in sunlight
Good adhesion to the substrate	Application and curing depends on the temperature (normally, above +10^{o} C) – winter grades down to -5^{o} C
Good chemical resistance	It may be difficult to overcoat cured epoxy
Very good alkali resistance	They are two-component products and therefore require good mixing and may give increased wastage
Great resistance to mechanical damage	Moderate resistance to acids
High durability	Can cause allergy (eczema)
Temperature resistant up to 120^{o} C (somewhat lower/higher for certain systems)	Require knowledge on how to be used correctly
High solids contents / lower VOC possible	
Certain systems officially approved for potable water tanks and in contact with food	

For epoxies to be used correctly, the following should be acknowledged:

- Using the correct mixing ratio and making sure that mixing has been done so well, that all reactive groups come into contact with each other. Use of the mechanical agitator is advised.
- There is a specific time limit for the use of two-component products after mixing, which can be found on the technical sheet data.
- The substrate must be clean and dry with intact shopprimer or blast cleaned to min Sa 2½ . Exceptions are the surface tolerant epoxies.
- The film thickness per coat as well as the dry film thickness shall conform to requirement given by the technical data sheet for the product. This is to obtain good protection and to avoid cracking/sagging.
- The rate of curing is dependent on the temperature. Below 10^{o} C the chemical reaction will usually be too slow and the curing of the paint will be unsatisfactory. This is why, in some products, a special "winter version" has been developed, which can be used down to -5^{o} C.
- The maximum potential of the characteristics has not been achieved, until after complete curing, normally after a week at an estimated temperature of 23^{o} C.
- Good ventilation during the curing process is necessary, both for safety reasons, as well as for the film to be formed in the best way possible.

2.6.3.2 Pure epoxy

In severe corrosion environments, such as offshore oil platforms, structural steel in refineries, tanks exterior and interior, pure epoxies are preferred. They require blast cleaned steel to a minimum of 2½ . Most pure epoxies act as a barrier coating. They are compatible with most inorganic and organic pigments. Properly selected inert extenders (fillers) add to the physical properties of the epoxy coating by creating a denser film and by improving the barrier properties. Such pigments include talc, barite, aluminium flake, glass flake and micaceous iron oxide etc.

It must be noted that none of the epoxies are resistant to UV light. When colour or gloss durability are of essence, other generic coatings such as polyurethanes or acrylics should be used as topcoats.

2.6.3.3 Phenolic epoxy

The phenolic epoxies have even better chemical resistance than regular epoxy, being the reaction products of Phenolic Novolacs and Epichlorhydrin. Phenolic novolacs epoxies have more reactive groups, resulting in higher cross-linking density and some other improving factors. Due to this more than adequate chemical resistance, along with the corrosion resistance they offer, they are used inside tanks, transportation tanks etc.

2.6.3.4 Modified epoxies - Coal Tar Epoxy (CTE)

Coal Tar Epoxies (CTE) consist of basic epoxy resin, modified with a coal tar and a curing agent. The combination of these materials offers a superior water-resistant coating. Epoxy, as it is already known, gives the chemical strength to resist chemicals and solvents. Coal tar gives flexibility, greater water resistance and enhanced substrate tolerance. By adding coal tar, which is a low-molecular weight binder, the solid by volume can be increased compared to pure epoxy, and VOC is reduced. They are mostly used for underwater exposures and work entirely as a barrier system. They have shown very good protection on power-tool cleaned surfaces due to the very good penetrating properties they have. A typical system for coal tar epoxies includes 2 coats of 125- or 150-microns Dry Film Thickness (DFT).

However, they are not without disadvantages. The typical dark colour they have makes application and inspection in tanks – or confined spaces, quite difficult. Also, the tar will bleed into any topcoat making tar containing paints unsuitable above the water line, in cases where the appearance is a critical parameter.

2.6.3.5 Modified epoxies – Epoxy Mastic

Epoxy mastics consist of epoxy resin, modified with a hydrocarbon resin and a curing agent. The hydrocarbon resin is used to enhance the moisture resistance, flexibility and the wetting properties of epoxy coatings. They also make the paint more user friendly and economical to use.

They are in many aspects similar to CTE. However, they are much more versatile and most of the drawbacks of CTE are either reduced or eliminated. More specifically:

- They have lighter colours to improve the painting conditions, especially when working in confined spaces. In this way, the application is much easier, and the applicator can see the result in real-time, and can intervene if needed.
- The mastics show excellent penetrating properties, meaning they can be used on almost all types of substrates.
- They have reduced VOC emission.
- They cause no bleeding on the topcoat, and thus, they do not affect in a bad way the appearance of the surface.

- They contain no coal tar (which has been linked to many skin irritations, as well as cancer).

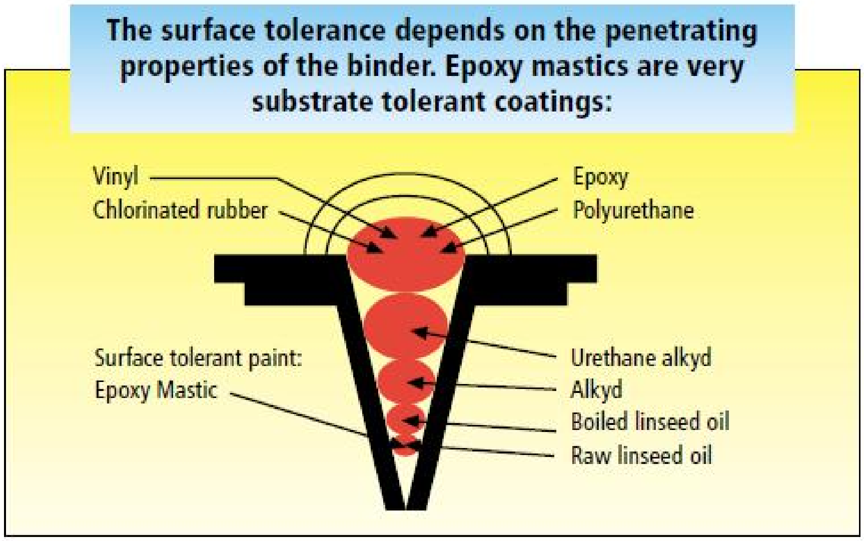


Figure 31: Epoxy mastics and penetrating properties of the fellow binder ((Basic Paint Technology & Terminology, PPG, 2013)

The reason for the excellent penetrating properties they have are the small sized molecules and the low viscosity of the binder, which gives good flow. As such, they can be used well on both hand and power tool cleaned surfaces, water jetted surfaces and on blast cleaned surfaces. Actually, blast cleaning is usually recommended to obtain optimum corrosion resistance for immersed service conditions or for use in very aggressive environments.

The mastics form a barrier between the substrate and the surrounding environment. Thus, they are primarily designed to be applied as two-coat system, with minimum film thickness of two times 125 to 150 microns
DFT. They can usually be applied up to 300 microns of DFT in one coat without sagging. However, from a corrosion protection point of view, it is always better to apply two coats of 150 microns than one single coat of 300 microns. To improve the barrier effect, and thereby the corrosion resistance even more, it is recommended to apply the first coat with an epoxy mastic with aluminium flake pigmentation. This will surely slow down the water absorption and give better results (Figure 32).

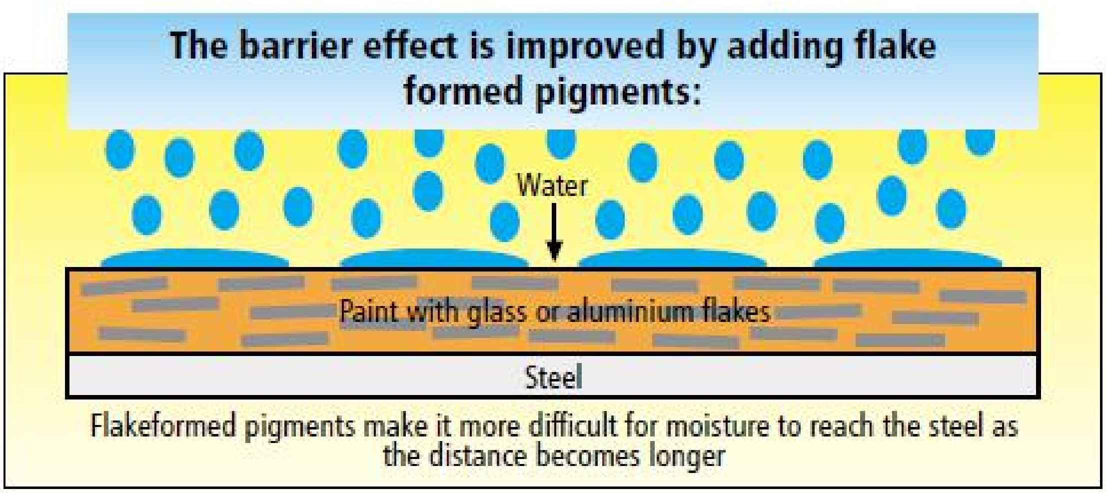


Figure 32: Improving the barrier effect of the epoxy mastics (Basic Paint Technology & Terminology, PPG, 2013)

2.6.3.6 Modified epoxies – Solvent Free Epoxy

They are mechanically very strong, high build coatings. They are used for the protection of steel both below and above water, as well as for potable water systems. In addition, they provide sufficient chemical resistance.

2.7 Choosing the paint system

There are quite a few factors that influence the choice of coatings for protection of a structure (or a part of it). The selection usually relies on the owners' own experience and on the advice provided by the applicator. Generally speaking, a high-cost system is better than a low-cost system, as this depends on the time of the paint, number of coats, and total thickness of the actual system (although that may not always be the case).
Regulations that are implemented on each country may vary, so this must be considered before choosing the paint system. Paint consists of many chemical components, mixed together, and as it is logical, when they are released in the environment, they can negatively affect both the living creatures and the environments itself. Ultimately, the health condition of the owner, the painting crew and the personnel using the structure afterwards must be guarded. e.g. Spray application will lead to some loss of paint, which is easily carried on the wind and might pose a threat to the surrounding environment (Figure 33).
One of the main goals of the customer should be to select a coating system that offers the lowest Life Cycle Cost possible (More on the Life Cycle Cost can be found on Chapter 10).
Therefore, the customer's prime interests concern:

- Cost-effective systems
- Systems to perform according to expected lifetime
- Easy inspections
- Easy maintenance

The main interest of a production facility is to ensure cost-effective production. In other words, to have a fast production rate, firstly they choose to operate according to established procedures, and later on, they can use their personally gained experience, available technology and the personnel's skills.

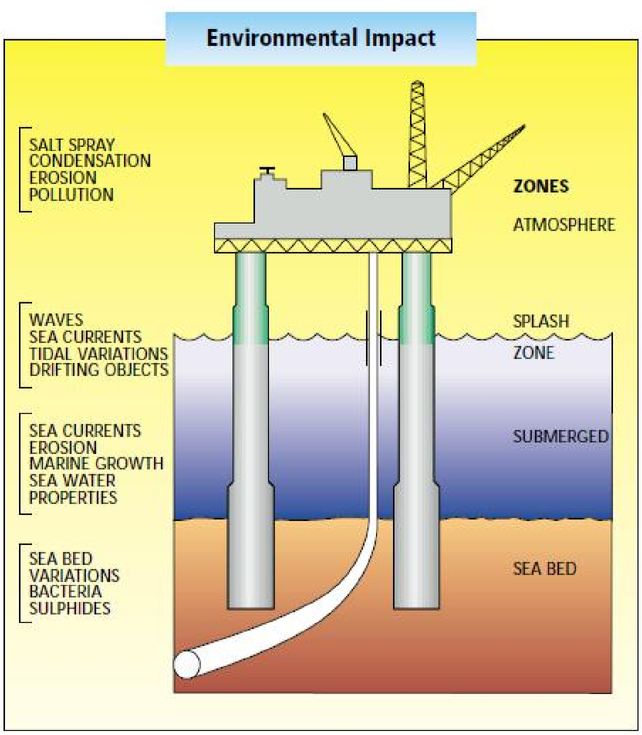


Figure 33: Environmental Factors (How to select the right paint system, Hempel, 2019)

The durability of a protective coating system is dependent on several factors, such as:

- Type of paint system
- Design of the vessel
- Condition of the substrate before preparation
- Effectiveness of the surface preparation
- Standard of the application work
- Conditions during application
- Exposure conditions after application

As can be seen, the selection of a coating system is a complex procedure and must be done on a case by case basis. It is therefore impossible to end up with a plan that is applicable for all cases. A few general points, however, can be used as a checklist:

- Consider the corrosivity of the environment in the area where the structure is or will be located (ISO 12944-2: C1, C2, C3, C4, C5-I, C5-M, Im1, Im2, Im3 – see Table 4 & 5 for better understanding).
- Make sure that all legislation relevant to the application, use of coating and use of construction unit is known before the coating is selected.
- Take all relevant precautions to protect applicators and the surrounding environment.
- Is the required/expected lifetime of the system clear and is the proposed system capable of meeting this requirement?
- Is the pre-treatment compatible with the paint to be applied?
- Is the paint system well defined and in line with technical requirements given in the data sheets?
- Is the proposed paint system suitable for protecting the structure/unit in question?
- Are the maintenance frequency, methods and routines able to meet with the selected system?
- Will cathodic protection be used to back up the paint system? If so, the coating system must be compatible with the supplementary cathodic protection system.
- Are the products accompanied by detailed technical and safety specifications?
- Is the manufacturer capable of providing adequate technical services?

Table 4: Atmospheric-corrosivity categories and examples of typical environments (ISO 12944-2), (How to select the right paint system, Hempel, 2019)

Corrosivity category	Mass loss per unit surface/thickness loss (after first year of exposure)				Examples of typical environments in a temperate climate (informative only)	
	Low-carbon steel		Zinc		Exterior	Interior
	Mass loss g/m^2	Thickness loss µm	Mass loss g/m^2	Thickness loss µm		
C1 very low	⩽ 10	⩽ 1,3	⩽ 0,7	⩽ 0,1	—	Heated buildings with clean atmospheres, e.g. offices, shops, schools, hotels.
C2 low	> 10 to 200	> 1,3 to 25	> 0,7 to 5	> 0,1 to 0,7	Atmospheres with low level of pollution. Mostly rural areas.	Unheated buildings where condensation may occur, e.g. depots, sports halls.
C3 medium	> 200 to 400	> 25 to 50	> 5 to 15	> 0,7 to 2,1	Urban and industrial atmospheres, moderate sulfur dioxide pollution. Coastal areas with low salinity.	Production rooms with high humidity and some air pollution, e.g. food-processing plants, laundries, breweries, dairies.
C4 high	> 400 to 650	> 50 to 80	> 15 to 30	> 2,1 to 4,2	Industrial areas and coastal areas with moderate salinity.	Chemical plants, swimming pools, coastal ship- and boatyards.
C5-I very high (industrial)	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Industrial areas with high humidity and aggressive atmosphere.	Buildings or areas with almost permanent condensation and with high pollution.
C5-M very high (marine)	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Coastal and offshore areas with high salinity.	Buildings or areas with almost permanent condensation and with high pollution.

NOTES

1 The loss values used for the corrosivity categories are identical to those given in ISO 9223.

2 In coastal areas in hot, humid zones, the mass or thickness losses can exceed the limits of category C5-M. Special precautions must therefore be taken when selecting protective paint systems for structures in such areas.

Table 5: Categories for water and soil (ISO 12944-2), (How to select the right paint system, Hempel, 2019)

Category	Environment	Examples of environments and structures
Im1	Fresh water	River installations, hydro-electric power plants
Im2	Sea or brackish water	Harbour areas with structures like sluice gates, locks, jetties; offshore structures
Im3	Soil	Buried tanks, steel piles, steel pipes

2.8 Paint System Analysis

When troubleshooting involves solving a case where no documentation or information is available, it is advised to first identify the paint system in use. A practical way to do this, or at least obtaining a good idea of the type of the system, is by counting the number of coats, estimating their individual thickness and the total film thickness.

For additional information, "analysis" of the generic type of the paint is helpful. This can also be done by a sophisticated method in a specialized laboratory, but simple field methods should be enough in most cases. As the paints have different curing mechanisms, specific types can be eliminated by using solvents, as a simple way of testing. For this procedure, cotton rag and a strong solvent are needed.

If the cured paint is in the form of paint flakes, they can be put into various types of solvent for determination of the curing or drying mechanism. It is important to follow up what happens with the flakes, since, among other things, a paint system can be composed of several different paints (Figure 34).

The following are very useful in reality:

- If the paint dissolves in the solvent, it is a physically drying paint.
- If there is no direct dissolution of the paint, but rather a form of blistering or swelling, it can be presumed that it is an oxidative drying paint.
- No blistering or dissolution will be an indication of a chemically curing paint.

With these tests, it is important that the paint is given sufficient time to react. An old oxidative drying paint will, unless given sufficient time, react similarly to a chemically curing paint.

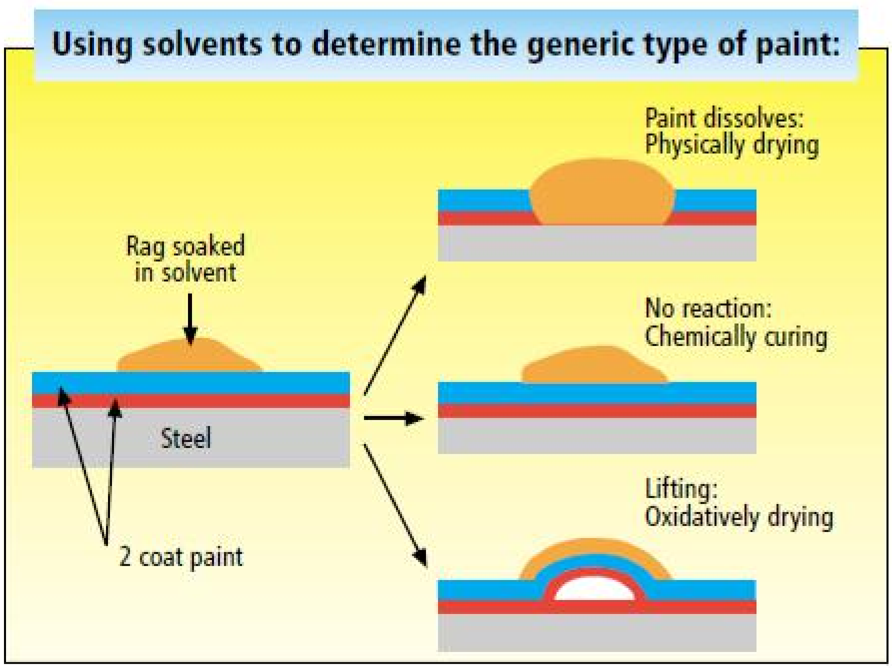


Figure 34: A brief diagram that shows the reaction of the paint when solvent is used (Basic Paint Technology & Terminology, PPG, 2013)

Chapter 3: Surface Preparation

3.1 Surface Preparation and Life Expectancy of Paint Films

Surface preparation for paints' application, mainly from a technical point of view, means the removal of all kinds of foreign materials, such as mill-scale, rust, oil and moisture on the substrate surface. This aims to achieve optimum surface conditions, enabling paints to obtain and maintain the maximum of their properties.

The level of surface preparation exerts an important factor and effect upon the adhesion and the durability of the paint film. In general, factors that affect and particularly determine the life expectancy of a paint film are as per below attached table (Table 6), including their ration of contribution.

Table 6: Factors that affect the life expectancy of a paint film and their rate of contribution (How to Select the right Paint System, Hempel, 2019)

FACTORS	RATIO OF CONTRIBUTION
Level of surface preparation	50%
Type and essential properties of paint	20%
Dry film thickness	20%
Other	10%

3.2 Methods for Surface Preparation

For removing mill-scale, rust or other foreign materials from steel surface, there are several kinds of methods that could be applied. Most of the times, those are divided into two (2) categories that are physical or mechanical and chemical.

Physical treatment includes the following four (4) methods:

1. <u>Blasting, either dry-blasting or wet-blasting</u>
   At that method abrasive, such as sand, grit, steel grit, shot or cut wire is sprayed by compressed air or compressed water, or is thrown by centrifugal force in order to be removed mill-scale (for black film) and rust on the steel surface.
2. <u>Power Tool Treatment</u>
   Reciprocating or rotating tools are used, that are driven by compressed air or electric power, and thus steel surfaces are cleaned by impact, chipping, sanding or abrasion.

3. <u>Hand Tool Treatment</u>
   That includes manual treatment (impact, chipping, sanding or abrasion) by using only simple tools

4. Flame Treatment
During that method application, steel surfaces are heated by using a high temperature flame from a burner and thus mill-scale and rust are removed by the differential of coefficient of thermal expansion (Figure 35).

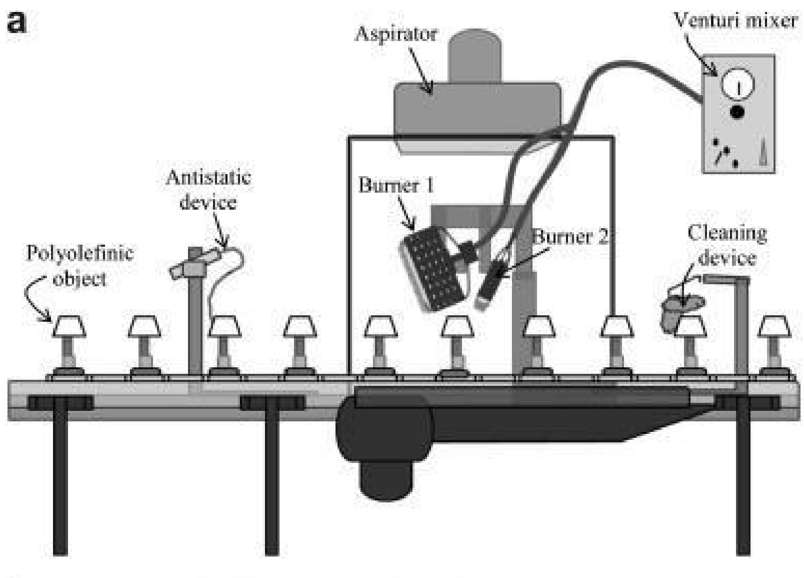


Figure 35: Schematic representation of a flame treatment station (Basic Paint Technology & Terminology, PPG, 2013)

Chemical treatment includes degreasing and formation of a protective film. Degreasing is a method of treatment using alkaline solution, solvents or steam. Those compounds by washing aim to remove the greases adhered to the steel surfaces (Figure 36).

The formation of a protective film could be either by acid pickling (phosphoric acid, hydrochloric acid, etc) or chemical and synthetic (film formation by phosphate, oxidation, chromate, oxalate etc) (Figure 37).

In general, insoluble chemical compounds are formed on the steel surfaces by using a chemical solution.

Depending also on the time of the treatment, application methods are also classified into primary and secondary surface treatments. The treatment of original steel surfaces generally carried out at the steel works or a fabricator, that could be either a shipyard or factory of paint assembly, is called “primary” surface treatment. This also includes the application on steel of a shop primer. Thereafter, prior the application of protective coatings, shop primed steel parts are assembled and treated again. This surface treatment is called “secondary” surface treatment. Although above various treatments have been practically used, each of them do have their relative advantages and disadvantages. The type of paint and also the conditions of applications should be taken into account carefully for correct selection of a method that is the most suitable for the occasion needed at the time.

Figure 36: Photos taken during the "primary" surface treatment (PST, Photo Gallery, 2015)

Figure 37: Photos taken during the "secondary" surface treatment (PST, Photo Gallery, 2015)

3.3 The Parameter of Corrosion

Paints come across in almost every kind of construction. From deep sea to remote space, and from small village's home to heavy industry, paint coatings are utilized to provide protection, cosmetic enhancement and particular properties, in relation to the desirable usage it is destined to have. Correct paint formulation is a skilled role and requires good training, experience on smooth application and an eye on the future market's trends. This paint is where all paints manufacturer companies should focus.

Most of the paints are initially in liquid form and when they are applied or sprayed on the substrates surfaces, they dry with the passage of time and change of ambient temperatures. The most common and basic role of paints is described as below:

1. Protection of Materials: Inhibiting rust and protection from chemical contamination and corrosive gases
2. Cosmeticuse and markings: Decorate the substrate with the various colors and glosses. Furthermore, providing color control and markets for traffic and labor safety.
3. Providing various functions and particular properties: Upon their application, paints provide the surface with heat, oil and chemical resistance, waterproofing and anti-fouling properties. Besides these traditional functions, below mentioned additional uses are also available.

- Resistance to the build-up of ice and radial rays
- Anti-condensation and anti-slip
- Soundproofing and vibration-proof
- Anti-seaweed and bacillus and anti-fungus
- Mothproofing, fireproofing and flame resistance

- Luminous/phosphorescence, heat-reflection, UV interception
- Electrical conduction

All above are of vital importance for the protection of surfaces, during vessel's daily operation, especially on external and deck areas that are all day long exposed to weather conditions (See Figure 38).

At that point, if a general definition about corrosion should be given, then it should be as follows:

"It's the irreversible and interfacial deterioration of materials as result of their chemical interaction with environment elements".

Iron's corrosion is a natural phenomenon, where the unstable metallic iron wishes to return to a more stable iron oxide. There are two kinds of corrosion, wet and dry.

Figure 38: Part of the ship chain corroded (PST Photo Gallery, 2015)

The first one occurs when rusting by an electrochemical reaction in the presence of moisture and oxygen at ambient temperatures. The latter takes place by oxidation at high temperatures, more than $600^{O}C$, when a typical phenomenon is the production of a mill-scale (the heavy oxide layer which formed during hot fabrication or hot treatment of metals).

The actual problem which should be solved and treated on vessels areas is wet corrosion. Therefore, the point is to examine the corrosion mechanism of iron and the procedure for its minimization. While corrosion in ships is inevitable, there are various ways of countering it. Either by allowing for extra steel thickness, by adding new steel to replace what is lost to corrosion, and perhaps most effectively by properly selecting, applying, and maintaining protective coatings.

First of all, the contact between water and oxygen should be intercepted. Anodic and cathodic reaction takes place simultaneously (Figure 39). In case that one reaction does not progress, the other reaction will not progress either. Cathodic reaction does not progress, if moisture and oxygen do not exist and thus under those circumstances, anodic reaction also does not progress respectively. Based on that point, one of the best protective methods for removal all sources of moisture and oxygen is by stopping the electrochemical reaction with formation of a local active cell. Coatings can help achieve this aim.

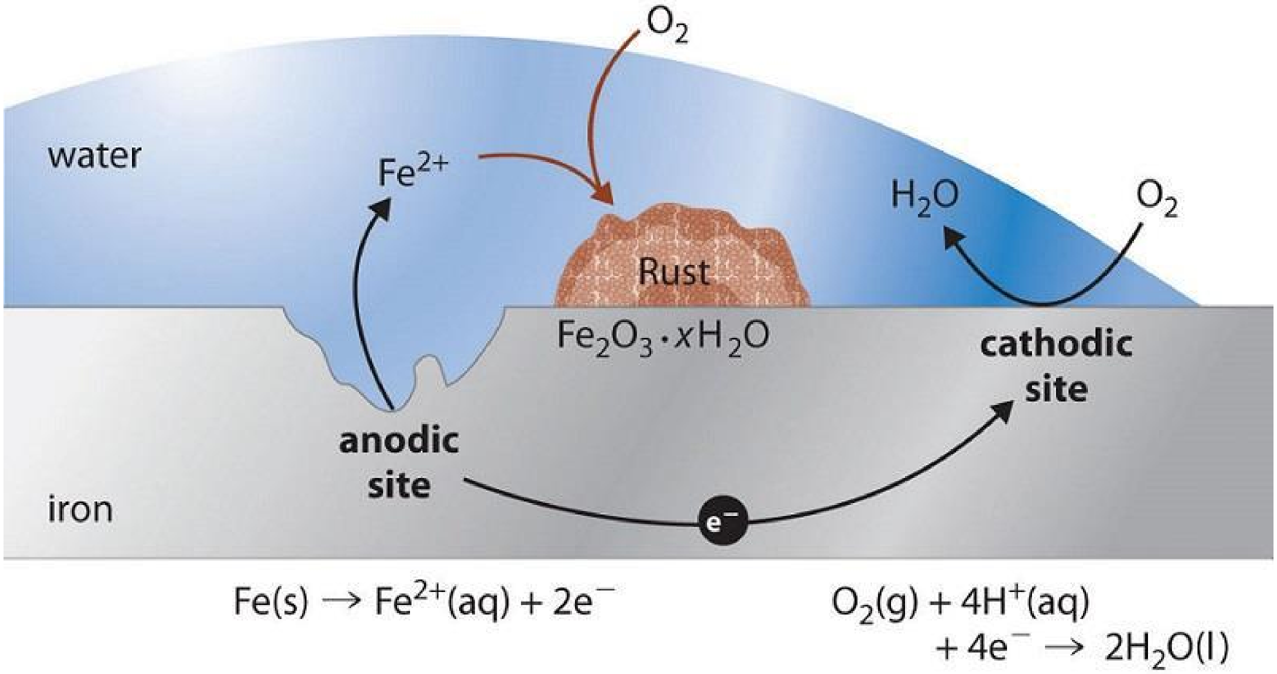


Figure 39: An effective depiction of the reactions leading to the formation of rust (How to Select the right Paint System, Hempel, 2019)

Additionally, through application of anti-corrosive paints we aim to reduce the surface potential toward a more stable range, maintain steel's alkalinity and a passive state on the substrate surface. Under a technical consideration, for creation of all above mentioned protective methods on steel's surface, anti-corrosive paint is the simplest and time and cost effective way.

After anti-corrosive paints application, following effects are expected to be achieved:

1. Interception of water transmission
2. Reduction in the quantity of oxygen's supply
3. Reduction of the transmission of corrosive iron's
4. Rust inhibiting action by the paints' components

In table 7, the most commonly used anti-corrosive mechanisms and the typical applied paints for that purpose each time are presented.

Table 7: Basic anti-corrosive mechanisms and typical applied paints for each purpose (How to Select the right Paint System, Hempel, 2019)

ANTI-CORROSIVE MECHANISM	TYPICAL PAINT FOR THAT PURPOSES
Interception from water and oxygen	Aluminum paints, Paints containing micaceous iron oxide (MIO) Paints containing glass flakes
Maintaining the lower electric potential on the steel surface	Zinc primer Zinc-rich primer
Maintaining the surface in an alkaline condition with anti-corrosive paints	Various primers, which contain red lead, lead suboxide, lead cyanamide, calcium plumbate
Conversion of steel into a passive state (stable state)	Various primers which contain zinc chromate and basic lead chromate

At the following also attached table, the main kinds of rust inhibition pigments and their particular rust inhibition action are included.

Table 8: The main kinds of rust inhibition pigments and their particular rust inhibition action (How to Select the right Paint System, Hempel, 2019)

Kind of rust inhibiting pigments/Rust inhibition Action	Maintaining surfaces alkalinity	Inhibiting the ionization of metal ,controlling cathodic to intercept the corrosion current	Conversion of the steel into a passive state
Red lead	X		
Lead suboxide	X		
Lead cyanamide	X		
Calcium plumbate	X		
Zinc chromate			X
Basic lead chromate			X
Zinc dust		X	

Paints classification can be made on many different ways, depending always on various criteria. An aggregated table is prepared below, in an effort to include all the possible existing categories.

Table 9: Paints Categorization (How to Select the right Paint System, Hempel, 2019)

System of Categorization	Classification Categories
According to objects to be applied	Paints for steel structure, non-ferrous metal, woodworking, concrete, ships, rubber and constructions
According to appearance of final paint film	Color paint, clear paint, gloss paint, mat paint and multicolor pattern paint
According to paint conditions	Ready-mixed paint, multi-component paint, sol type paint, emulsion paint, water-soluble paint, powder coating and non-solvent type paint
According to the pigments contained into the paints	Red lead paint, zinc chromate paint,zinc-rich paint, lead suboxide paint and aluminum paints

According to resins contained in the paints	Oleoresinous paint, alkyd resin paint, vinyl resin paint, acrylic resin paint, epoxy resin paint, polyurethane resin paint, chlorinated rubber paint and silicone resin paint
According to the drying method/curing mechanism	Air drying paint, baking paint, moisture-curing paint, catalytic curing paint, ultra-violet ray curable paint and electro beam curable paint
According to painting process	Surfacer, filler, primer, undercoat and topcoat
According to tolerance to be exposed	Indoor paint, exterior paint and underwater paint
According to the application method	Brushing paint, spraying paint, electrostatic spraying paint, roller coating paint, dip-coating paint, electro-deposition paint, vacuum coating paint and paint for trowel coating
According to properties or function of paint film	Rust inhibiting paint, ship bottom paint, anti-bacterial paint, oil/chemical resistant paint, heat resistant paint, fire-resistant paint, electro-conductive paint, ice-free paint, fluorescent paint

Of all above categories those of vital importance of a correct choice of paint are according to painting process, tolerance to be exposed and, last but not least. based on the properties or function of paint film.

Chapter 4: Pre - Treatment

Because of its prime importance, it is necessary to set a quality standard of pre-treatment cleanliness. The most important internationally standard is that described in Swedish Standard SIS 055900.Additionally to that as per ISO requirements, following chapters are also related to surface pre-treatment:

(1) ISO 12944-Part 4: Describes types of surfaces & surface pre-treatment prior to paint application.

(2) ISO 8502-Part 3: Describes methods for assessment of surface cleanliness prior to paint application

As a rule, it should be mentioned that any kind of foreign material on the steel surface is considered as kind of future source for contamination and should be removed prior to paint application. These materials could be:

• Water & Moisture

• Rust & Mill-Scale

• Dust

• Water Soluble Salts

• Oil & Grease

• Loose Paint Coatings

• Marking Paints, Inks, Chalk

• Surface Irregularities, (lamination, etc.)

• Rust & Contamination Traps (adhered from ship's design stage)

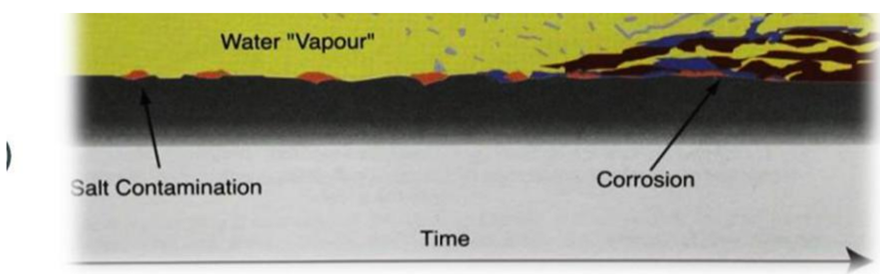


Figure 40: Corrosion according to time (Coating Manual, Jotun, 2018) 8

As it is described above, pre-treatment is of prime importance for the result obtained with respect to anticorrosive action and thus the final and total cost. When deciding on the type of pre-treatment and the paint system to be used, the large sums of money involved must always be borne in mind.

The pre-treatment norms are based on four (4) different grades of corrosion, A, B, C and D, which represent respectively (Figure 41):

- A - Steel surface covered completely with adherent mill scale with little, if any, rust.
- B - Steel surface which has begun to corrode and from which the mill scale has begun to flake.
- C - Steel surface on which the mill scale has corroded away or from which it can be scraped, but with little pitting visible to the naked eye.
- D - Steel surface on which the mill scale has corroded away and on which considerable pitting is visible to the naked eye.
-

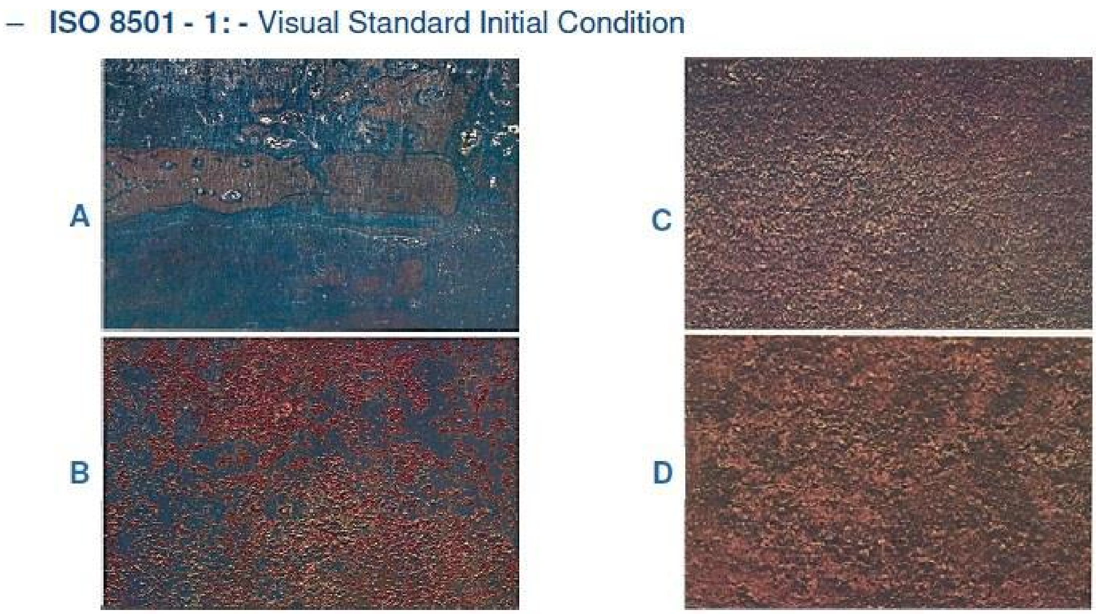


Figure 41: The four (4) different grades of initial-level corrosion, as defined by ISO 8501-1 (Painting Specification, Hyundai, 2006)

According to SIS 055900, pre-treatment for these degrees of corrosion is respectively wire-brushing and blast-cleaning to the following quality scale:

1. Bad (light brushing or light scraping).

2. Middle quality (thorough scraping with hard metal scraper and wire-brushing or thorough blast-cleaning).

3. Thorough scraping and wire-brushing till distinct metal luster is obtained or blast cleaning to clean, grey steel.

“St” indicates wire-brushing and “Sa” blast cleaning. Thus, the norm will be the following: St 1, St2 St 3, Sa1, and Sa 2 Sa 3.

After the norms had been in use for a while, a norm lying between Sa 2 and Sa3 was found necessary. The steel had to be thoroughly sandblasted and all mill scale, rust and foreign particles removed, but faint shadows or stripes were allowed on the surface. An extra norm was thus made Sa 2 ½. The norms can be found in a book published by the Swedish Standards Institution. In this book the norms are described by a text explaining how the work should be done, and illustrated by colour photos which can be compared to the finished pretreatment to see whether this is up to the specified standard or not (Figure 42).

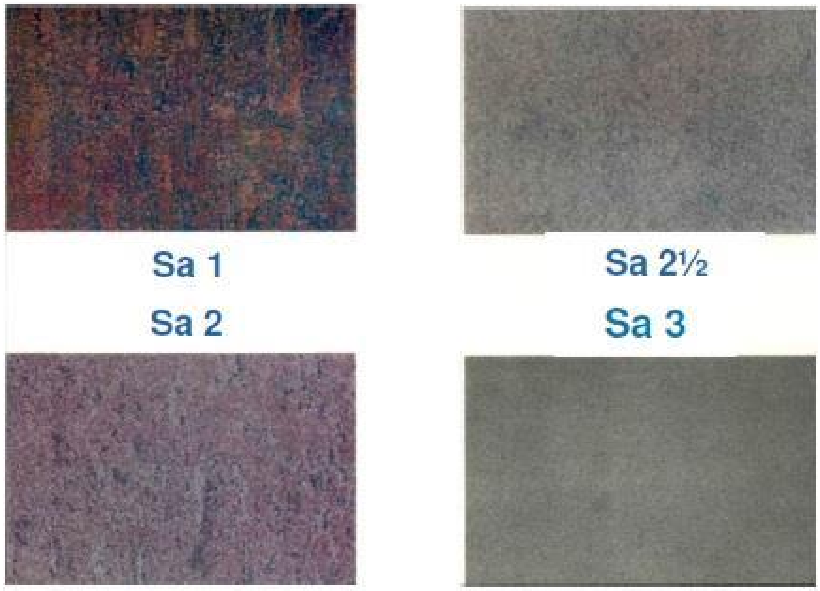


Figure 42: A sample of the norms Sa1, Sa 2 ½, Sa 2 and Sa 3 (PST, Photo Gallery, 2015)

When the pretreatment norms have been agreed upon, there is a little basis for discussion afterwards regarding the quality of the work.

All paint maintenance work on board is carried out for one or both of the following reasons:

1. Protection against corrosion, which can diminish the usefulness and value of the vessel.

2. To improve the appearance of the vessel; to improve environment and efficiency and give better PR for the ship owners.

Maintenance, however, does not consist of painting alone, but also – as repeatedly emphasized – of pretreatment, washing and cleaning processes.

In choosing the procedure for the maintenance work, two factors are considered. These vary in importance, depending on the type of vessel to be maintained. A passenger ship should look clean and bright and freshly painted – here point 2 (above) is perhaps the main factor. For a tanker, point 1 will be the most important.

For the pretreatment the methods and the tools must be considered, when planning maintenance, depending on the following:

1. Degree of damage to the surface – if the whole surface is more or less destroyed by rust, certain methods and tools are chosen. If there are only smaller spots of rust, for instance on a welding seam or bolt-head, another method and other tools will be chosen.

2. What kinds of tools are available? – Unfortunately, not every ship carries all the necessary equipment.

3. Which paint system is to be used? –As modern, sophisticated paint systems are in use on many ships, it is important to note that the different paint systems require different pretreatment norms.
4. The nature of the surface – different methods and tools are used for deck and deck-machinery.
5. Previous treatment – If, for instance, epoxy paint has been used, it is necessary to flatten the surface mechanically to obtain good adhesion for the next coat. If chlorinated rubber paint has been used, this is not necessary.
6. Result required – In certain cases durability is the most important factor. On the other hand, it is often necessary to do the work quickly for a liner or passenger ship, so that the ship can always appear freshly painted. In this case the work will not always be done as well as possible and the durability will accordingly be shorter.

Pretreatment includes far more than wire brushing or scraping. A well done maintenance job includes as a role most of the following operations:

1. Removal of rust and mill scale.
2. Removal salt.
3. Removal of grease, oil, dirt.
4. Removal of unwanted paint (if the former coat of paint is so thick that it has lost its protection properties – if a more advanced system is desired or if the original coat of paint is of poor quality)
5. Abrasion of sharp edges.
6. Malting glossy paint.
7. Thorough removal of dust.
8. Special pretreatment of aluminum and galvanized surfaces (degreasing and treatment with wash primer).

Table 10: Cleaning Methods and their results (Basic Paint Technology and Terminology, PPG, 2013)

	Method	**Result**
1.	Blast-cleaning	Ideal
2.	Mechanical wire-brushing	Risk of polishing
3.	Mechanical disk-sanding	Some risk of polishing
4.	Needle chipping	Some risk of indentations
5.	Mechanical rust-chipping	Heavy indentations

6.	Mechanical scraping (air powered)	Good combined with other methods
7.	Hand brushing	Poor
8.	Hand scraping	Only to be used in combination with other methods

Nothing can compete with blast-cleaning to obtain the best result. Air-powered (mechanical) tools generally give better results than hand tools. There is no doubt about the superiority of the blast cleaning method. This method gives an ideal foundation for paint, and blast-cleaning (Figures 43-46).

Figure 43: Dry abrasive blast-cleaning (PST, Photo Gallery, 2015)

Figure 44: Wet abrasive blast-cleaning (PST, Photo Gallery, 2015)

Figure 45: Degreasing (PST, Photo Gallery, 2015)

Figure 46: Disk sanding (PST, Photo Gallery, 2015)

Chapter 5: Application of Paints

The protective properties of paints will have no value and effectiveness till their correct application on the pre-treated surface. It is a general consideration that all the problems will be solved as soon as an anticorrosive paint is applied in the specific film thickness. It is a fact, however, that the chosen method of application is of equal importance for the final result. Given that paramount attention should be paid on this aspect for maximizing the paints efficiency (Sørensen, Kiil, Dam-Johansen, & Weinell, 2009).

Practical experiments have shown that paint application by roller is most unsuitable for the first coat and more convenient for the rest (Figure 47). This is particularly the case where on surface the pre-treatment procedure has not been ideal or alternatively where there is the risk of moisture, or impurities having collected on the surface. From a technical point of view, the ideal method for applying paints is with a brush. This tool will work the paint into the dents and pores of the surface. Furthermore, it will ensure that any drops of water, dust or other impurities will be removed, always to a certain degree, and allow the paint film to make good contact with the surface. A paint brush, however, is not a very practical choice when paints are going to be applied on large areas. On this occasion, paint spraying equipment is a more suitable alternative. Airless spray is an effective means of making the paint penetrate the pores and crevices of the surface.

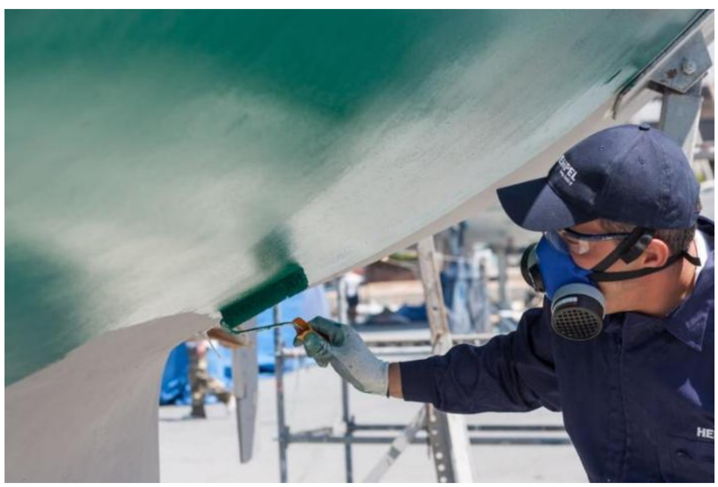


Figure 47: Paint application by roller (PST, Photo Gallery, 2015)

When the paint is rolled on to the surface, large amounts of air are retained in the cavities under the paint film. This air very often contains some moisture; thus it gives the ideal conditions for rust formation under the paint film. The major rule is therefore that the first coat of paint should be never applied by roller. A paint roller may be used with good results for applying the subsequent coats after the first coat of paint has been applied either by brush or by airless spray.

Thus, a paint brush could be used for the first coat of paint and the subsequent coats could be applied using a paint roller. Alternatively, all subsequent coats of paints could be applied by means of airless spraying (Figure 48). The latter alternative is suggested to be the best as it minimizes the risk of possible destruction of paint coats.

For large areas that should be painted, all coats including the first may be applied by airless spray. Airless spraying, when of course it is used correctly, has the advantage of giving a greater film thickness per coat. Consequently, fewer coats will be needed with an airless spray than with a roller, to obtain the same total thickness. As it is already known, the film's thickness is of deciding importance for the protective properties of the paint system.

Figure 48: Applying paint with the use of airless spray (PST, Photo Gallery, 2015)

That was the reason why many manufacturers have realized the importance of developing special paint systems which can be applied by airless spray, and thus giving paints coats of extra thickness. An additional advantage of airless spraying equipment application is that a much more even film thickness will be obtained. This advantage is of paramount importance as it is the thinnest parts of a paint film which are the weakest points and thus the deciding factor for the durability of the paint film.

Regarding this recommended film thickness, the technical data sheet of each chosen paint should always be checked. If a film thickness is too low, it will give a poor corrosion resistance and thus protection against it. On the other hand, if it is too high, it may lead to solvent entrapment, slow drying and incorporation of air and bubbles in the film.

The ideal method of applying paints is the usage of paint brush for the first coat to obtain good penetration of the corrosion inhibiting primer. Airless spraying for subsequent coats to obtain a sufficiently thick paint film of even thickness.

Airless spraying has gained increasing popularity as paint application equipment on board. Whether or not such equipment will give the advantages claimed is entirely dependent on current use. However, the principles of conventional spraying should be considered first.

In the case of airless spraying, the paint is atomized when forced, under high pressure, through a very fine nozzle on the spray-gun. The paint is atomized on to the substrate by the sudden fall in pressure when it leaves the nozzle, which means less formation of dust.

By correct use of airless spray equipment, it is possible to carry out the spraying operation with hardly any dust formation at all. The most important detail and part of the airless spray equipment is the nozzle. It has a tungsten carbide tip with a narrow opening through which paint is forced. The dimension of the opening varies for the different nozzles. Furthermore, the shape of the opening may also vary, allowing a choice of fan angles during spraying. The result is, to a large extent, dependent upon the correct choice of nozzle.

The instruction for application of most paints used on board ship and in all books of instructions published by, will indicate the type of nozzle recommended for the different paints. These indications can be considered as good guidance and point of reference, but very often it is possible to experiment and find that alternative nozzles give excellent results.

What should always be remembered is that the nozzle will gradually become worn, and thus will change the dimensions of its opening. Additionally, it should not be disregarded by all users that nozzle is too expensive and thus have to be treated by special attention and care as per the manufacturer guidance. For its holes cleaning, a metal object should never be used. If necessary, wooden splinters may be used, but never by a harder material.

As a conclusion to the above, since nozzle is considered the most important part of the airless spray equipment and must therefore be handled very carefully. It should always be remembered to choose the correct nozzle for the job.

In order obtain the necessary pressure for complete atomization of the paint, a pump is required. For practical reasons, this pump is generally operated with compressed air, but may well be operated hydraulically or by other means, although this is not suitable for on board use.

The high-pressure pump (Figure 49) functions in the following way. At the top, there is a compressed air motor into which air is introduced through a reduction valve. A distributing valve in the top of the motor casing is placed, so that the air passes through it and continues through a duct and down under the piston in the compressed air motor. The piston is pushed up, forcing the air above the piston through the valve and out into the atmosphere. The piston in the compressed air motor is connected to the piston in the paint pump through a piston rod. The paint pump is equipped with two ball valves, one in the piston itself and the other in the bottom of the cylinder. The piston in the paint pump is now on the way up, closing the ball valve in the piston and opening the ball valve at the bottom of the cylinder. The paint above the piston is forced up through the filter and out through the high-pressure hose to the spray gun.

Figure 49: A high pressure paint pump (PST, Photo Gallery, Technical Records, 2019)

The air-distributing valve decides in which direction the piston shall move and is controlled by means of a plunger on the piston rod. When both the air piston and the paint pump piston are near the top of the cylinder, the plunger receives an impact from below which makes the valve change its position. The compressed air will now enter above the piston, forcing it down. The air below the piston will be forced out through the air distribution valve and into the atmosphere.

This results in the paint piston being forced downwards. The ball valve at the bottom of the cylinder closes while the ball valve in the piston opens. The large density of the piston will partly displace the paint present in the pump cylinder. The paint is thus forced out through the filter and the high pressure hose to the spray gun. When the piston is nearly at the bottom, the air distribution valve will again be displaced, and the piston again is forced upwards. The paint is pumped out through the filter to the spray gun, both by upward and downward piston movements. The pressure of the paint leaving the cylinder is decided by the input air pressure, which can also be regulated by the gear ratio.

The gear ratio is the ratio between the area of the compressed air piston and the area of the piston in the paint pump. Most high pressure pumps have a gear in the range of 1-28 to 1-60.

Recommended air pressure is normally 5-7 kg/sq. cm (70-100 psi), assuming input air pressure of 7 kg/sq. cm. At this point, no nozzle is attached to the spray gun.

The trigger, on the spray-gun, is pressed and the thinner in the equipment pumped out. This thinner could be kept for later use. When the paint has forced all the thinner out of the system, the trigger is released. The spray gun is pointed into the paint container, the trigger again is pressed, and the paint allowed to circulate through the system to remove any residual solvent present in the equipment. A nozzle is then fitted, and the equipment is then ready for use.

When the spraying is finished, the nozzle is disconnected and this, together with the spray-gun, is thoroughly cleaned. The nozzle must not be fitted on the spray-gun during storage period and must be safely kept separately. The can of paint is subsequently removed and replaced by a container filled with thinner/cleaner. Before circulating the thinner through the system, all residual paint should be forced out and back into the paint can for next future use. Thereafter, thinner/ cleaner is circulated through the system until clean. The air valve is then closed, and the pressure is released by pressing the trigger again. This is followed by disconnecting the filter. The latter is thoroughly cleaned, using a spray-gun. All parts, except for the nozzle, are subsequently reassembled. Finally, the complete equipment is filled with thinner/ cleaner and set under pressure. The spray gun is now secure, and the compressed air supply disconnected. The spraying equipment, being filled with thinner/ cleaner, is left like this, ready for use.

Knowing the technical characteristics of this tool, it is understandable that one should never aim the spray-gun at anyone. As it was earlier mentioned, in airless spraying the operating pressure will be as high as 300 kg/ sq cm (400 psi) and thus paint escaping the spray-gun without being atomized through the nozzle will have a very high force of propulsion. An air-less spray-gun must therefore be considered as a loaded weapon. On the other hand, a high pressure-gun is not dangerous if it is handled correctly. The following should always be borne in mind that the spray-gun should never be pointed at ourselves or anyone else. What should always be ensured is that the spray-gun is secured; expect of the occasion that it is pointed down towards the substrate to be painted. Also, when the spray-gun is not fitted with nozzle, using its full pressure should be avoided for safety reasons. At this point, it is needless to be mentioned that a high pressure spray gun should never be used as plaything. There are far too many people who have shot off a finger while thoughtlessly fingering the trigger.

Chapter 6: Reasons of Maintenance

If ships are not well maintained, we are aware that sooner or later, they will fall into disrepair and will lose their value and usefulness. It is also known that they will look unsightly, become uncomfortable and will not be a very good advertisement for the company in which it is used. Maintenance work can be divided into two main groups:

1. Protection against direct breakage and damage, which would render the ship less suitable or useless for its intended purpose.

2. Maintenance will make the ship enjoyable to live on for those on board and a ship to be proud of when one is ashore or on board other vessels. Thus, a vessel is a good advertisement for its country and the owners too, even if the ship owner company is enlisted.

In fact, it could be said that both of above mentioned reasons are of equal importance. At the same time, it is very difficult to draw any definite lines between them as there is a close connection between comfort on board and the technical running of a ship, where all the parameters are dependent on each other.

An important form of maintenance is protection against rust with the aid of paint. Consequently, we paint in order to make the surroundings pleasant and to preserve the value of a ship. The paint application related to the maintenance of a ship each year is very expensive and requires a great deal of work. One thing that we do not realize is that pre-treatment in connection with paint often costs six times as much as the painting itself. In general, the results of a paint maintenance are dependent on the following reported three important factors:

1. Pre-treatment (surface preparation)

2. Execution of work (especially paints conditions)

3. Paint quality

It is generally believed that painting results depend only on the quality of the paint, which is completely wrong as the first above two points are of far greater importance for the results than the paint quality itself, even though the latter is also very important. For removing any doubt, the basis of the maintenance achievement should be considered, that is rust protection and what should be always kept in mind is what is rust and in order to be put more precisely, what is corrosion.

Generally speaking, we could allege that corrosion is more or less the same as rust formation or rusting. Rust occurs when iron goes through the corrosion process.

Iron and steel are not found in their natural stage but are extracted from iron ore in a blast furnace or electro oven. The iron ore, together with coal or coke, is heated to a very high temperature, after which large amounts of energy are introduced into the ore. Some of this energy is stored in all iron and steel and any piece of steel can therefore be regarded as a charged battery. The iron or steel can also set free this accumulated energy in the form of electricity, in the same manner as a torch battery connected to an electric light bulk.

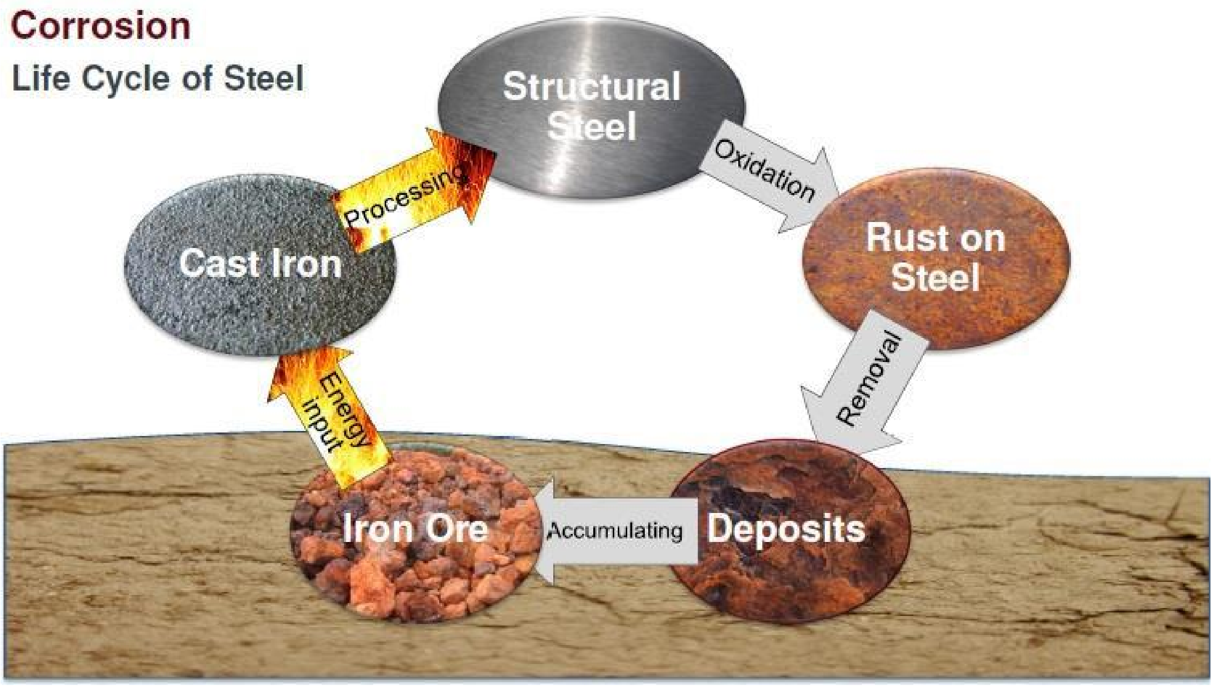


Figure 50: Life Cycle of Steel (Basic Paint Technology & Terminology, PPG, 2013)

We know that when a torch battery is discharged, the zinc capsule around the battery is consumed and the liquid electrolyte runs out. The zinc capsule is also called the anode. Exactly the same thing happens with steel. Some constituents of the steel are consumed or corroded during the release of energy and thus the steel rusts. In order to have this action we must have the same conditions on a steel plate as in a battery. An electric element or battery has 2 terminals. These terminals are called “anodes” and “cathodes”.

While looking at the steel through a microscope, we see that it consists of particles or crystals of different colors, that is to say that they are of different composition. Steel, greatly magnified, is full of irregularities and pores. In these, moisture and water can be easily collected and this, together with impurities from steel or salt, forms the electrolyte. Furthermore, because oxygen in the air reacts with iron when electric energy is released, a supply of air is necessary to start the corrosion’s process.

A steel plate that is not protected and is exposed to air and moisture acquires a large number of microscopic electrical elements which could well be compared with a torch battery. Thus, the energy which was originally supplied to the steel during its extraction is released and as a result, rust is getting. Exanimating this procedure under chemical criteria, rust is same as iron ore. The cycle is completed and thus we are back at the beginning of the natural condition in which iron and steel are found (Figure 6.1).

What is initiating the rusting process is the air, consisting of oxygen and moisture. Therefore, is one of the above factors or better both that should be prevented from coming into contact with the steel for counteracting rust.

This could be achieved either by putting a barrier or membrane on the steel, that will be impermeable to moisture and oxygen. Under that way, we will have prevented all rust-formation and corrosion. In order to make this possible, it is important that oxygen and water are not allowed to penetrate underneath the barrier or membrane.

A paint film will give us such as barrier and for effective protection should have the following mentioned properties:

- Should be as impermeable as possible: Naturally a thick paint film is more impermeable than a thin paint film. Therefore, within practical limits, the paint film must be sufficiently thick.
- No oxygen or moisture should be present under the paint film, so that corrosion could not be initiated without a supply of these from outside.

At this point is where pre-treatment comes into the picture for its great importance. Considering the composition of rust, it contains both oxygen and water. If the steel surface is corroded prior to painting, then a new rust formation under the paint film will be created, even if this will be completely impermeable. This is because the corroded surface contains both water and oxygen, and when coated with paint, air pockets often occur. These air pockets may also contain enough water to support new corrosion.

The final and great conclusion therefore is that when a pre-corroded surface is painted without sufficient pre-treatment, there is a danger of rust formation being continued under the paint film. In other words, regardless of the used paint's type, the better the pre-treatment makes, the better the paint result is.

Nearly all paint and paint protection act as a barrier between steel and outside factors, such as moisture. How good this barrier is depending on the quality of the paint and how it is applied.

For protection against corrosion, two chief principles are generally followed. Those are:

- There are paints that form barriers between the air and moisture on one side and steel on the other side. These are called "barrier-forming" coatings. Those are conventional paints, epoxy paints, vinyl paints, polyurethane paints, and chlorinated rubber paints. This kind of corrosion protection is the most common.
- The other chief principle is based on the use of active rust-preventing zinc-rich paints. This kind of corrosion protection is widely used due to its effectiveness. The old-fashioned red lead paint and zinc chromate primer stops corrosion primarily by forming a barrier. In addition, the special pigments (lead compounds and zinc chromate) act as corrosion inhibitors. This effect is partly based on the lead compound reacting with linseed oil and partly on water dissolving the pigment by penetrating the paint.

Corrosion inhibition is therefore obtained through a chemical reaction. This kind of corrosion prevention is now of less importance: lead compounds, for example, make the paint poisonous (danger during spraying) whilst at the same time the increasing use of water resistant binders has reduced the importance of these pigments types and principals. Furthermore, using linseed oil as a binder is impractical because of the long drying time that is required. The use of quick-drying binders reduces to a large extent the effect of the read lead pigments.

6.1 Protection of Steel Structures in Sea Water against Corrosion and Fouling

Steel in sea water may be protected against corrosion by:

1. Coatings
2. Cathodic Protection Systems (sacrificial anodes or impressed current)
3. Or by a combination of the above two options

The only practical way to protect against fouling is to use anti-fouling. Coating systems may be designed to give long term corrosion protection, but applied under practical conditions there will always be some weal or bare spots in the coatings due to faults which occurred during pre-treatment, application, curing, burning and welding effectuated after coating, application, mechanical damages during handling and services.

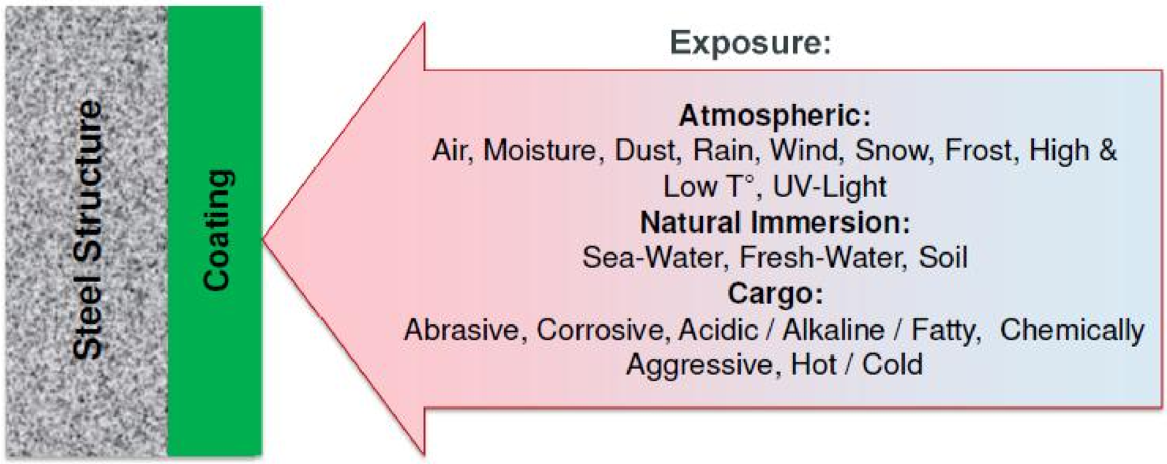


Figure 51: Factors which a steel structure is exposed (How to select the right paint system, Hempel, 2019)

There is therefore great uncertainty as to prediction of "protective lifetime" for coatings applied and exposed under various conditions (Figure 51). Today, there is no effective method of repairing or renewing coatings on major areas in water.

Cathodic protection systems alone can be designed to give complete corrosion protection to parts of steel structures which are continuously immersed in sea water.

They can be repaired, renewed or reinforced in situ, but they cannot give protection against fouling.

The best way to protect steel structures in sea water is therefore to use a combination of coatings and cathodic protection systems. This will give:

1. Complete corrosion protection also to damaged coatings.
2. Greatly reduced current demand and thereby lower cost of the cathodic protection system compared to uncoated structures.
3. Reduced weight compared to a sacrificial anode system only.
4. Protection against fouling by anti-fouling.

6.2 Hull Structural Integrity

Most ship losses are caused by a series of events that include operational factors and human error. Groundings and collisions are the most common reasons for serious hull damages as per the last decades provided statistic figures from class societies. Hull failures as the initiating event account for about 15–17% of serious casualties, according to DNV statistics for the world's fleet from 1978–95. Failures that are caused by corrosion are included in figure 51. Especially for bulk carriers, corrosion of cargo hold structures has contributed to the loss of several ships and lives during the previous decade.

The relative amount of hull damage, including corrosion, cracks, and fractures is presented for different ship types, as per the records of DNV Class Society for classified vessels from 1985-1994. For a deep comprehension of that table outcome, we should define that the relative hull damage rate is calculated as the damage rate for the actual ship type divided by the damage rate for all ships, and the multiplied by 100. From those data, it is obviously noticed that bulk carriers, chemical carriers, and oil tankers are among the types of ships listed as being above average (index 100) for hull damages in comparison with all the other kinds, where those damages are quite limited. It should be underlined that different average ages of the ship types may be significant for the results (Det Norske Veritas, 2020).

6.3 Coatings

When coatings are combined with cathodic protection systems, special care must be taken as to pre-treatment and choice of coating system to secure long service life. The failing of coatings by adhesion loss and blistering is more pronounced on structures with cathodic protection system than without, unless precautions are taken to choose correct, pretreatment coating system (Figure 52).

The cathodic protection system should be designed to give potentials not lower than what is necessary to prevent corrosion.

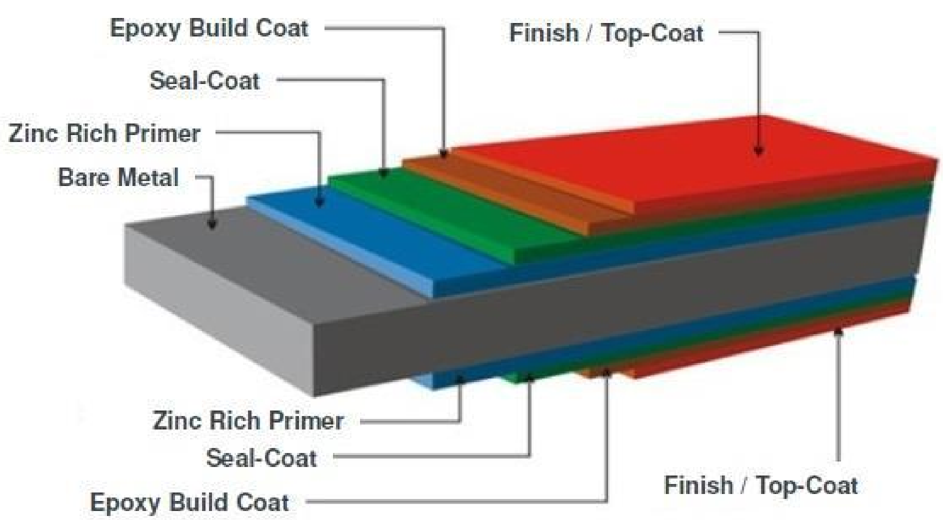


Figure 52: Presentation of the coating system (Coating Manua, Jotun, 2018)

6.3.1 Pretreatment of the Substrate

Pretreatment before coating application is always very important to get good results. When coatings are combined with cathodic protection systems, this is even more important (Figure 6.2.1.1). Coatings applied on rust will fail by adhesion loss and blistering even quicker on structures with cathodic protection than without. Blast cleaning of steel to min. SA 2 ½ is necessary.

a) Shop-primers/Holding primers

Numerous tests made by JOTUN's laboratory and others, as well as practical experience, have shown that the best and most reliable results are obtained by using thin coats of zinc rich primers. Most experience is obtained with zinc rich epoxy primers, but laboratory tests have also given good results for thin coats of zinc ethyl silicate primers. It is however very important to keep the film thickness for the zinc rich primers low (less than 30 microns) (Jotun, 2018).

Based on laboratory tests and practical experience, we will give the following ranking of shop primers / holding primers:

1. Zinc-rich ethyl silicate.
2. Zinc-rich 2-pack epoxy.
3. Iron oxide 2-pack epoxy.
4. Iron oxide polyvinylbutyral / phenolic resin.

b) Main Coating System

For the main coating system it is even more important to choose the right type of coating and to apply adequate film thicknesses on structures with cathodic protection systems than on those without.

For JOTUN's coating we will give the following ranking:

Epoxy/tar coatings:

1\. Jotaguard 85 250micr.

1\. Safeguard 250micr.

Vinyl/tar coatings:

1\. Vinyguard Black/Brown 240micr.

2\. Vinyguard Silver-gray 240micr.

Chlorinated rubber coatings:

2\. Pioner Primer Aluminum 225micr.

3\. Arcanol Silver-gray 180micr.

Increasing the film thickness will give higher resistance against adhesion loss and blistering.

c) *Anti-foulings*

We have found no difference in antifouling performance between structures with cathodic protection systems and those without.

The antifouling system may therefore be chosen freely to fit the ship's operation (speed, routes, dry-docking intervals etc.).

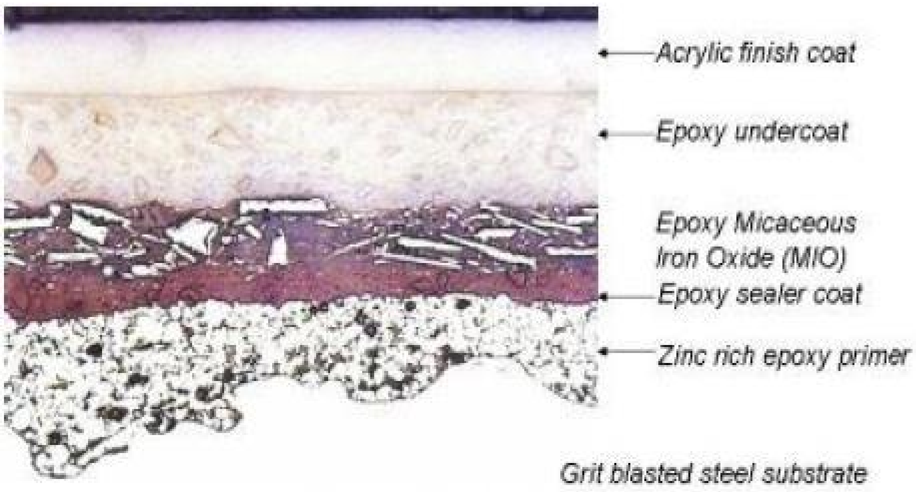


Figure 53: Example of coat layering (How to select the right paint system, Hempel, 2019)

6.4 Zinc - Rich Paints

There is, however, a kind of corrosion protection for which so-called cathodically protecting paints, zinc-rich paints, are used. The zinc in these paints will form an anode in the aforementioned electrical system and thus will protect almost completely the hull.

It is known that in order to protect the underwater hull against corrosion, zinc anodes are welded-on. The zinc anodes take over the earlier function of the anode in the steel plate itself. Thus, the zinc will be dissolved instead of the steel.

It is too difficult and expensive to weld zinc anodes to the whole of the underwater hull and other places where corrosion occurs. However, as zinc is very effective in preventing corrosion, we make use of paints containing large amounts of zinc, in which each individual zinc particle in the paint acts as an anode.

The only difference from ordinary anodes is that in zinc-rich paint, the anodes are "glued" to the hull by the binder instead of being welded to the hull. If zinc-rich paints are used, the zinc will corrode while the steel remains un-attacked. Zinc-rich paints are therefore very effective with regard to protection against corrosion. In order to act, they need complete electrical contact with the steel. This is best obtained if the steel has been blast cleaned beforehand (min Sa 2 ½).

There is no point in applying a zinc-rich paint to a wire-brushed surface, because even microscopic amounts of rust or other impurities will prevent electrical contact and thus will make the zinc-rich paint inactive.

Zinc-rich paints contain 93-94 % metallic zinc and only a small percentage of binder. When this paint is freshly applied it will be porous as there is very little binder present. Moisture will therefore easily het into the paint film and as it is well known, when moisture and air are present, corrosion will initiate. Thus, zinc will be corroded and will form hydroxide, that by reaction with carbon dioxide in the atmosphere, gives zinc carbonates. Those substances are insoluble in water and accumulate between the individual zinc particles, like cement in a concrete mixture.

The film will be less permeable. It will be water and airtight, hard and solid. If a leakage forms in the film, water and moisture will immediately penetrate through to the steel. However, this will not corrode because the zinc will corrode instead. Thus, new zinc carbonates are formed, which will immediately close the leakage (Figure 54).

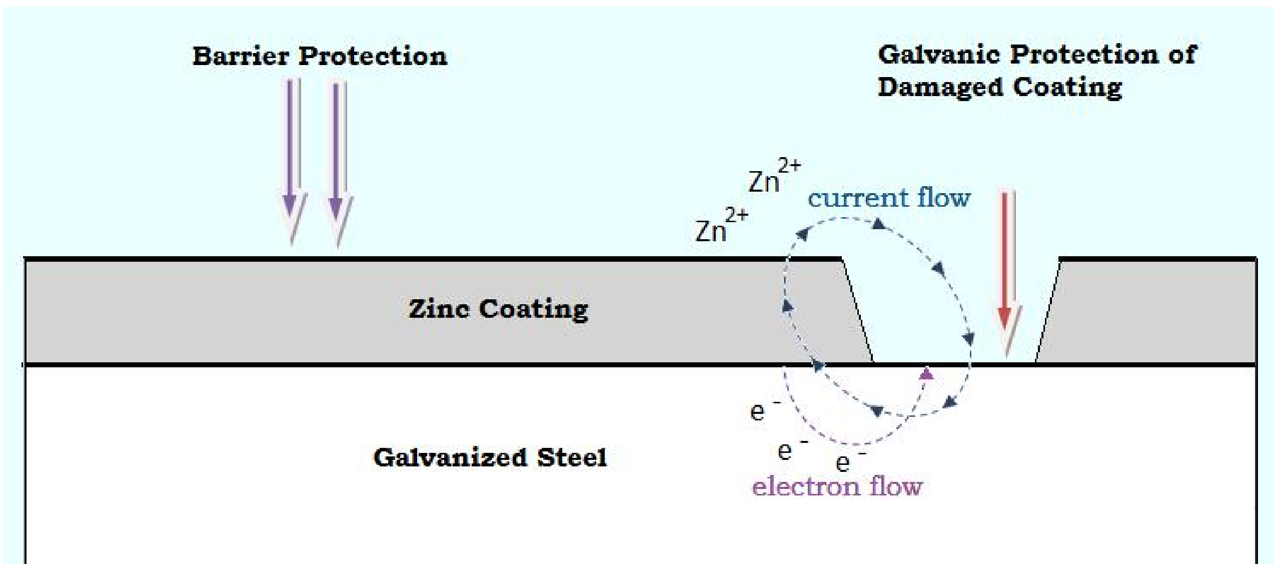


Figure 54: Schematic presentation of the above-mentioned procedure (Coating Manual, Jotun, 2018)

The use of zinc-rich paints is a very special method of protecting steel against the attack of rust. The principles discussed in connection with zinc-rich paints are also adhered to in other connections and that is the anode that corrodes. If the hull becomes an anode in a giant electrical element, the hull will corrode of course. This can be caused by electrical welding if the welding transformer is situated ashore. In particular, the welding seams of the underwater hull are exposed in this connection, as they very often have a somewhat poorer paint protection than the rest of the plates.

The problem can be overcome by grounding the hull direct to land so that the current does not go through the sea. Hull can also be protected by making it cathodic. A negative electric charge can also be given to hull by impressed current. The principle is the same as when anodes are used, but in this case the power supply on board is used (transformer & rectifier). In this case, the hull and the platinum anodes form an electrical element which is continually being charged and which discharges through the sea. Thus, the hull is the cathode and therefore will not be corroded (Figure 55).

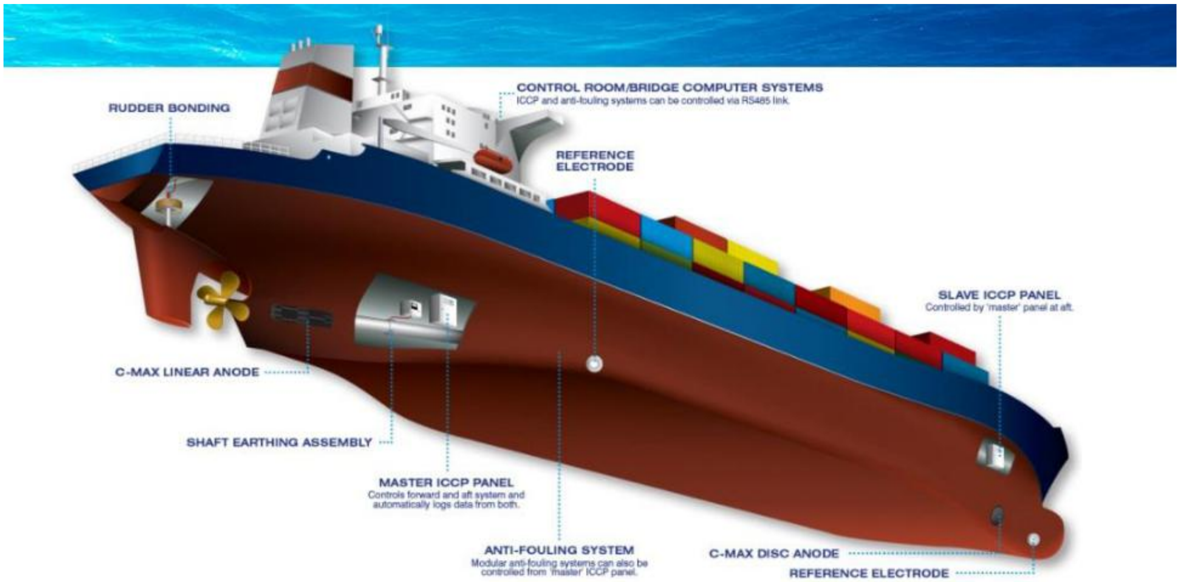


Figure 55: Basic ICCP (Impressed Current Cathodic Protection) Layout (Coating Manual, Jotun, 2018)

Chapter 7 Specialties

In the following chapter, Chapter 8, the coating system on Water Ballast Tanks will be examined, since it is a gigantic part of the coating study alone, as it is, nonetheless, for every different type of ship. So, before analyzing thoroughly the above type, some basic points will be mentioned for some other structures as well.

7.1 Systems for Superstructure and Deck Fittings

The coating system applied here must be suitable for all metal surfaces, ferrous and non-ferrous. Furthermore, especially the fore, but also the rest of the superstructure and deck fittings, should be carefully painted considering the aesthetic factor. It is of great importance that the ship is visibly attractive, as a reflection of the care and attention of the owner and crew on it (Figure 56).
Moreover, the coating system is required to have good anti-corrosive properties, resistance to wind, rain, seawater and UV, good color and gloss retention, and should be easy to maintain.

Figure 56: Superstructure (PST, Photo Gallery, 2015)

7.2 Systems for Decks

The systems that fall into this category should be suitable for all decks on a ship, both external and internal. As far as the basic requirements are concerned, it should be stressed that the decks are exposed to sunlight, UV, rain and wind –basically every weather condition possible, and are subject to foot and mechanical traffic, as well as to chemical spillages. Also, they are sometimes washed with seawater, so the coating has to be resistant to it (Figure 57).

Figure 57: Decks on different types of ships, exposed to the above mentioned conditions (Coating Manual, Jotun, 2018)

7.3 Systems for Cargo Holds

In this case, it should be reminded that both wet and dry cargoes are included. This means that there are multiple factors that affect the type of coating system applied and is quite a big chapter. However, to briefly name a few, most of these places are exposed to severe mechanical abrasion and impact, especially when there are aggressive, hard angular cargoes, such as ores, coal, bauxite etc. In addition, “floodable” cargo holds are quite frequently exposed to seawater. Mentioning these, it is important to know that a sufficient curing time to first cargo is critical for optimal properties and performance of the coating system, which is also determined by the quality and nature of Shop-Primer.

7.4 Systems for Boottop and Topsides

The coating systems here should be suitable for all of ships’ outer hull, above-water areas. The considerable surface areas included here are exposed to all the above mentioned –sometimes extreme, weather conditions, and are also sometimes washed with seawater. They are subject to mechanical and abrasion impact, and to thermal and mechanical stress. Again, aesthetics, color and gloss quality should be taken into account, before choosing to apply the system (Figure 58).

Figure 58: A series of pictures of Boottop and Topsides (PPG, SIGMACARE Plus, 2019)

7.5 Systems for Engine Room/ Accommodation Interiors

Besides these systems mentioned, that are dependent on the variations of the structures of the ships, it is of importance to mention that there are different systems of coating that should be taken into consideration, depending on the interior of each ship. It is easier to classify them into two main categories:

- **Systems for Wet Accommodation Spaces**

When wet accommodation spaces are mentioned, they usually refer to bathrooms, showers, galleys, and toilets. As one can easily comprehend, the paints that are applied there should be resistant to corrosion, water, soap and scratch resistant and easy to clean as they are places where high standards of hygiene levels must be held. Finally, the paints in use ought to be non-yellowing and light-colored, for aesthetic reasons as well.

- **Systems for Dry Accommodation Spaces**

In this category, the engine room, provision stores, cabins and “hospital” or rooms with medical supplies, are included. Thus, the paint coats that are applied here should have long lasting adhesion to various substrates, and allow to re-coat quite easily, in case it is needed. The decorative factor should not be dismissed, as the pleasure of the passengers and the crew is much needed, as has already been underlined.

Chapter 8: Coating Defects

Introduction

It is not surprising that coatings can suffer from premature failure and/or exhibit defects that gradually may or may not result in failure, given the enormous number of factors that can lead to this phenomenon. Due to those exact factors, it is most of the time difficult or even sometimes impossible to determine the cause of such a defect or predict it and prevent it. Failures and defects can manifest themselves at various times in the life of a coating. Prior to application, they can take the form of settlement and skinning, during application as runs and sags, shortly after application as solvent popping and peel, and during service as blistering and rust spotting. The most important and frequently caused defects are mentioned below.

8.1 Abrasion

Abrasion is the mechanical action of rubbing, scraping, scratching, gouging or erosion. It is most often caused by the (slight) removal of a portion of the surface of the coating, or even in some cases, a more extreme removal takes place, so as for the substrate to be exposed and come in contact with another object nearby, such as cargo or the grounding of the ship.

Figure 59: The effect of abrasion (PST, Photo Gallery, 2015)

It can mostly be prevented, or at least reduced to a certain point, by using abrasion resistant coatings, formulated with particular regard to resins and extender pigments.
Once it has taken place, it can be re-coated after preparing the affected area with either mechanical cleaning, or blast cleaning, depending on the extension of damage and the size of the area. Naturally, when it is repaired, an abrasion resistant coating is advised.

8.2 Adhesion Failure

The “Adhesion Failure” term describes the phenomenon during which paint fails to adhere to substrate or underlying coats of paint. Surface contamination or condensation, incompatibility between coating systems and exceeding the over-coating time are the most probable causes.

Ensuring that the surface is clean, dry and free from any contamination, as well as that it has been suitably prepared, is one effective way to prevent it from happening. Another preventive measure is to use the correct coating specification and to follow the advised over-coating times.

Figure 60: Adhesion Failure (PST, Photo Gallery, 2015)

Again, depending on the severity and extension of adhesion failure, different measures can be taken to repair it. However, one thing that is certainly needed is to remove the defected areas prior to adequate preparation and application of the correct coating system, as advised by the manufacturer.

8.3 Alligatoring

Alligatoring is a very large cracking, which in some cases may penetrate through to the undercoat, and resembles the skin of an alligator (thus, the name), as depicted in Figure 61.

There are several probable factors that may cause the appearance of this defect, such as:

- Application of a hard topcoat over a more flexible softer undercoat
- Application of a topcoat before the undercoat has dried
- Excessive film thickness and limited paint flexibility

Internal stresses in the coating, where the surface shrinks at a faster rate than the body of the paint film.

Figure 61: Alligatoring (Coating Manual, Jotun, 2018)

To avoid alligatoring from emerging, correct coating specification and compatible materials should be used. In addition, application at high ambient temperatures should be avoided, as well as excessive film thickness. If alligatoring has affected the body of the paint film, the affected coats have to be removed, and suitable undercoat and topcoat should be applied, following recommended application procedures.

8.4 Application Defects

We are actually referring to a family of defects, which are mainly associated with application by brush, contamination from rollers, fingering and spattering from spray application.

Figure 62: A hair of brush, causing the defect (Coating Manual, Jotun, 2018)

Here, the causes for such defects are more certain, poor quality brushes, incorrect brush and roller materials, incorrect spray setup and inadequate care during application, maybe because of inexperience or tiredness. By using the correct materials, good quality equipment in general, and following the guidelines provided, these defects can be prevented.
To treat this type of defect, rubbing and re-coating give satisfying results, always, however, bearing in mind the variations of the exact type and extend of it.

8.5 Bubbles

It is a phenomenon commonly confused with blistering. Bubbles within a paint film appear as small blisters.
These may be intact or broken and can be found in excessively thick paint films.

Figure 63: Bubbles (Coating Manual, Jotun, 2018)

These bubbles can be caused mainly by trapped air (or solvent) within the coating, which is not released before the surface dries. Another cause is the air entrainment during mixing. It can also be caused when overcoating antifouling without the removal of the leached layer and zinc silicates.

To prevent bubbles from forming, viscosity of the paint film should be adjusted with thinners, whereas the maximum temperatures allowed do not exceed those of the data sheet requirements. Another way to prevent it is to use suitable equipment, so as not to allow air to get trapped, or stirred in during mixing.

As in most cases, to repair the damage caused by bubbles, the affected area must be removed and proper re-coating should be applied.

8.6 Cargo Damage

This kind of defect is essentially the deformation or removal of a coating by physical action or a chemical one, such as the abrasive contract of a hard angular cargo on the holds of a bulk carrier and the aggressive chemical cargo on a tank lining, respectively.
It is best to use a protective coating, an abrasive resistant to be exact, which can at least reduce the effect of this damage, but not prevent it.

Figure 64: Cargo Damage (PST, Photo Gallery, 2015)

In case this damage occurs, spot repair and a touch-up are recommended. If the damage is more extensive, then even blast cleaning might be needed, along with re-coating.

8.7 Chalking

Chalking is the phenomenon during which a friable, powdery layer on the surface of a paint film is formed. It is a characteristic which can be predicted based on the type of each paint, such as epoxy paints. Based on the pigment concentration and choice of binder, there are
Evidently, the most probable cause of chalking is the disintegration of the paint binder due to exposure to the weather conditions and, of course, UV light.

Figure 65: Chalking and its "powdery" feeling on hand (PST, Photo Gallery, 2015)

As one can think, the best way to prevent it from happening is to apply a suitable protective coat, with high resistance to chalking, and preferably with UV resistance.

Finally, in case of chalking, all the deposits formed should be removed using whichever method feels the most suitable, given the circumstances, and, afterwards, a chalk resistant topcoat should be applied.

Figure 66: Chalking (2) (PST, Photo Gallery, 2015)

Figure 67: Chalking (3) (PST, Photo Gallery, 2015)

8.8 Cracking

The splitting of a dry paint film through at least one coat, so as to form visible cracks which can penetrate down to the substrate, is called cracking. The degrees of severity vary, depending on the factor (or factors) that caused it.

Figure 68: Cracking (PST, Photo Gallery, 2015)

It most commonly attributed to surface movement, ageing and absorption (and consequently, desorption) of moisture. Generally, the possible lack of flexibility of a layer of the coating system can lead to the appearance of cracking.
To prevent cracking, more flexible coating can be used, while the film thickness should be the appropriate one, since the thicker the paint film is, the more possible it is for a crack to emerge.

Lastly, to deal with cracking, (after taking place), as it logically occurs, the defective paint should be removed, the area should be cleaned, and the proper coating applied, which will be more resistant to cracking, than its predecessor.

Figure 69: Cracking (2) (PST, Photo Gallery, 2015)

Figure 70: Cracking (3) (PST, Photo Gallery, 2015)

Figure 71: Cracking (4) (PST, Photo Gallery, 2015)

Figure 72: Cracking (5) (PST, Photo Gallery, 2015)

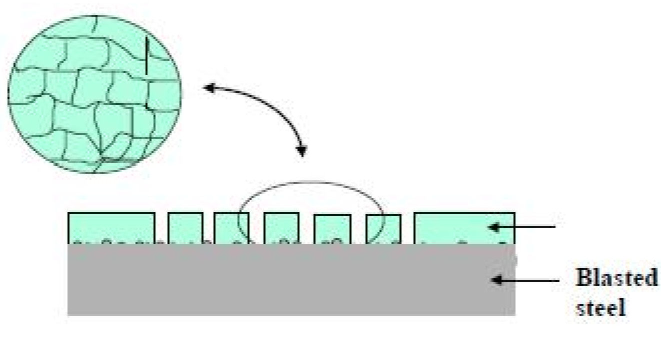


Figure 73: Mud Cracking (Coating Manual, Jotun, 2018)

8.9 Anti-fouling

It would be unwise to claim that a paragraph would be sufficient enough to cover the whole, immense subject of anti-fouling. However, it is imperative that we mention a few basic things about it, and, mainly, some of the most frequent problems related to it.

As already mentioned previously, the anti-fouling coating is a specialized category of coatings applied as the outer layer to the hull of a ship, in order to slow down the growth of subaquatic organisms that attach to the hull and can affect a vessel's performance and durability (Giorgiutti, Rezende, Van, Monteiro, & Gustavo, 2014; Kovanen, 2012). Most of the time, they have multiple functions such as protecting the ship from corrosion. There are different types depending to vessel sailing parameters. They also are fuel saving, since they contribute to smoother sailing (Chapman, 2011).

It is possible that, at least sometimes, an anti-fouling coating turns white just after application. The main cause for this is that it has been exposed to fresh water, or even detergents, before the film has properly dried. As the levels of resin rise (it is more possible for this phenomenon to arise. It is important to emphasize that this whitening does not affect the efficiency of the properties of the coating, it has purely cosmetic effects. One simple way to treat it is with solvent washing or simply by letting it polish off during trade (Demirel, Khorasanchi, Turan, & Incecik, 2013).

Figure 74: The whitening of anti-fouling coating due to premature water exposure (PST, Photo Gallery, 2015)

Figure 75: White powder on anti-fouling coating (PST, Photo Gallery, 2015)

Another cause for the same phenomenon is the structure of the paint itself. In some cases, for example in red vibrant colors, the only component that contributes to its color is the cuprous oxide (Cu_2O). This oxide is water soluble, and, as a result, the colour will be dominated by the water in-soluble pigments, e.g. titanium oxide, which appears in the form of white powder. It is not emergent to act on it, as it is natural mechanism (Maréchal & Hellio, 2009).

It is not rare that the colour of the coating in some cases may turn in blue and green tones. This is because of the high concentration of the cuprous oxide that exists in the freshly applied coating, which reacts with the components of the seawater and turns the cuprous oxide to copper salts that have a distinguishing blue or green colour. Similarly to the above, it is not urgent for measures to be taken in order to repair it, as the discoloration starts to polish off as soon as the trade begins (European Coatings, 2018).

Figure 76: The blue-ish colour because of the reaction of the cuprous oxide with the components of the sea water (PST, Photo Gallery, 2015)

8.10 Blooming (Blushing)

It is a hazy deposit on the surface of the paint film, resembling the bloom on a grape (thus the naming), which results in a loss of gloss and a dulling of color.

This occurs usually because of the exposure of the paint film to condensation or moisture during curing, especially when it takes place at low temperatures, something which is common when dealing with amine cured epoxies. Also, incorrect solvent blend can possibly lead or contribute to blooming.

To prevent this phenomenon, the coating systems should be applied correctly and cured as advised, under controlled environmental conditions, following, as always, the manufacturers' recommendations. It has basically cosmetic effects, so, if one wants to repair the coating to restore the external view of the vessel, he should remove bloom with a clean cloth and/or suitable solvent cleaners (Yebra, Kiil, & Dam-Johansen, 2004).

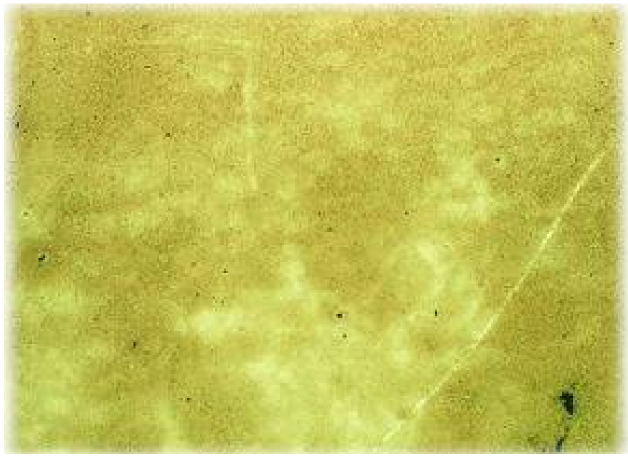


Figure 77: Blooming (1) (PST, Photo Gallery, 2015)

Figure 78: Blooming (2) (PST, Photo Gallery, 2015)

Figure 79: Blooming (3) (PST, Photo Gallery, 2015)


Figure 80: Water leaking on the wet paint film which resulted to blushing (PST, Photo Gallery, 2015)

8.11 Dry Spray (Over-spraying)

The result is the rough and uneven finish to the surface of the paint film, where the particles are insufficiently fluid to flow together and are often poorly adhered. It has the look and feel of sandpaper.

Dry spraying is a condition caused by the partial drying of the liquid coating prior to reaching the surface. Overspray, in general, is due to poor application technique, a result of either poor gun adjustment or application of the coating at too great a distance from the surface. This leads to an uneven wet film and a rough, sandpaper texture on the surface, as mentioned above. Some of the main reasons for the appearance of the dry spraying are:

- Too long distance; object - spray gun.
- Too high temperature during application
- Too high pump pressure.
- Too windy or too good ventilation.

By using correct coating application equipment and techniques, over-spraying could be prevented. Also, it is advised to use a slower drying solvent, or a solvent blend and the gun should be properly positioned, in relation to the substrate. It can be repaired by abrading and removing any loose dry spray and re-applying coating or topcoat.

Figure 81: Dry Spray (1) (PST, Photo Gallery, 2015)

Figure 82: Dry Spray (2) (PST, Photo Gallery, 2015)

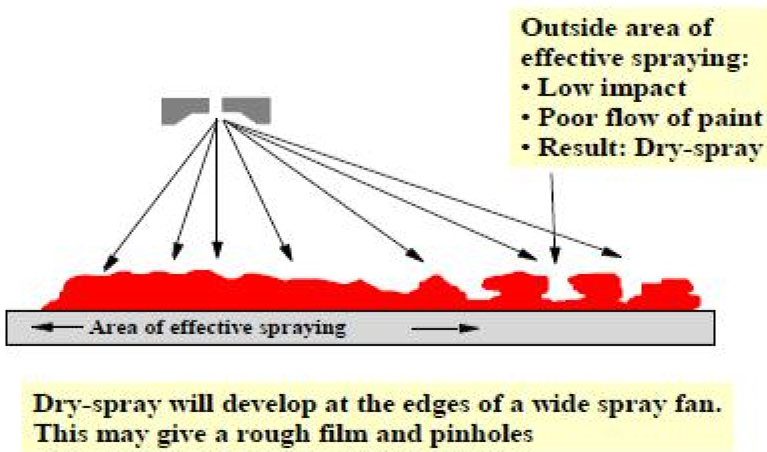


Figure 83: Dry Spray (3) (Coating Manual, Jotun, 2018)

8.12 Fish Eyes

'Fish Eyes' defect has a very characteristic appearance, which resembles to 'fish eyes', as small circular areas that have at their center a source of contamination, appear on the coating.

Surface contamination is in the form of small spots of wax, silicone, grease, or particles from contaminated airlines. It can be prevented by slowly degreasing the surface and maintaining equipment. By abrading the affected area, degreasing and re-applying the coating system, this phenomenon can be treated.

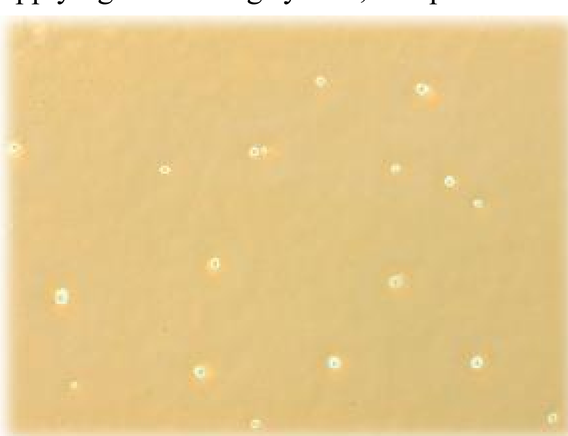


Figure 84: Fish eyes (1) (How to select the right paint system, Hempel, 2019)

Figure 85: Fish eyes (2) (How to select the right paint system, Hempel, 2019)

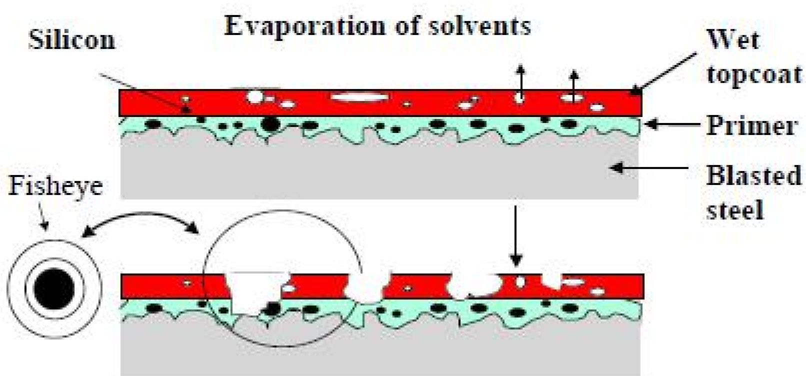


Figure 86: Illustration of the phenomenon 'Fish Eyes' (How to select the right paint system, Hempel, 2019)

Chapter 9: Hazards

9.1 Health Hazards

Generally, it can be said that the health hazard can be eliminated by good working conditions. Good ventilation, for example, is an air vent at the lowest point in the room in which the work is being carried out, or the use of an air-fed hood will lessen the risk. If painting is being done in tanks or narrow spaces, extra safety aids should also be used, such as having an assistant with a lifeline, and intervals in fresh air.

Paint factories always use as little as possible of the most dangerous solvents. Even so, good ventilation is necessary and air-fed hoods should be used in tanks. In this way, health hazards will be strongly reduced and may even disappeared completely.

Some paint contains pigments such as lead (red lead) and an air-fed hood ought always to be used while such paint is being sprayed.

Figure 87: A man, using an air-fed hood during the painting procedure(SIGMACARE Plus, PPG, 2019)

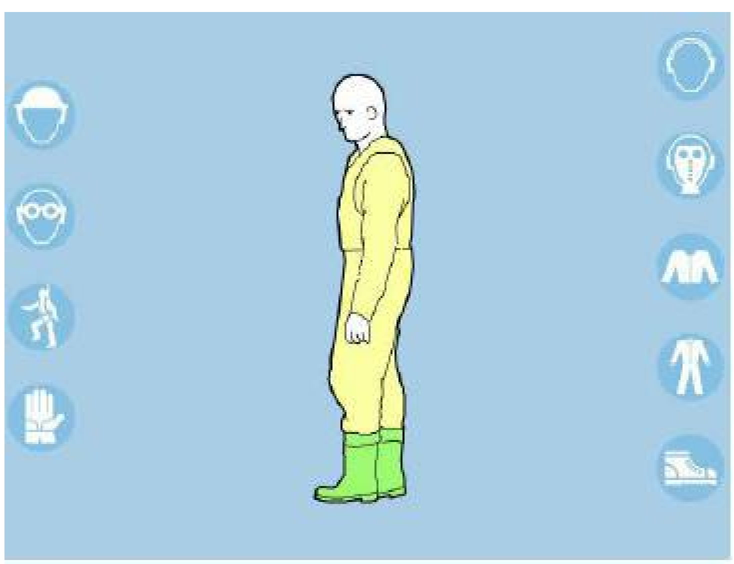


Figure 88: Health and Safety (SIGMACARE Plus, PPG, 2019)

9.2 Skin Complaints

Continual exposure to solvents can cause skin irritation to the hands. The skin will become very dry and eczema can also be developed. This is seldom caused by any specific type of paint, or by working with the paint, but by the work is finished. This problem will be greatly reduced if the hands are first washed in water and, while still wet, as much of the paint as possible removed with a cloth wrung out in the solvent. In this way, one can avoid paint, solvent and dirt penetrating the skin. Finally, the hands should be washed with soap and water and of course never in the solvent itself.

Figure 89: Wearing chemical resistant protective gloves (SIGMACARE Plus, PPG, 2019)

Another disadvantage is that the skin can become hypersensitive (allergic) to certain solvents. When this has first occurred, it takes a negligible amount of solvent to start an eczema condition and such an allergy will often last for a long time.

This type of eczema can be started off by continual use of epoxy paint. It is therefore advisable to take special care when using such paints.

9.3 Danger of Fire

When paint is being used, both oxygen and inflammable material will always be present. Heat, therefore, will be the only missing factor and a cigarette lighter or a spark from electric welding taking place nearby, is all that is needed to start a fire.

Figure 90: Ship on fire on Ha Long Bay (How to select the right Paint System, Hempel, 2019)

How dangerous the paint is depending on the flash point and the rate of evaporation of the solvent. In most types of paint, there are several solvents, and the flash point is the temperature at which the fumes from the solvents take fire or explode if ignited. The lower the flash point is, the greater is the risk that a mixture of solvent vapor and oxygen in the air will give an explosion-prone result. Flash point of the paints is given on the relevant technical date sheet of each one separately for users and crew attention and general references.

It is seldom considered to be of any great danger to apply paint outdoors, as there is no ventilation problem and the dangerous vapors quickly disappeared. Smoking, however, ought not to be allowed, nor should welding be allowed within 15 meters of the painting operation.

The best thing that could be done is to provide good ventilation and as this will also give better environmental hygiene, two advantages will be achieved at the same time.

9.4 First Aid

In cases of poisoning, medical attention is of course necessary. If the poisoning has been caused by solvents, the best solution is for the person to be carried out into the fresh air and if he is unconscious, the "mouth to mouth" procedure should be applied immediately. General burns ought to be treated as quickly as possible with cold water. Charred clothing which has burned into the skin must not be torn away. Medical treatment is necessary for serious burns.

For work in tanks following mentioned directions should be applied:

Figure 91: Person working, under controllable conditions (PST, Photo Gallery, 2015)

1. Making sure that there is good ventilation, so that the concentration of vapor from the solvents is kept as low as possible in all sections of tank. Ventilation must continue also after the paint has been applied for drying reasons.
2. Vapors from the solvents should be removed by mechanical ventilation, with the outlet placed at the lowest possible point in the tank.
3. Explosion-proof and spark-proof equipment should be used. Only approved cables, motors and lighting should be in use.
4. Inside the tanks, any kind of extension cords and connections are strictly prohibited.

5. Approved light fittings should be used and the cables must not be pulled around, because should they become disconnected, there would be sparks of electricity. Workers carrying out the tank coating should have rubber-soled shoes.

6. Within a margin of 10-20 meters of the area in which the tank-coating is being applied, smoking and welding should not be allowed.

7. An air-fed hood should be used when painting is applied in a closed room. Paint-spray in the face can be avoided by using an air-fed hood with a "window" at the front, as air pressure inside the hood will blow away the paint dust and this will be of high danger.

Figure 92: Use of respirator masks (PST, Photo Gallery, 2015)

Figure 93: Paints (Hyundai Painting Specification, 2006)

Chapter 10: Economics of paint systems

10.1 Life Cycle Cost

The process of identifying and documenting all the costs involved in the life of an asset is known as **Life Cycle Costing (LCC)**. The Life Cycle Costing process can be as simple as a table of expected annual costs or it can be a complex (computerized) model that allows for the creation of scenarios based on assumptions about future cost drivers. A life cycle cost analysis involves the analysis of the costs of a system or a component over its entire life span.

So, when discussing the cost of the painting system (and thus the cost of corrosion protection), it is imperative that the LCC is calculated. More specifically, by deciding the preferred paint system that is going to be applied on the project early on, and calculating its cost, LCC is going to provide its maximum benefits. Ideally, at least a general plan of the system that is to be applied should be in place before the bid specifications are finalized since at that point, an estimated 70% of the Life Cycle Cost is locked and cannot be influenced. Realistically speaking, to have a notable impact on the remaining 30% will become more and more difficult, and correspondingly expensive, as the project moves towards its completion. On the following figure 94, this association is depicted.

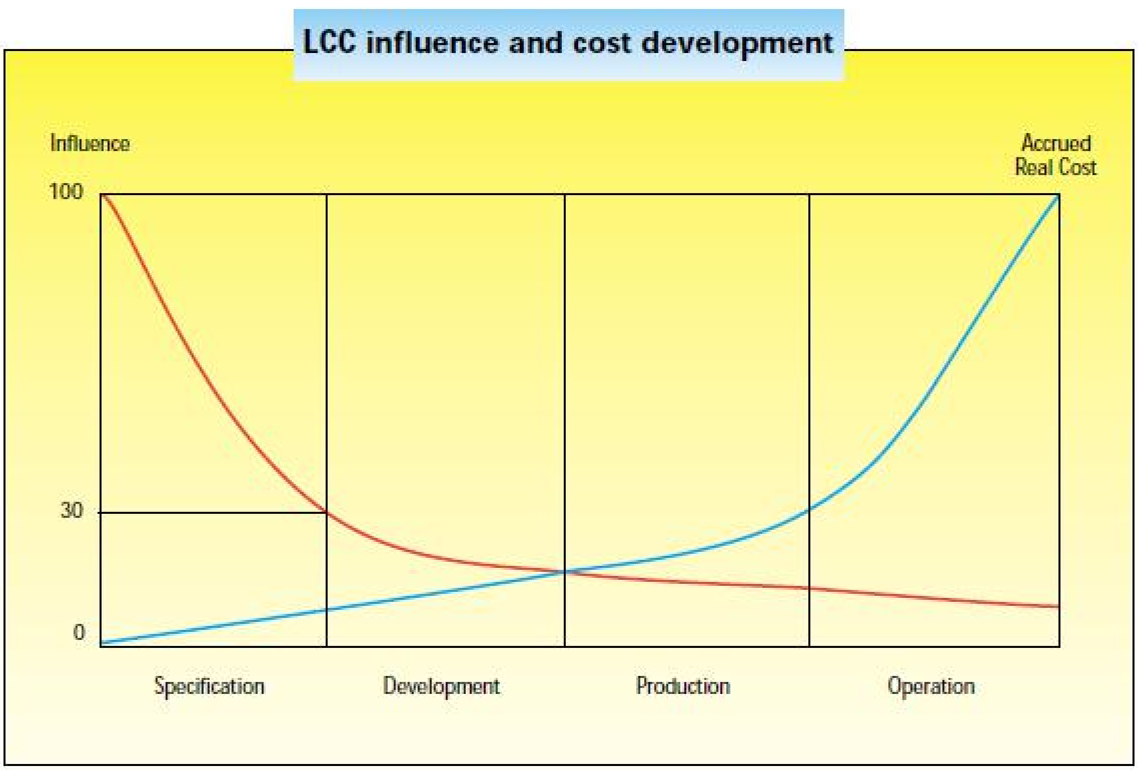


Figure 94: LCC influence and cost development (Journal of Coatings Technology and Research, Sorensen, 2009)

Life cycle cost analyses have been conducted for offshore structures with a 25 year life span. One tested (and environmentally friendly) way to reduce costs and corrosion rates is by choosing a high quality system. For example, experience from Norwegian offshore sector shows that maintenance has been reduced by 25-40% after implementing systematic surveys, long-term maintenance concepts and programs.

The cost of maintenance is quite a bit higher than the application cost, per square meter, at the new construction stage. Lifetimes of different coating systems vary considerably, that means that the comparisons between possible systems should not be based only on price per liter (or price per square meter) but on other factors as well. (More of these comparisons are to be found on 11.)

10.2 The cost of paint and the factors in consideration

Paint as a material itself takes up only a small proportion of the total cost of any project. In most cases, its value is less than 10% of the value of the painting contracts, and, to prove the above-mentioned point, when compared to the total project cost, it represents only 1% or even less.

Factors
To make a valid LCC evaluation it is necessary to compare only systems that are considered to be appropriate.
The important factors for choosing the right system are:

- **Design Life.** The expected lifetime of the project is very important. For example, a different system would be selected for a 25 year design life and another one for 10 year life span.
- **Accepted Level of Breakdown at Maintenance**
  The grade of deterioration of the system that will be acceptable is necessary to be determined before any action is taken.
- **Expected Life to First Maintenance**
  In certain standards, such as British Standards, Norwegian Standards etc., indications of expected life to first maintenance can be found. These should be combined with recommendations provided by paint suppliers and any data based on experience which the owners may have.
- **Maintenance Frequency and Extent**
  Maintenance frequency is decided (annual, two-yearly, etc.) along with the extent of repair on each occasion,
- **Accepted Level of Breakdown at End of Life**
- The owner decides what the condition of the structure should be at the end of its lifetime.
- **Cost of Newbuilding**
  Costs at certain stages, such as preparation, pre-treatment and costs related to materials are taken into consideration, keeping in mind that they vary geographically and thus, are calculated accordingly.
- **Cost of Maintenance**
  Maintenance cost for corrosion protection can differ drastically, and usually it is quite higher than the new building cost.

A key factor in life cycle costing is selecting a threshold level at which the substrate will need coating maintenance. The different paint systems present different developments during exposure. To evaluate the condition of a paint system there are certain standards available, relating to various kinds of defects (Krapp & Vranakis, 2013).

The most relevant accepted standard as to deciding the time to carry out maintenance, is “ISO 4628 – Evaluation of degradation of coating”. This pictorial standard gives objective criteria for evaluating the coating breakdown, and includes rusting, blistering, cracking, flaking and chalking. ISO 4628 quantifies the degree of coating breakdown and is used for deciding at which point of the breakdown cycle the existing coating should be repaired or completely replaced. It should be mentioned that the use of this standard is the basis for defining the guarantees and expectations of durability of paint systems, in conjunction with reference to other standards, such as ISO 12944 (Hempel, 2019).

Figure 95: The actual cost reduction for a Norwegian oil company after implementing an ISO 4628-based long term maintenance program. (Journal of Coatings Technology and Research, Sorensen, 2009)

It is easily comprehended that maintenance is a disruptive process, and a long-lasting coating system will minimize maintenance frequency and all the associated long-term costs, environmental impacts and health hazards. Also, rapid cure systems can be of assistance, as they reduce shop costs through increased production rates and reduced downtime. To deeply conceive how much all these disruptions and shutdown time affect the cost, the below figure is self-explanatory:

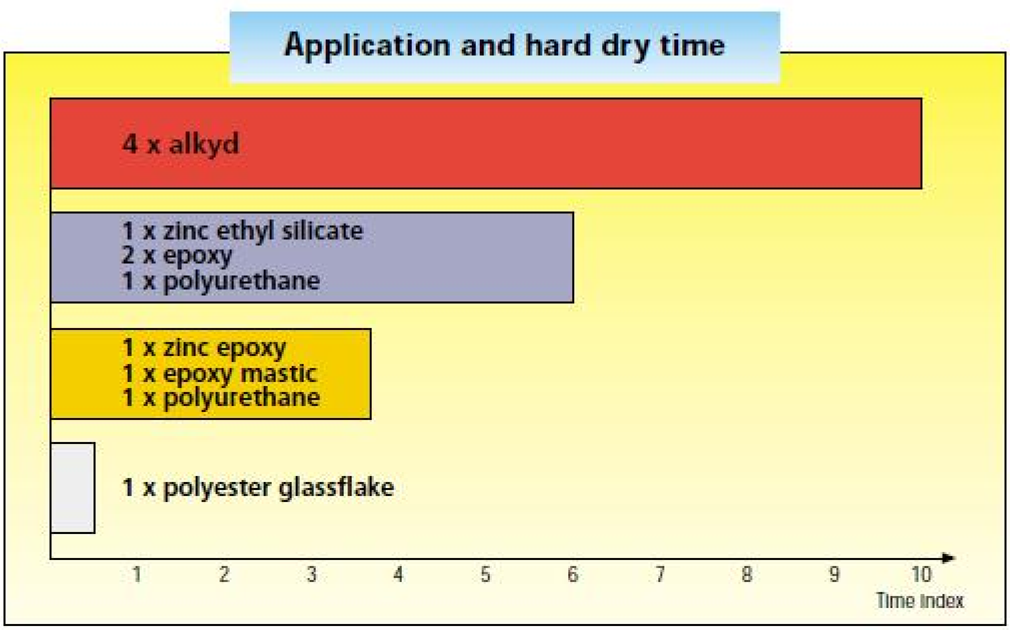


Figure 96: Application and hard dry time (Journal of Coatings Technology and Research, Sorensen, 2009)

10.3 Example of comparison of different systems

In the following paragraph three different systems, most commonly used in aggressive environments are examined as an example:

A. a four-coat system:
   - zinc silicate primer
   - tie coat
   - epoxy high build
   - polyurethane topcoat
B. a three-coat system:
   - zinc epoxy primer
   - epoxy mastic
   - polyurethane topcoat
C. a two-coat system
   - polyester glass flake

So, given the three systems above, the following cost comparison occurs:

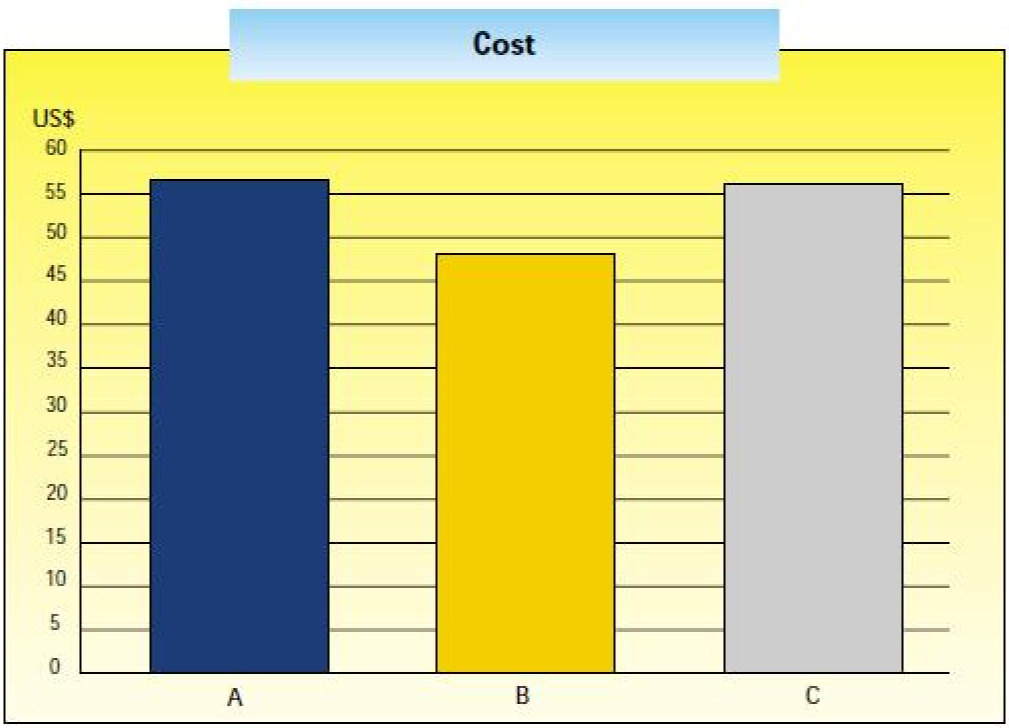


Figure 97: Cost Comparison made between the three above-mentioned systems (PST, Technical Records, 2019)

As it easily illustrated, the three-coat system is the least expensive between three compared, with its main difference being the transition from zinc silicate primer to zinc epoxy primer. But it should be underlined that the other two systems depict similarities, even though the system C seems to be more expensive due to its high-class material, it is compensated by the easier and quicker application of the coatings.

Since each system has different types of paints, different life spans can be expected for each case. To be more specific, based on information kindly provided by the Jotun Technical Department, there are indications for the following life expectancies:

A. 12 – 15 years
B. 8 – 10 years
C. 25 – 30 years

(It must be noted, however, that for different environments, which may or may not be harsher for a specific type of paint, life expectancies can vary

Now, based on information regarding breakdown development, a bi-annual maintenance frequency, and the level of costs in the Norwegian market, the following Life Cycle Cost diagram has been made:

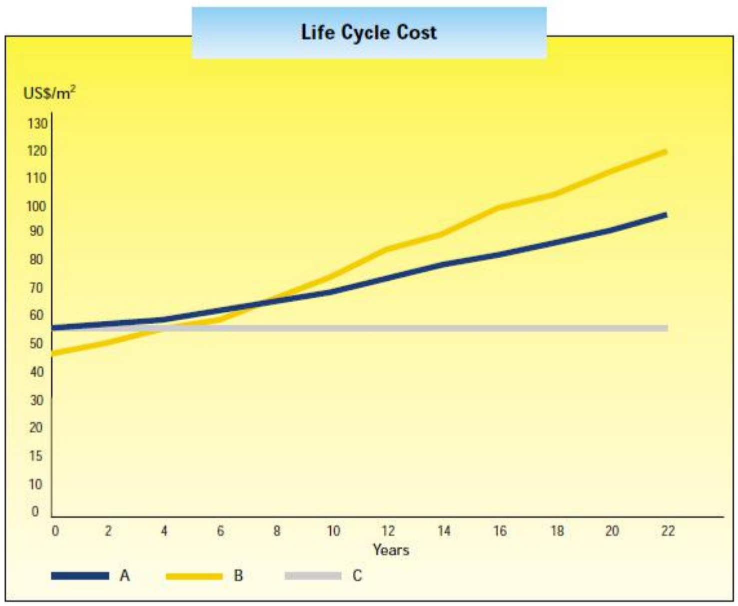


Figure 98: : Life Cycle Cost – Comparison of the three systems (PST, Technical Records, 2019)

This is a very distinctive example which shows that if one is relied only on one factor, in order to make a choice for the least costly one, it can be deceiving. Here, for instance, even though B was calculated as the cheapest of the three, it can be observed that after around 5 years, the costs exceed the others, whereas system C seems to have a more stable course.
As a conclusion, a company should follow a Life Cycle Cost evaluation. Even if this seems to add to the initial cost, it will provide far greater results in the long-term, especially when talking about such big investments.

10.4 Real costs taken from statistics

For a deeper comprehension of the financial sizes of the coating appliance and maintenance, information provided by PST, Product Shipping & Trading SA is listed below, along with some general conclusions.

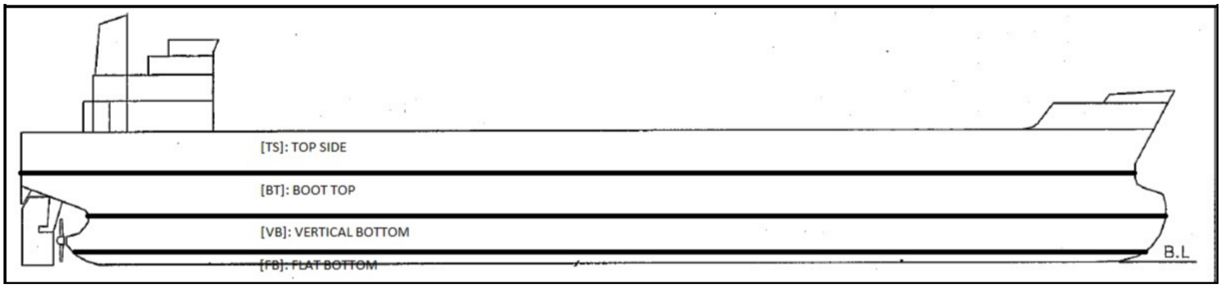


Figure 99: Schematic presentation of the parts the ship is divided into, for the current study (PST, Technical Records, 2019)

At this point of the presentation of the statistic results, the exact characteristics of the ships are not required. However, for informational purposes, and for a more general picture, the total area of each ship is presented. The most useful data that can be obtained from the table below are the percentages that refer to the estimated area of the respective section of the side shell that will be found affected by mechanical damaged and will need to be treated with Sa2.0 until bare steel (PST Product Shipping & Trading SA, 2019).

Table 11: Size of the ships in study (PST, Technical Records, 2019)

	Undine	**Twinkle Star**	**Northern Light**	**Ariel**	**Lorelei**	**Laima**
DWT	50.000	50.000	45.000	75.000	75.000	37.000
Total Area	11.310 m^2	11.305 m^2	11.513,5 m^2	15.300m^2	15.137,2 m^2	9.991,2 m^2

Therefore, based on the partition that is perceived in Figure 99, it is quite interesting to evaluate how much of each part contributes to the total area in treatment.

Table 12: Percentage contribution of each part of the ship to the total painting area (PST, Technical Records, 2019)

	Undine	**Twinkle Star**	**Northern Light**	**Ariel**	**Lorelei**	**Laima**
TS: Top Side	20%	20%	20%	20%	20%	10%
BT: Boot Top	60%	60%	60%	60%	60%	15%
VB: Vertical Bottom	30%	30%	30%	30%	30%	5%
FB: Flat Bottom	20%	20%	20%	20%	20%	5%

From above table, in the ships that were chosen to be studied, which are approximately the same DWT and have approximately the same area, the contributions are almost the same, whereas in Laima, the smallest ship of the fleet here, there are some differences on the percentage contribution of each part of the ship.

As far as paints' purchase is concerned, a thorough list was held regarding 2019. For instance, the below quantities and indicative costs refer to those of the Undine's treatment. The numbers 1, 2 and 3 in the columns refer to the paints as they can be seen in table 13.

Table 13: An extensive list of the different kinds of paints used for a 50K tanker vessel, named MT Undine (PST, Technical Records, 2019)

KIND	COLOR	1	2	3	4	5	TOTAL QTY
ACRYLICS	RED BROWN	140		120			260
	BLACK	60		40			100
	WHITE	60		80			140
	GREY						0
	YELLOW	40		20			60
	BLUE						0
	RED						0
	SIGNAL RED						0
	GREEN	60		40			100
	ORANGE						0
ALKYDS	RED PRIMER						0
	BLACK						0
	WHITE		60				60
	GREY		80				80
	YELLOW						0
	BLUE						0
	SIGNAL RED						0
	GREEN		60	80			140
	Machinery Green	40		60			100
	CREAM						0
EPOXIES	RED BROWN	120		100			220
	BLACK						0
	WHITE						0
	GREY	120		100			220
	YELLOW						0
	BLUE						0
	SIGNAL RED						0
	SIGNAL GREEN						0
	ORANGE						0
	GREY						0
HEAT RESISTANCE							0
ALUMINIUM			40				40
FRESH WATER TANKS							0
							0
THINNERS	ACRYLICS						0
	ALKYDS	60					60
	EPOXIES	60					60

Total not incl. thinners		760	240	640	0	0	1.640 1.520
						ACR	660
						ALK	380
						EPO	440

REQUISITION LIST					
No.	Description	Qty (ltrs)	COST	Port	
1	UND-C1-19004	760	$3.027,50	Amsterdam, 1/19	PhilaCoatings
2	UND-V1-19025	240	$931,00	Amsterdam, 1/19	PhilaCoatings
3	UND-V1-19075	640	$2.765,28	Gibraltar, 4/19	HEMPEL

Figure 100: Commercial Paints used for Undine during 2019 maintenance (PST, Technical Records, 2019)

The estimated cost for Udine was calculated during 2019 as follows:

- 49,32$ per day or
- 8.777,6$ for 6-months time

Respectively, an equivalent recording for Twinkle Star during 2019 was made:

Table 14: An extensive list of the different kinds of paints used for Twinkle Star (PST, Technical Records, 2019)

KIND	**COLOR**	**1**	**2**	**3**	**4**	**5**	**6**	**TOTAL QTY**
ACRYLICS	RED BROWN	160	100					260
	BLACK		20					20
	WHITE	100						100
	GREY							0
	YELLOW							0
	BLUE							0
	RED							0
	SIGNAL RED		20					20
	GREEN		40					40
	ORANGE							0
ALKYDS	RED BROWN							0
	BLACK							0
	WHITE	60						60
	GREY	80	20					100
	YELLOW							0
	BLUE							0
	RED							0
	MACH. GREEN		40					40
	ORANGE							0
	GREEN		60					60
EPOXIES	RED	100	80					180
	BLACK							0
	WHITE							0

	GREY	100	120					220
	YELLOW							0
	BLUE							0
	SIGNAL RED							0
	SIGNAL GREEN							0
	ORANGE							0
								0
HEAT RESISTANCE								0
ALUMINIUM								0
FRESH WATER TANKS								0
								0
THINNERS	ACRYLICS							0
	ALKYDS							0
	EPOXIES	60	60					120
Total		**660**	**560**	**0**	**0**	**0**		**1.220**
not incl. thinners								**1.100**
						ACR		440
						ALK		200
						EPO		400

The numbers 1 and 2 refer to the following:

REQUISITION LIST					
No.	Description	Qty (ltrs)	COST	Port	
1	TWINK-V1-19010	660	$3.763,48	New York, 1/19	Hempel
2	TWINK-V1-19057	560	$2.415,46	AMS, 3/4/19	Hempel

Figure 101: Commercial Paints used for MT Twinkle Star (Chemical / Tanker vessel, 50K) during 2019 for maintenance purposes. (PST, Technical Records, 2019)

The estimated cost for Twinkle Star was calculated during 2019 as follows:

- 68,49 $ per day or
- 12.328,2 $ for 6months time

Chapter 11 Conclusion

Coating in its entirety has been extensively presented throughout this thesis. All paints categories and types have been displayed in detail, as well as their fundamental properties, the chemistry involved, along with the necessity of surface preparation prior application commencement.

The coating system in general is of greater importance than people working in the shipping industry or associated with it, are sometimes led to believe.

To adopt and adapt to such a belief, paints must be treated as a living organism, not as solely a soulless means to an end, which in the ship industry is the good mainly external condition of the vessel. They are ever-changing, especially during the last years, when technology has taken huge leaps in the paint industry. As new methods are coming up every year, concerning the ways the paints are made and applied, it becomes easier to vastly improve the appearance of the ship and, most importantly, prevent the paint defects, as the evidence after each defect is thoroughly studied and solutions are found to avoid reoccurrence.

Nonetheless, all shipyards will need to modernize their paint facilities for meeting the Standards, something which will give them an opportunity to become stronger, if finally, the challenges of PSPC (mentioned in Chapter 8) could be met. For fulfilling that achievement, shipyards and builders also should get well prepared for reverting with accurate response on the 3 most imposed questions.

- When? – Commence Planning Now
- What? – Transform challenges into opportunities
- How? –Act quickly without delays

The response for a planning on questions of "what" and "how" could be given if below parameters are under consideration especially from the yard's side, at the building-up time of each vessel, when its lifetime is zero.

1. Planning of current orders of construction, production capacity and also technical capacity as concerns the inspectors, supervisors and painters availability.
2. Allocating the increase of man-hours
3. Upgrading and improving the yard's facilities for primer shops, blasting cells, painting cells and other related equipment.
4. Proper technical training and qualification for the inspectors and painters training
5. Better design from its initial stage and more regular management review
6. Preparing documentation for PSPC (Coating specification, QC procedure of coating work, Inspection procedure, Coating Technical Files)

To summarize all above points, as far as the people responsible and capable of these changes are concerned, a process should be followed, during which the main class surveyor's duties are to review relevant documents and monitor implementation of the coating inspection requirements. This should have as final outcome the formal verification that PSPC requirements have been met. In the case that class surveyor reports that the PSPC has not been satisfied, in accordance with his findings, a corrective action should be agreed between the builder, the Class Society and the paint inspection body. Otherwise, with mathematical accuracy within a certain time period a paint defect will occur and its dealing with will be more difficult while sailing and vessel in operation.

Coatings applied by a ship's crew or in repair yards will often have shorter useful lives than coatings applied at the new building stage. This is because the surface preparation and strict control of temperature and humidity conditions necessary for good results often are not obtained. However, semi-hard or other coating types have been especially developed for ships in operation, and they are intended for application on non-blast-cleaned surfaces.

Looming on the horizon paints technology will demand to reduce incidents with damages as feasible as this could be and increase paints lifetime itself. Also, to due world-wide demand, a “greener” vessel and an “environmentally friendly” application will be requested since shipping industry is leading to “green” as a choice for every equipment link with it, as evidence that planet respect is treated in order of priority comparing same with vessels’ incomes.

Last, but not least, having developed on the measures that should be taken, in order for the coating system to progress, another important aspect of this thesis should not be disregarded as an inferior one; It was a major goal from the start of writing that it would appeal to practically everyone who is interested in reading it, not only color experts and people who have experience with on-board maintenance, but people who would like to broaden their knowledge on such a topic and obtain as much as possible.

Appendix 1: Coating Condition on Water Ballast Tank

In accordance with the *Rules and Regulations for the Classification of Ships*[16], any damage, defect, breakdown or grounding at the coating, which could invalidate the conditions for which a class has been assigned, is to be reported to Class society in written and officially without delay.

Most of the classification societies have produced a list of "**Recognised Corrosion Control Coatings"** for tanks as an essential tool for their assessment of coating conditions. To obtain recognized status, the coating must have either:

(a) 2 years minimum satisfactory service experience,

(b) Satisfactory performance during specific laboratory tests carried out for not less than 1 year, or

(c) Passed recognized qualification tests

Similarly, a list of **Provisionally Recognized Corrosion Control Coatings** is produced and includes those coatings that are undergoing service experience qualification to obtain full recognition.

The List of **Maintenance Coatings** for salt water ballast tanks are located in relevant Chapters of classification society's rules and regulations. As an example, same are located in Chapter 5 of the Lloyd's Register "*List of Paints, Resins, Reinforcements and Associated Materials"*[16]. Laboratory test data is submitted by the manufacturer to support the application for recognition to 'make a case'. Not all the classification societies specify such tests. The maintenance coatings can usually be applied on surfaces that have not been prepared to the same quality as by abrasive blasting.

Some maintenance coatings are formulated around animal fats, lanolin etc. These are the **soft**, non-oxidizable type and, in according with "*Rules and Regulations for the Classification of Ships"*, and IACS regulations, are subject to examination at Annual Survey. Care is often needed with soft maintenance coatings when used in conjunction with cathodic protection due to saponification. Care is also required during inspections or surveys to avoid damage or removal of the soft maintenance coating. Application of soft coatings in ballast tanks by floatation is not permitted.

As soft Coating is considered a coating that remains soft so that it wears off at low mechanical impact or when touched. Often are based on oils (vegetable or petroleum) or lanolin (sheep wool grease). Application of soft coating generally does not allow relaxation of the extent of periodical hull survey requirements of ballast tanks.

Other maintenance coatings are deemed **semi-hard** and do not require annual survey such as the soft. These coatings may be based on bitumen, in combination with vinyl or vinyl tar, and other petroleum refining byproducts. There are also conversion coatings that react with pre-rusted surfaces. The main difficulty with conversion coatings is the specifying of the correct degree of rusting and guaranteeing the satisfactory removal of hard scale.

By definition, semi-hard coating is a coating that dries or converts in such a way that it stays flexible although hard enough to touch and walk upon. Application of semi-hard coating may, under certain conditions, allow relaxation of the extent of periodical hull survey requirements of ballast tanks.

Maintenance Coatings are given the following classifications:

Class 1: A coating that has proven corrosion protection for 3 years minimum.

Class 2: A coating that is undergoing a 3 year qualification period to obtain Class 1 status.

It is important to remember that ballast tanks with coatings in **POOR** condition, are repaired using Class 2 Maintenance coatings, and all **'soft'** coatings, will be subject to examination at Annual Survey.

Below is attached an indicative table for all coating conditions and their definition by figures measurements.

Table 8.1: Coating conditions and their definitions by figures measurements

Rating/Condition	**GOOD**	**FAIR**	**POOR**
Spot Rust	MINOR	**>20 %**	
Light Rust	MINOR		
Edges	**<20 %**	**>20 %**	
Weld			
Hard Scale	MINOR	**<10 %**	**>10 %**
General Breakdown	MINOR	**<20 %**	**>20 %**

What should be stressed at that point is that the lowest rating within any category shall govern the final rating.

A1.1 IMO Performance Standard for Protective Coatings (PSPC)

PSPC is issued as Resolution MSC.215(82) dated 8 Dec 2006
Design of a specification and coating system, with target service life of 15 years
Protective Coating System approval
Definition of inspection procedures
Production of a Coating Technical File (CTF)
Verification of compliance

- Coating manufacturer/yard to provide specification of the protective coating system that satisfies the basic coating system requirements of PSPC
- Owner, Builder, and Coating manufacturer to agree the Specification which meets PSPC requirements as a minimum and submit to the RO for approval
- RO shall verify the Technical data sheet and statement of compliance or TA cert
- Builder to apply the coatings in accordance with the verified Technical Data Sheet and its own verified procedures
- Builder/Coating manufacturer/Owner to agreed the inspection procedures and submit to RO for review.
- RO to monitor implementation of the coating inspection requirements
- Builder to meet national and local regulations of Health, Safety, Fire & Explosion
- Builder to create, provide, and maintain Coating Technical File (CTF)
- RO to review CTF when close to ship delivery

The specification should include following topics in details:

1. Technical Data Sheet containing data which meets PSPC Technical Requirements
2. Copy of Statement of Compliance or Type Approval Certificate
3. Steel preparation and coating application standards and procedures (e.g. number of coatings, application method, dry-to-recoat time, walk-on time, etc.)
4. Coating repairs standards and procedures
5. Inspection of surface preparation and coating process
6. Procedures for in-service maintenance and repair of coating system
7. Precautionary measures on Health, Safety, Fire and Environmental hazards

The first step of the Coating System design should take under serious consideration all the technical requirements as so to be in accordance with the IMO Performance Standards for Protective Coatings for Seawater Ballast Tanks (PSPC).

1. Coating System should be selected for 15 years of target useful coating life
2. Service conditions and planned maintenance to be considered following factors:
    - Whether location is relative to heated surfaces or affected from that
    - The frequency of ballasting and de-ballasting, which determine the requirement on the coating durability
    - Required service conditions
    - Required service cleanliness and dryness
    - Compatibility with supplementary cathodic systems (such as sacrificial anodes)
3. Coating type to be epoxy-based, multi coat, and light colour top coat
4. Two stripe coats and 2 spray coats
5. The NDFT (Nominal total Dry Film Thickness) to be not less than 320 μm with 90/10 rule (≥320 μm for ≥90% and ≥288 μm for ≤10%)

6. Surface Cleanliness and Blasting Profile
    - Sa 2½; profile between 30-75 μm
    - Relative humidity ≤85%
    - Steel surface temperature above dew point ≥3º C
7. Water Soluble Salt Limit ≤ 50 mg/m2 of sodium chloride
8. The initially used Shop primer has to be compatible with all the rest coatings and that is to be confirmed by coating manufacturer.

Figure 8.1.1: Measuring Dew Point with the help of PDS (PST, Photo Gallery, 2015)

Concerning the secondary surface preparation, the following should be taken under consideration and their completion is necessary prior proceeding to following steps of coatings application.

1. As far as the steel condition and its geometry are concerned:
    - No sharp edges – 2mm radius or 3 pass grinding
    - Grind weld beads
    - Removal of weld spatter and any kinds of surface contaminants
2. Surface Treatment
    - Damaged shop primer and welds, sand blasting (Sa 2½)
    - In case that shop primer did not pass pre-qualification test, then at a percentage of 70%, sand-blasting of Sa2 is needed.
    - Alternatively, if pre-qualification test is passed, then primer is to be cleaned by sweep blasting, high pressure water washing, or equivalent
3. Surface Treatment after erection
    - Butts – St 3 or better to Sa 2½ where practicable
    - At small noticed damages up to 2% of total area is applied St 3
    - In cases of contiguous damages with extended area over than 25 m2 or over 2% of total area, is applied Sa 2½
    - Coating in overlap to be feathered

For the purpose of deep comprehension of this Performance Standard, the following definitions should be applied.

1. **Dew point** is the temperature at which air is saturated with moisture (Figure 8.1.1). As a term, it was analysed more in above chapter.
2. **DFT** is an abbreviation of dry film thickness.
3. **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.
4. **Edge grinding** is the treatment of edge before secondary surface preparation (ssp).
5. **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.
6. **NDFT** is an abbreviation of 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.
7. **Primer coat** is the first coat of the coating system applied in the shipyard after shopprimer application.
8. **Shop-primer** is the pre-fabrication primer coating applied to steel plates, often in automatic plants and before the first coat of a coating system.
9. **Stripe coating** is painting of edges, welds, hard to reach areas, etc., to ensure good paint adhesion and proper paint thickness in critical areas.
10. **Target useful life** is the target value, in years, of the durability for which the coating system is designed.
11. **Technical Data Sheet** is paint manufacturers' Product Data Sheet which contains detailed technical instruction and information relevant to the coating and its proper application and maintenance.

Before proceeding to any kind of inspection at Dedicated Water Ballast Tanks in all kinds of ships and also double-side skin spaces of bulk carriers, below mentioned general principals should be followed and taken under consideration during the construction period of the ship.

- The ability of the coating system to reach its *target useful life* depends on the type of selected coating system, steel preparation, application and coating inspection and maintenance. All these aspects contribute to the good performance of the coating system.
- Inspection of surface preparation and coating processes shall be agreed upon, between the ship-owner, the shipyard and the coating manufacturer and presented to the Administration 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). The administration may entrust a recognized organization acting on its behalf to determine compliance with the provisions of this Standard.

- When considering the Performance Standard provided, the following is to be taken into account:
    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
    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.
    3. The coating performance standard 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 could be also provided.

A1.2 Coating Technical File

Specification of the coating system applied to the dedicated seawater ballast tanks and double-side skin spaces, record of the shipyard's and ship owner's coating work, detailed criteria for coating selection, job specifications, inspection, maintenance and repair shall be documented in the Coating Technical File (CTF), and the Coating Technical File shall be reviewed by the Administration. 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 (GURUVIAH, 1987; Hyundai CSAV , 2006):

- ✓ Copy of Statement of Compliance or Type Approval Certificate;

- ✓ Copy of Technical Data Sheet, including:
  product name and identification mark and/or number
  materials, components and composition of the coating system, colours
  minimum and maximum dry film thickness;
  application methods, tools and/or machines;
  condition of surface to be coated (de-rusting grade, cleanness, profile)
  environmental limitations (temperature and humidity)

- ✓ Shipyard work records of coating application, including:
  applied actual space and area (in square metres) of each compartment
  applied coating system
  time of coating, thickness, number of layers, etc.;
  ambient condition during coating; and
  method of surface preparation;

- ✓ Procedures for inspection and repair of coating system during ship construction;

- ✓ 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)

- ✓ Shipyard's verified inspection report, including:
  - completion date of inspection
  - result of inspection
  - remarks (if given) and
  - inspector signature

- ✓ Procedures for in-service maintenance and repair of coating system

Apart from the above, there are also three **basic coating requirements** for protective coating systems that are to be applied at ship construction for dedicated seawater ballast tanks of all ship types and double-side skin spaces arranged in bulkcarriers of 150 m in length and upwards. Those are:

- Coating manufacturers shall provide a specification of the protective coating the requirements as they are defined at below attached table.
- The Administration shall verify the Technical Data Sheet and Statement of Compliance or Type Approval Certificate for the protective coating system.
- The shipyard shall apply the protective coating in accordance with the verified Technical Data Sheet and its own verified application procedures.

At the first stage of "**Design of coating system**", what should be done in order of priority is the Selection of the coatingsystem, which shall be considered by all parties involved with respect to the service conditions and planned maintenance. The following aspects, among other things shall be taken into consideration:

1. The location of space relative to heated surfaces, due to humidity and moisture
2. The frequency of ballasting and de-ballasting operations, caused of the salinity
3. The required surface conditions,
4. The required surface cleanliness and dryness, and
5. The supplementary cathodic protections, if any (where coating is supplemented by cathodic protection, the coating shall be compatible with the cathodic protection system).

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 and updated in any case of repairing coating condition.

Additionally, 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.

Table 8.2.1: Basic Coating System Requirements (Coating Manual, Jotun, 2018)

1	Coating Type
2	Coating Pre-qualifications test
3	Job Specification
4	NDFT (Nominal Total Dry Film Thickness)

The selection of coating type should always define epoxy-based systems. In case of a multi-coat system, it is strongly recommended that each coat of colour is contracted and that also the top coat should be of a light colour in order to facilitate in-service inspection and easily recognized of possible break down.

As far as the second factor is concerned, all epoxy-based systems have to be tested prior to the date of entry into force, in a laboratory by a method corresponding to the test procedure as per Annex 1 or any other equivalent, which as 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. For all other systems, testing according to the procedure as defined in Annex 1, or equivalent, is required.

As regards the job specification, there shall be a minimum of two stripe coats and two spray coats, except that the second sprite 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 such reduction in scope of the second stripe coat shall be fully detailed in the CTF (Coating Technical File). All stripe coats shall be applied by brush or roller. Usually, roller is used for scallops and rat holes only.

Prior the application of the next coat, each main coating layer shall be appropriately cured, in accordance with coating manufacturer's recommendations. Surface contaminants such as rust, grease, dust, salt, oil 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 times of dry-to-recoat and the walk-on as they are given from the manufacturer.

Finally, as concerns the NDFT, it should be 320 μm with 90/10 rule for epoxy-based coatings and for all other systems in accordance to coating manufacturer's specifications. Also, maximum total dry film thickness is defined by the manufacturer's detailed specifications. At this point care shall be taken to avoid increasing the thickness in an exaggerated way. During application of the coating at each layer, wet film thickness should be regularly checked and reported at relevant report. Additionally, all kind of used thinners shall be limited to those types and quantities recommended by the manufacturer.
Upon completion of the first stage for the coating system design, if should be then contemplated the surface preparation, which consists of the primary stage and the second one as per below details.

A1.2.1 PSP (Primary surface preparation)

Blasting with Sa 2½ is required with profiles between 30-75 m^2**.** This shall not be carried out when:
1. Relative humidity is above 85%, or
2. Surface temperature of steel is less than 3°C above the dew point.

Additionally, 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. As regards the water-soluble salt limit equivalent to NaCl shall be less than 50 mg/m^2 of sodium chloride.
Finally, shop primer Zinc containing inhibitor free zinc silicate based or equivalent.

Their compatibility with main coating system shall be confirmed by the coating manufacturer in a timely manner and in written.

A1.2.2 SSP (Secondary surface preparation)

1. <u>Condition of steel</u>: 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 contaminants. 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.
Blasting of Sa 2½ shall be applied on damaged shop primer and welds.

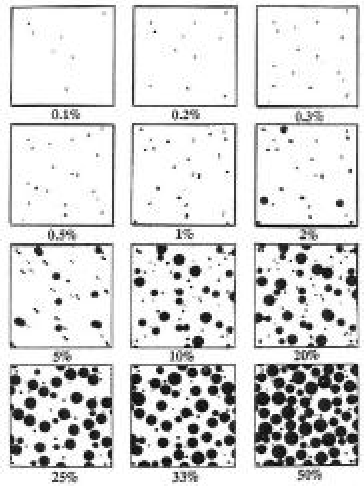


Figure 8.2.2.1: Assessment Scale for Breakdown

2. Treatment of surface: Sa 2 removing at least 70% of intact shop primer, which has not passed a prequalification certified by test procedures. If the complete coating system comprising epoxy-based main coating and shop primer has passed a pre-qualification certified by test procedures, 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. If a zinc silicate shop primer has passed the pre-qualification test as part of an epoxy coating system, it may be used in combination with other certified epoxy coatings, provided that the compatibility has been confirmed by the manufacturer by test.

3. Surface treatment after erection: Butts St 3 or better or Sa 2½ where practicable. Any kind of small damages up to 2% of total area should be blasting with St 3,but contiguous damages over 25 m2 or over 2% of the total area of the tank, have to be blasting with Sa 2½. Coating in overlap shall be feathered (Figure 8.2.2.1).

4. Profile Requirements: In case of full or partial blasting of 30-75 m^2 is required, otherwise as recommended by the coating manufacturer.

Dust, water soluble salts and oil contamination: 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. Of course, no oil contamination is acceptable and permitted. Regarding the water soluble salts after blasting and grinding the acceptable limit is below 50 mg/m2 of sodium chloride (Figure 8.2.2.2).

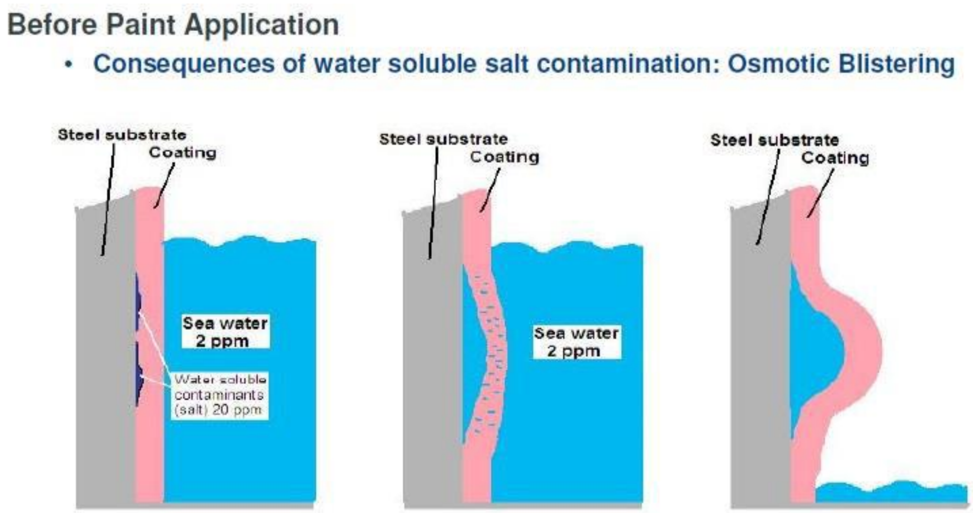


Figure 8.2.2.2: Water soluble salt contamination

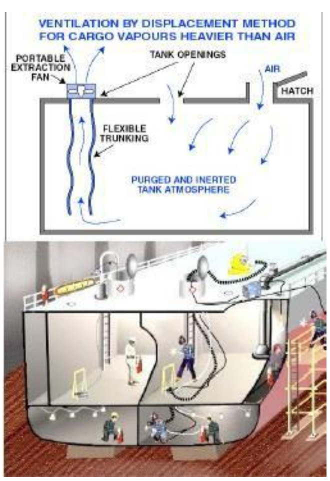
During all the above described stages should be also taken under consideration miscellaneous factors such as:

1. <u>Ventilation</u>: 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 (Figure 8.2.2.3).

<u>2. Environmental conditions</u>: 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:

- Relative humidity is above 85%, or
- Surface temperature is less than 3°C above the dew point

3. <u>Testing of coating</u>: 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.



5. **Figure 8.2.2.3:** Example of ventilation by displacement method

6.

4. <u>Repair</u>: 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 in a detailed reported and included at TCF.

A1.2.3 Coating Inspection Requirements

The main purpose of coating inspection is to ensure compliance with Standards, and thus this shall be carried out and verified by qualified coating inspectors certified to NACE Coating Inspector Level 2, FROSIO Inspector Level III or any other equivalent as verified by the Administration. The coating inspector shall inspect surface preparation and coating application during the coating process by carrying out, as a minimum, those inspection items identified to ensure compliance with Standards as per below attached table. 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. Results from the inspection shall be recorded by the inspector and shall be included in the CTF (Coating Technical File). In case that any coating inspection takes place during vessel's operation life, same along with all relevant details it has to be documented at daily log and also non-conformity reports. More details on coating inspection requirements is presented on Chapter 8.3

Construction Stage	Inspection Items	
Primary Surface Preparation (PSP)	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 as previously defined.
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 blocks 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/ cleaning and prior to the application of the first system's coat, the steel surface shall be tested for 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.
	5	DFT measurements shall be taken to prove that the coating has been applied to the thickness as it was specified and defined at specification.
Erection	1	Visual inspection for steel surface condition, surface preparation and verification of conformance to other requirements as above defined along with 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

A1.2.4 Verification Requirements

Prior the Coating Technical File (CTF) being reviewed, for the new building ship, the Administration should carry out the following for compliance to their Standard:

1. All used paints and kinds of coats Technical Data Sheet (TDS) and Statement of Compliance or Type Approval Certificate comply with Standards.
2. Coating identification on representative containers is consistent with the coating identified in the Technical Data Sheet and Statement of Compliance or Type Approval Certificate
3. The inspector is qualified in accordance with the qualification standards as they have been specified above.
4. 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
5. Implementation of the coating inspection requirements to be monitored.

As a vital footnote to all above subjects, it should be clarified that all systems that are not an epoxy-based system applied according to the above table of this Standard are defined as an alternative system. This Standard is based on recognized and commonly used coating systems. For being avoided any misunderstanding that not meant to exclude other, alternative, systems with proven equivalent performance, for example non epoxy-based systems. 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. 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 previous section, 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.

A1.3 Coating Inspection Requirements

As it has been mentioned already, for a coating inspection being carried out, as per requirements and mainly to be ensured compliance with Standards, this should be done by qualified coating inspectors, who should certified to (Figure 8.3.1):

- NACE Coating Inspector Level 2, or
- FROSIO Inspector Level III, or
- Equivalent as verified by the Administration(e.g. approved courses provided by coating manufacturer)

Figure 8.3.1: Most Required Inspectors' Qualifications

At this point, it should be underlined that only coating inspectors with at least 2 years relevant coating experience can write and/or authorise procedures or decide upon corrective actions to overcome non-compliances that may be possible imposed.

Additionally, for an explanation on the mean of equivalent as above mentioned for a coating inspector's qualification, as per class societies given definition, it is the successful completion, as determined by course tutor, of an approved course, such as internal courses run by the coating manufacturers or Shipyards. The course tutors shall be qualified with at least 2 years relevant experience as well and, of course, certified as per above standards. Upon inspection completion, relevant results should be recorded by the inspector be included in vessel's Coating Technical File (CTF). Always on board should be also completed a daily log and non-conformity report, if exists in case of coating problem, as per each company's Performance Maintenance System (PMS). Other equivalent formats of daily log or conformity reports are also acceptable, subject to include the following detailed comments:

- Applied method for surface preparation
- Surface and air temperature, as measured prior and after the method's application
- maximum relative humidity
- treatment of edges
- surface and capacity of repaired area

As concerns the Non-conformity reports, at those should be detailed reported the description of the inspection findings to be corrected, meaning the part of structure that damaged is observed, description of findings, reference documents and also action that are to be taken for its rectification.

At coating inspector's requirements, the Dry Film Thickness (DFT) measurements that should be taken as determined in Annex 3 are also included. Those are below described as per the categorization suggested by the IACS.

- Every 5 m of Flat Area is required 1 gauge reading

- Every 2 to 3 m interval at tank boundaries is also required 1 gauge reading, as close as possible to tank boundary, but not more than 15 mm from edge
- At every longitudinal and transverse members of ship one set of readings as shown below, taken at 2 to 3 m run and not less than 2 sets between primary support members
- At each set of primary support members should be taken 3 gauge readings
- At each set of other members are needed 2 gauge readings (as indicated by arrows)
- At all primary support members, such as girders and transverse, in required 1 set of gauge reading for 2 to 3 m run but not less than 3 sets.
- Around all kind of openings is needed 1 gauge reading from each side of the opening
- Per square metre (m2) is defined 5 gauge readings but not less than 3 readings for complex members (large brackets of primary support members)
- Finally at randomly selected points by coating inspector's consideration to check thickness

At this section, the role should also be defined either of the Flag Administration or the Class Society and their responsibilities. In general, those authorities have the right and are obliged to:

- Check Technical Data Sheet (TDS) for all the used paint products and Statement of Compliance (SoC) or Type Approval Certification (TA-Cert.) of the applied coating system
- Control and oversee coating ID on container as shown in TDS, SoC or TA-Cert
- Verify coating inspector's qualification as per Standards requirements
- Inspect inspector's report showing compliance with TDS, SoC or TA-Cert
- Monitor implementation of coating inspection, on a sampling basis for sections such as:
    1. Correct equipment
    2. Techniques
    3. Reporting methods
- In case of, final result found not complying with PSPC, then corrective action with appropriate and concerned parties should be agreed
- If corrective actions are not rectified within the imposed time period and of course prior vessel's delivery to owners, then relevant discussion with shipyard should be arranged
- All those corrective actions have to be dealt with prior to issuance of Class certificate
- At matter in hand should be also designated the role and the action's plan of the builder's side in contrast with the Class or Flag one, which comprises:
- Assessment of ship type and size for checking applicability of PSPC
- Arrangement of training for shipyard's QC in obtaining recognized inspector qualification
- Evaluation of own facilities for ensuring that requirements of PSPC can be complied with
- Taking PSPC requirements into account in the design state (e.g reducing scallops, using rolled profiles etc)
- Ensuring paint and coating system conformed to PSCP
- Esteem of addition work content for calculating contract price, construction period and delivery schedule
- Development of ship yard's standards on general coating procedures and inspection procedure in accordance with IMO PSPC

Summarizing the major impacts of the PSPC application on each concerned group, we could determine that the mainly affected parties are:

1. Ship Owners
2. New Construction yards
3. Paint manufacturers
4. Flag administrations or Class Societies

Every of each above party have different factors to take under consideration for the impact. The ship owners own to consider the influence of:

1. Vessel's price, since it is increased due to higher imposed Standards
2. Construction period, that is prolonged caused of regular inspection requirements and possible needed rectified actions
3. Less tank maintenance and related downtime in service

As per a survey carried out by the Class Society of Lloyd's Register, it was indicated that IMO PSPC application on ships, is beneficial to ship owners despite the higher cost and the dispensaries construction period. Same is illustrated at the below attached table, where the percentages of two cases are shown. The first one is the benefit overweight cost and the second one for higher specification than IMO PSPC.

The secondly mainly affected party of IMO PSPC is the paint manufacturers, who should:

1. Ensure that their applied products are in compliance with the IMO PSPC
2. Provide more technical assistance and support to the ship yards
3. Train adequately more inspectors and advisers for a smooth and in timely manner coating system application.

The ship yards, are the third mainly concerned party of the IMO PSPC impact.
That could be summarized as per below:

1. Vessel production cost, that is enough increased
2. Construction period, that is considerable prolonged
3. Ship production at yards where capacity is fully utilized would decrease
4. Man hours for paint work would increase and thus an increase is also noticed at relevant cost for coating system's application.
5. Ship yards could need to upgrade or extend coating facilities, either with relevant and approved equipment or with certified coating techniques/ applicators
6. Need for additional coating inspectors
7. Need for training of coating inspectors and applicators
8. Shipbuilding industry could consolidate or share common paint facilities

.

In reference with the class cost's to implement PSPC verification, there are 2 cost elements associated with class work:

• Initial approval and ongoing auditing of the yard processes.
• Verification of PSPC on each vessel. Dependant on vessel type and size and configuration but for the first vessels expected to range from US$5000 to US$20,000 per vessel, always depends on the Class Society.

Additionally at the most commonly posted question, whether the PSPC will result in an unscheduled delay in the production process, the answer consists of 3 different options:

• PSPC is a standard which must be met and therefore a risk does exist for corrective actions to be raised.
• To minimise the number of corrective actions, current production processes and facilities should be reviewed and upgraded if deemed necessary according to the new standard's requirements.
• Once any necessary facility upgrades have been completed and the production processes have been successfully implemented the risk of PSPC delaying the production process is no greater than exists with any other element of the vessel's construction.

The guidelines were first issued in 1992 as an advisory document for voluntary use. After its maiden issuance, they were amended in 1994 and 1996. There are defined three target durability levels for coatings: approximately 5, 10, and 15 years, with emphasis on the coating applied on water ballast tanks and cargo tanks. Same has been made based on the Dry/Docks periodicity during vessel's lifetime, which is on/about every 5 operational years' completion.

More or less parallel with the development of the IACS unified requirements,1-3 similar although less specific advisory documents on corrosion protection were issued by most classification societies.

A1.4 Coating Performance Standards

A1.4.1 ABS: Guide for the Class Notation

Below is attached the Coating Performance Standard (July 2010 version), as provided by the American Bureau of Shipping, so as the reader becomes more familiar with subjects surrounding the regulations and standards on coatings (American Bureau of Shipping, 2010).

This Guide has been developed with the objective of promoting the effective use of Type Approved protective coatings on ABS-classed vessels. The requirements as 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 as listed in 1.3 below may be assigned a class notation CPS, Coating Performance Standard.

In order to get a better understanding, the following abbreviations are used through this Guide:

CPS: Coating Performance Standard notation or general reference to this Guide.
CSR: Common Structural Rules, see ABS *Rules for Building and Classing Steel Vessels*, Part 5A (Double Hull Oil Tankers) and Part 5B (Bulk Carriers).
CTF: Coating Technical File
IACS: International Association of Classification Societies
IACS PR34: IACS Procedural Requirement No. 34
IACS UR Z17: IACS Procedural Requirements for Service Suppliers
IMO PSPC: IMO Resolution MSC.215(82) – Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks in All Types of Ships and Double Side Spaces of Bulk Carriers

It is a prerequisite for receiving the class notation **CPS** that the applicable requirements of the following are fully complied with:

i) SOLAS Regulation Chapter II-1/3-2, Consolidated Edition 2004, amended by IMO Resolution MSC.216(82)

ii) 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 (IMO PSPC)

iii) IACS PR 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

iv) IACS UI SC223, IACS Unified Interpretation For Application of SOLAS Regulation II-1/3-2 Performance Standard for Protective Coatings(PSPC) for Dedicated Seawater Ballast Tanks in All Types of Ships and Double-side Skin Spaces of Bulk Carriers, adopted by Resolution MSC.215(82) to vessels other than CSR for Bulk Carriers and Oil Tankers

v) IACS UR Z17, IACS Procedural Requirements for Service Suppliers

vi) IACS Common Structural Rules for Bulk Carriers and Oil Tankers (see ABS *Steel Vessel Rules* Part 5B and Part 5A)

In those instances, where the flag Administration has specific mandatory national regulations regarding coating protection, documentation confirming compliance with these regulations is to be submitted and considered to be fundamental to the **CPS** notation.

Effective Date

- SOLAS II-1/3-2 Application

  These reviews check for compliance with the requirements of Protective Coatings for Dedicated Seawater Ballast Tanks as driven by SOLAS II-1, A-1/3-2 adopted by the IMO Resolution MSC.215(82) (hereinafter called "IMO PSPC"), as interpreted by IACS UI SC223 together with any special instructions that may have been issued by the flag Administration. Compliance with the Performance Standard of the IMO PSPC is mandatory for all ships 500 gross tonnage and above for all dedicated seawater ballast tanks arranged in all ships and double-side skin spaces arranged in bulk carriers of 150 meters in length and upwards for which:

  - The building contract is placed on or after 1 July 2008; or
  - 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
  - Regardless of the applicability of the above two criteria, the delivery of which is on or after 1 July 2012.

  This process begins upon receipt of plans and data from a client requesting ABS issuance of a Cargo Ship Safety Construction Certificate, which may be confirmed on the request for ABS classification. It ends with the return of plans to the client, stamped appropriately to indicate ABS review in accordance with this guide.

- CSR Vessel Application

  These reviews check for compliance with the IACS Common Structural Rules (CSR) which mandates compliance with the IMO PSPC for new CSR vessels contracted on or after 8 December 2006, as interpreted by IACS PR34. The standard is applicable to:

  - All dedicated seawater ballast tanks arranged in Oil Tankers of 150 meters in length or greater; and
  - All dedicated seawater ballast tanks arranged in Bulk Carriers of 90 meters in length or greater; and
  - Double-side skin void spaces arranged in Bulk Carriers of 150 meters in length and upwards.

Notes:

- Coating Scheme in Seawater Ballast Tanks and Manufacturer's Technical Product Data for oil tankers and bulk carriers 500 GT constructed between 1 July 1998 and 1 July 2008 should be guided by the coating scheme already approved under the IMO Res. A 798 (19) and IACS UI SC122.
- As interpreted by IACS UI SC227, the following tanks are not considered to be dedicated seawater ballast tanks and are therefore exempt from the application and requirement of the IMO PSPC:
  - Ballast tank identified as "Spaces included in Net Tonnage" in the 1969 ITC Certificate; and
  - Sea water ballast tanks in passenger vessels also designated for the carriage of grey water.

Process

The general coating process typically follows a process flow as shown in Figure 1. Each of the major coating steps is 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 Procedural Requirement No. 34 are also indicated along with cross reference to the applicable section within the IMO PSPC. Unified interpretations of IMO PSPC from IACS UI SC223 refer to the same section as the IMO PSPC reference.

The IMO PSPC also includes requirements for pre-qualifying IMO PSPC coating systems. The general process flow for pre-qualifying coatings is shown in Figure 8.4.1.1 below:

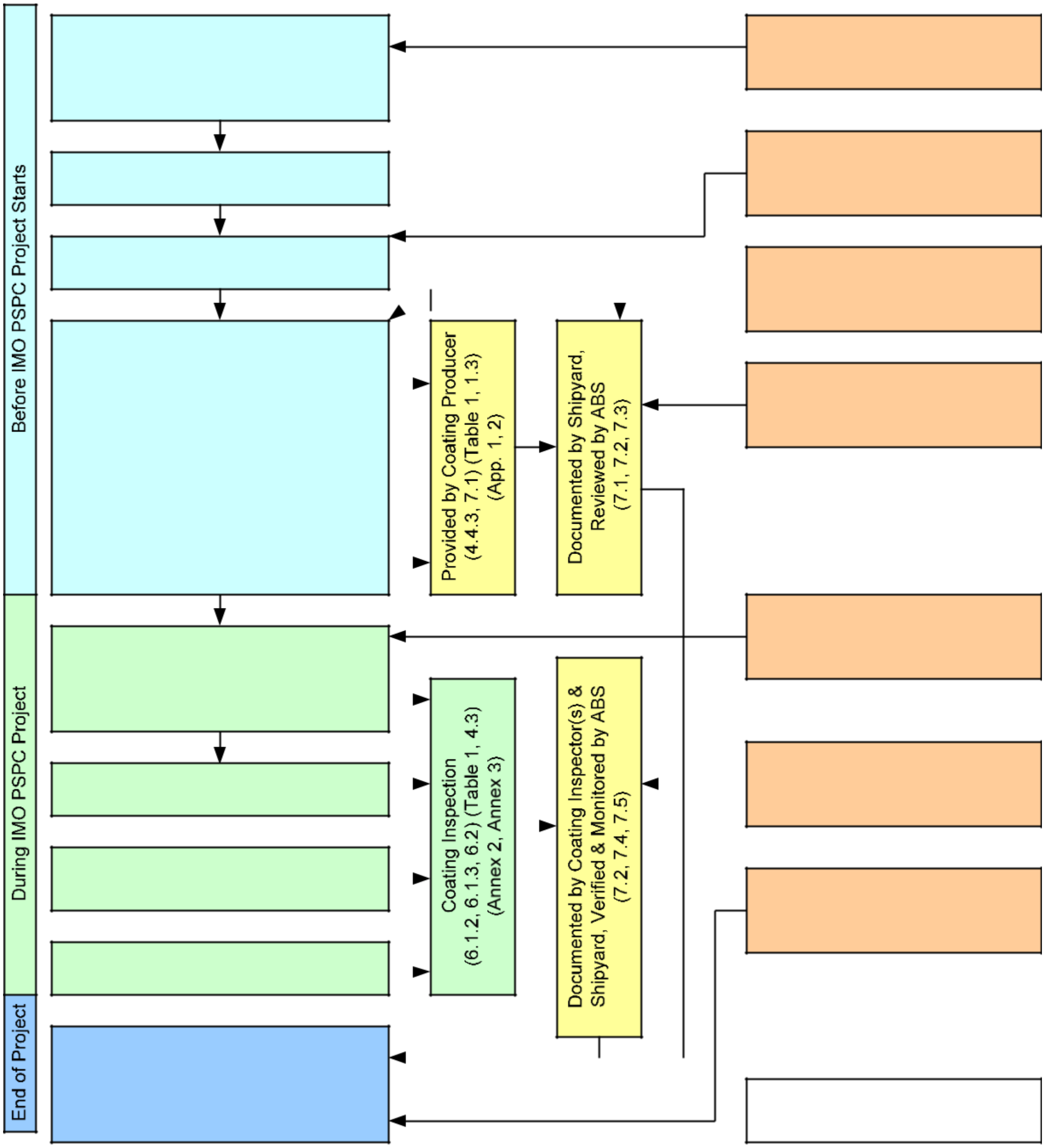


Figure 8.4.1.1: Process Flow

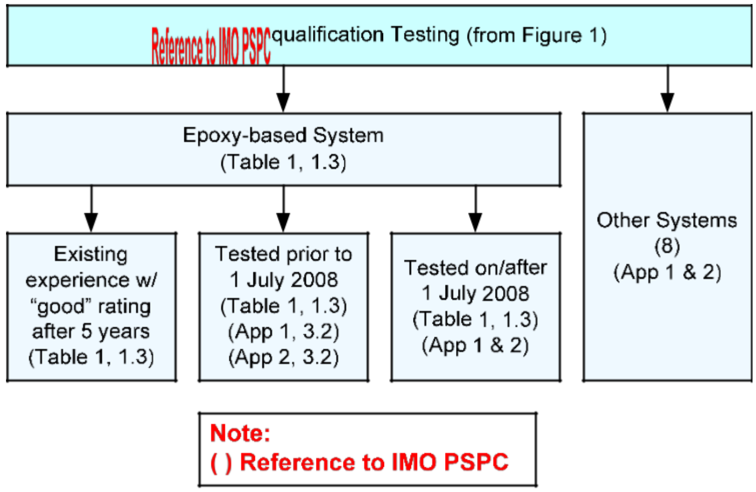


Figure 8.4.1.2: Coating Pre-qualification Testing Flow

Detailed Instructions

Coating Process

Detailed instructions for each of the major steps shown in Figures are provided in this section.

- Coating Inspection Agreement

The inspection procedure of surface preparation and coating processes is to be agreed upon between the ship owner, shipyard, and coating manufacturer and shall be presented to an ABS Technical Office for review prior to commencement of any coating work on any stage of a new building and, as a minimum, shall comply with the PSPC. ABS may, if it so determines, participate in the agreement process. The agreement, also called as Tripartite Agreement, is to be included in The Coating Technical File (CTF). See IMO PSPC 3.2 and IACS PR34, Section 3.

The specification is to be in accordance with all the requirements of IMO PSPC Table 1. The specification, as defined in IMO PSPC paragraph 2 of Annex 1, is to contain the type of coating system, steel preparation, surface preparation, surface cleanliness, environmental conditions, application procedure, acceptance criteria and inspection criteria.

- Selection of Areas to be Coated

The IMO PSPC is applicable for protective coatings in dedicated seawater ballast tanks of all types of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers per Section 1.4 above.

Together with the Tripartite Agreement submitted, the shipyard is to prepare and submit a list of all spaces to be coated in accordance with the IMO PSPC Sections 1, 4.2, and 4.3 to an ABS Technical Office for review. The final list is to be included in the CTF per Section 4.1.1 below.

- Qualifications of Coating Inspector(s)

The qualifications of the coating inspector(s) are to comply with the requirements in the IMO PSPC 6.1.1. Coating inspector qualification, requirements for assisstant inspectors, and equivalent qualification of coating inspectors are clarified in IACS PR34 section 2.

- Selection of Coatings

  The selection of coatings is to be made taking into account the expected service conditions and intended planned maintenance program that should provide a target useful coating life of 15 years in “GOOD” condition in accordance with IMO PSPC section 4.1. The selected coatings are to be listed and cross referenced to the spaces to be coated as per 3.1.2 above. See IMO PSPC Table 1, 1.1.

  The selected coating system shall be Type Approved (per 3.1.5 below) for compliance with IMO PSPC 5, by a pre-qualification test as illustrated in Figure 2. See IMO PSPC Table 1, 1.3, and IACS PR34 Section 1.

- Type Approval Certificate

  A “Type Approval Certificate” which signifies that one of the options as illustrated in Figure 2 has been satisfied is to be obtained for each coating system selected. See IMO PSPC Section 4.4.3 and 5.

  The coating manufacturer is to provide copies of the Type Approval Certificate for each coating system to be used in accordance with the IMO PSPC to the shipyard for inclusion into the CTF per Section 4.1.1 below.

- Technical Data Sheet

  Each selected coating is also to be documented by a “Technical Data Sheet” and its own verified application procedures which list technical information necessary to properly identify the coating product and application requirements. See IMO PSPC Sections 3.4.2.2, 4.4.4, and Table 1, 1.1.

  The coating manufacturer is to provide copies of the Technical Data Sheets for each coating system to be used to the shipyard for inclusion into the CTF per Section 4.1.1 below.

- Primary Surface Preparation

  The primary surface preparation is to comply with IMO PSPC Table 1, 2.1 and 2.2.

  The yard is to carry out the primary surface preparation and retain work records or other documentation as confirmation of the preparation treatment. Coating inspector(s) shall carry out inspections and document their confirmation that the primary surface preparation is within the standard. The documents are to be included in the CTF per Section 4.1.1 below.

- Shop Primer Application

  The shop primer is to be applied in compliance with the IMO PSPC Table 1, 2.3. See IACS PR 34 section 6 for review of Quality Control of Automated Shop Primer plants and section 7.3 for common interpretations concerning shop primer.

  The yard is to apply the shop primer and retain work records or documentation. Coating inspector(s) shall carry out inspections and document that the shop primer application is within the standard and compatible with the selected coating to be applied. The documents are to be included in the CTF per Section 4.1.1 below.

- Secondary Surface Preparation

  The secondary surface preparation is to comply with IMO PSPC Table 1, 3.

  The yard is to carry out the secondary surface preparation and retain work records or other documentation as confirmation of the surface preparation. Coating inspector(s) shall carry out inspections and document their confirmation that the secondary surface preparation is within the standard. The documents are to be included in the CTF per Section 4.1.1 below.

- Protective Coating Application

  The protective coating is to be applied in compliance with IMO PSPC Table 1, 1.4 and 1.5. The application conditions from IMO PSPC Table 1, 4.1 and 4.2 are to be followed. Inspection of the coating is to be performed as per Section 3.1.11 below.

  The yard is to apply the coatings and retain work records or documentation. Coating inspector(s) shall carry out inspections and document that the coating application is within the standard. The documents are to be included in the CTF per Section 4.1.1 below.

- Coating Inspection

  The coating is to be inspected at various stages of surface preparation and application to verify and document that the surface preparation and the coating application are within the standard as per IMO PSPC Section 6.1.2.

  The coating inspectors are to document the results from the inspections per IMO PSPC Section 6.1.3, Annex 2 and Annex 3. The documents are to be included in the CTF per Section 4.1.1 below.

- Coating Repair

  Any defective areas of the coatings are to be repaired per IMO PSPC Table 1, 4.4. The coating inspectors are to document the results from the inspections of the repaired areas per IMO PSPC Section 6.1.3 and Annex 2. The documents are to be included in the CTF per Section 4.1.1 below.

- CTF Documentation and Review

  The IMO PSPC mandates that each step in the coating process is performed strictly in accordance with the specifications and properly documented. The Coating Inspection Agreement, called the Tripartite Agreement, is to be documented and reviewed prior to the performance of the actual work. Daily log and non-conformity reports for the inspection items listed in IMO PSPC Section
  6.2 are required to illustrate the conditions and inspection results of the actual work carried out. The assembly and submission of all documents called the Coating Technical File (CTF) is the overall responsibility of the shipyard as per IMO PSPC Section 3.4 and Section 4 of this Guide below. The final CTF file is to be submitted to the attending ABS surveyor for review.

Verification Procedure

The basic verification procedure is included in IMO PSPC Section 7. The following information shall be verified by ABS prior to reviewing the CTF in support of the **CPS** notation.

- Technical Data Sheet, Type Approval Certificate

  Verify the Technical Data Sheet and Type Approval Certificates for compliance with the IMO PSPC Section 5 and IACS PR34 Section 1.

- Coating Identification

  The attending ABS Surveyor shall verify that the coating identification on representative containers is the coating identified in the Technical Data Sheet and Type Approval Certificate.

- Coating Inspector Qualification

  The attending ABS Surveyor shall verify that the coating inspector(s) and assistant inspector(s) are qualified in accordance with the qualification standards in IMO PSPC Section 6.1.1 and in IACS PR34 Section 2.

- Coating Inspector's Reports

  The attending ABS Surveyor shall verify that the coating inspector's reports of surface preparation and the coatings' application indicate compliance with the manufacturers' Technical Data Sheet, Type Approval
  Certificate and coating specification agreed in the tripartite agreement.

- Implementation of Coating Inspection Requirements

  The attending ABS Surveyor shall monitor implementation of the coating inspection requirements, see IMO PSPC Section 7.5 and IACS PR34 Section 4.

Maintenance, Repair, and Partial Re-coating

The coatings are to be maintained in accordance with IMO PSPC Section 3.4.3 and 3.4.4. The relevant sections of the IMO Guidelines for coating maintenance and repair are to be applied. It is noted that these IMO Guidelines are to be developed by IMO at a future date.

Records of maintenance, repair, and partial re-coating are to be documented in the CTF, which is to be kept on board and maintained throughout the life of the ship in accordance with IMO PSPC Section 3.4.5.

Documentation

Required Specific Certification and Documentation

The following documentation and certification are required in order to receive and maintain the **CPS** notation:

- Coating Technical File (CTF)

As mentioned above, the preparation and continuous update of the CTF and the existence of the CTF endorsed by qualified coating inspector(s) onboard the vessel are the basis for the **CPS** notation. The CTF is to include the information listed in IMO PSPC Sections 3.4.2, 3.4.3, and 3.4.4, and in IACS PR34 Section 5. The CTF is to be available for reference by the Surveyor during new construction and during class surveys after construction. See IMO PSPC 3.4.5.

Assembly of Information and Retention

- New Construction Phase

The CTF is to be initiated prior to commencement of any coating work and continuously updated by the shipbuilder or their representative qualified coating inspector(s) throughout the construction phase. The CTF is to be endorsed by qualified coating inspector(s) and is to be placed onboard the vessel upon delivery of the vessel. See IMO PSPC Sections 3.4.2 and 3.4.5

- In-service Phase

The CTF is to be retained onboard and continuously updated to reflect any coating work by the shipowner or their representative qualified coating inspector(s) throughout the vessel's life for the Surveyor's verification, as necessary, at the class surveys after construction. See IMO PSPC Sections 3.4.3, 3.4.4 and 3.4.5.

Certification of Coating Systems

General

There are three different methodologies for the coating manufacturer to apply for approval of its coating system, namely, laboratory testing for new coating system, five years of field exposure for existing coating system, or existing Marintek B1 test reported prior to 8 December 2006. Additionally, the coating manufacturer is to comply with sections of the procedural requirements for service suppliers as per IACS UR Z17 and IACS PR34 Section 1 Method D. The three methodologies have been clarified in IACS PR34 Section 1.

Existing Epoxy Coating Systems

- 5 Year Field Test

As indicated in IMO PSPC Table 1, 1.3, existing epoxy coating systems may be applied to provide protection against corrosion provided they have documented field exposure for at least five (5) years with a final coating condition of not less than "GOOD". An ABS Technical Office is to review the particulars related to an existing epoxy system and, if found satisfactory, may issue a Product Design Assessment (PDA) Certificate indicating adherence to the standard. See IACS PR34 "Method B".

- Marintek B1 Approvals

Epoxy coating systems with existing satisfactory Marintek B1 test reported prior to 8 December 2006 may be applied to provide protection against corrosion. An ABS Technical Office is to review the particulars related to an existing epoxy system and, if found satisfactory, may issue a Product Design Assessment (PDA) Certificate indicating adherence to the standard. See IACS PR34 "Method C".

New Epoxy Coating Systems

As indicated in IMO PSPC Table 1, 1.3 and Table 1, 3.2 ("Crossover Test"), new epoxy coating systems may be applied to provide protection against corrosion provided that they have been tested and documented in accordance with the procedures detailed in IMO PSPC Annex 1.

An ABS Technical Office is to review the particulars related to the testing of the epoxy system and, if found satisfactory, may issue a Product Design Assessment (PDA) Certificate indicating adherence to the standard. It is noted in IMO PSPC Annex 1, 3.2 that, if the testing is performed prior to the entry into force of the standard, only the criteria for blistering and rust needs to be satisfied. After the entry into force all aspects of the test need to be satisfied. See IACS PR34 “Method A”.

Alternative Systems

Alternative systems may be certified in accordance with IMO PSPC Section 8. An ABS Technical Office will review the particulars related to the testing of the alternative system (IMO PSPC Annex 1, Appendix 1 Section 3 and Appendix 2 Section 3) and, if found satisfactory, may issue a Product Design Assessment (PDA) Certificate indicating adherence to the standard.

Certification

Certification of a coating system may be made by issuance of a Type Approval Certificate.

Upon satisfactory review of the particulars related to the testing of the coating system as indicated in 5.2, 5.3, or 5.4 above, and the details of the ABS Type Approval Program specified in 1-1-4/7.7 and Appendix 1-1-A3 of the ABS *Rules for Conditions of Classification (Part 1)*, if found satisfactory, ABS may issue a Type Approval Certificate after ABS survey auditing to coating manufacturer.

Survey After Construction

In order to retain the **CPS** notation, all annual, intermediate, and renewal or periodic surveys, as applicable for the various documents listed in 1.3 above, are to be satisfactorily completed. At each periodical survey, the attending Surveyor is to verify:

i) That certification and documentation is onboard as outlined in 4.2 above.

ii) That approved operational procedures as outlined in 3.3 above are maintained onboard.

iii) That at the time of the corresponding periodical survey (Annual, Intermediate, or Renewal), any maintenance or repair of coating that have been carried out are properly documented, as per above paragraph 3.3.

A1.4.2 Bureau Veritas: Coating Performance Standard

In this subchapter, the Bureau Veritas Coating Performance Standard is provided, following the exact chapter division and formulation it has in the formal papers (Bureau Veritas, 2018).

MARINE & OFFSHORE DIVISION GENERAL CONDITIONS

ARTICLE 1

1.1. - BUREAU VERITAS is a Society the purpose of whose Marine & Offshore Division (the "Society") is the classification (" Classification ") of any ship or vessel or offshore unit or structure of any type or part of it or system therein collectively hereinafter referred to as a "Unit" whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submarines, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

The Society:

- "prepares and publishes Rules for classification, Guidance Notes and other documents (" Rules ");
- "issues Certificates, Attestations and Reports following its interventions (" Certificates ");
- "publishes Registers.

1.2. - The Society also participates in the application of National and International Regulations or Standards, in particular by delegation from different Governments. Those activities are hereafter collectively referred to as " Certification ".

1.3. - The Society can also provide services related to Classification and Certification such as ship and company safety management certification; ship and port security certification, training activities; all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board.

1.4. - The interventions mentioned in 1.1., 1.2. and 1.3. are referred to as " Services ". The party and/or its representative requesting the services is hereinafter referred to as the " Client ". **The Services are pre- pared and carried out on the assumption that the Clients are aware of the International Maritime and/or Offshore Industry (the "Industry") practices.**

1.5. - The Society is neither and may not be considered as an Underwriter, Broker in ship's sale or chartering, Expert in Unit's valuation, Consulting Engineer, Controller, Naval Architect, Manufacturer, Ship- builder, Repair yard, Charterer or Shipowner who are not relieved of any of their expressed or implied obligations by the interventions of the Society.

ARTICLE 2

2.1. - Classification is the appraisement given by the Society for its Client, at a certain date, following surveys by its Surveyors along the lines specified in Articles 3 and 4 thereafter on the level of compliance of a Unit to its Rules or part of them. This appraisement is represented by a class entered on the Certificates and periodically transcribed in the Society's Register.

2.2. - Certification is carried out by the Society along the same lines as set out in Articles 3 and 4 hereafter and with reference to the applicable National and International Regulations or Standards.

2.3. - **It is incumbent upon the Client to maintain the condition of the Unit after surveys, to present the Unit for surveys and to inform the Society without delay of circumstances which may affect the given appraisement or cause to modify its scope.**

2.4. - The Client is to give to the Society all access and information necessary for the safe and efficient performance of the requested Services. The Client is the sole responsible for the conditions of presentation of the Unit for tests, trials and surveys and the conditions under which tests and trials are carried out.

ARTICLE 3

3.1. - **The Rules, procedures and instructions of the Society take into account at the date of their preparation the state of currently available and proven technical knowledge of the Industry. They are a collection of minimum requirements but not a standard or a code of construction neither a guide for maintenance, a safety handbook or a guide of professional practices, all of which are assumed to be known in detail and carefully followed at all times by the Client.**

Committees consisting of personalities from the Industry contribute to the development of those documents.

3.2. - **The Society only is qualified to apply its Rules and to interpret them. Any reference to them has no effect unless it involves the Society's intervention.**

3.3. - The Services of the Society are carried out by professional Surveyors according to the applicable Rules and to the Code of Ethics of the Society. Surveyors have authority to decide locally on matters related to classification and certification of the Units, unless the Rules provide otherwise.

3.4. - **The operations of the Society in providing its Services are exclusively conducted by way of random inspections and do not in any circumstances involve monitoring or exhaustive verification.**

ARTICLE 4

4.1.1. - The Society, acting by reference to its Rules:

- "reviews the construction arrangements of the Units as shown on the documents presented by the Client;
- "conducts surveys at the place of their construction;
- "classes Units and enters their class in its Register;
- "surveys periodically the Units in service to note that the requirements for the maintenance of class are met.

The Client is to inform the Society without delay of circumstances which may cause the date or the extent of the surveys to be changed.

ARTICLE 5

5.1. **-The Society acts as a provider of services. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty.**

5.2. - **The certificates issued by the Society pursuant to 5.1. here above are a statement on the level of compliance of the Unit to its Rules or to the documents of reference for the Services provided for.**

In particular, the Society does not engage in any work relating to the design, building, production or repair checks, neither in the operation of the Units or in their trade, neither in any advisory services, and cannot be held liable on those accounts. Its certificates cannot be construed as an implied or express warranty of safety, fitness for the purpose, seaworthiness of the Unit or of its value for sale, insurance or chartering.

5.3. - **The Society does not declare the acceptance or commissioning of a Unit, nor of its construction in conformity with its design, that being the exclusive responsibility of its owner or builder.**

5.4. - The Services of the Society cannot create any obligation bearing on the Society or constitute any warranty of proper operation, beyond any representation set forth in the Rules, of any Unit, equipment or machinery, computer software of any sort or other comparable concepts that has been subject to any sur- vey by the Society.

ARTICLE 6

6.1. - The Society accepts no responsibility for the use of information related to its Services which was not provided for the purpose by the Society or with its assistance.

6.2. - **If the Services of the Society or their omission cause to the Client a damage which is proved to be the direct and reasonably foreseeable consequence of an error or omission of the Society, its liability towards the Client is limited to ten times the amount of fee paid for the Service having caused the damage, provided however that this limit shall be subject to a minimum of eight thou- sand (8,000) Euro, and to a maximum which is the greater of eight hundred thousand (800,000) Euro and one and a half times the above mentioned fee. These limits apply regardless of fault including breach of contract, breach of warranty, tort, strict liability, breach of statute, etc.**

The Society bears no liability for indirect or consequential loss whether arising naturally or not as a consequence of the Services or their omission such as loss of revenue, loss of profit, loss of production, loss relative to other contracts and indemnities for termination of other agreements.

6.3. - All claims are to be presented to the Society in writing within three months of the date when the Services were supplied or (if later) the date when the events which are relied on of were first known to the Client, and any claim which is not so presented shall be deemed waived and absolutely barred. Time is to be interrupted thereafter with the same periodicity.

ARTICLE 7

7.1. - Requests for Services are to be in writing.

7.2. **- Either the Client or the Society can terminate as of right the requested Services after giving the other party thirty days' written notice, for convenience, and without prejudice to the provisions in Article 8 hereunder.**

7.3. - The class granted to the concerned Units and the previously issued certificates remain valid until the date of effect of the notice issued according to 7.2. here above subject to compliance with 2.3. here above and Article 8 hereunder.

7.4. - The contract for classification and/or certification of a Unit cannot be transferred neither assigned.

ARTICLE 8

8.1. - The Services of the Society, whether completed or not, involve, for the part carried out, the payment of fee upon receipt of the invoice and the reimbursement of the expenses incurred.

8.2. **- Overdue amounts are increased as of right by interest in accordance with the applicable legislation.**

8.3. **- The class of a Unit may be suspended in the event of non-payment of fee after a first unfruitful notification to pay.**

ARTICLE 9

9.1. - The documents and data provided to or prepared by the Society for its Services, and the information available to the Society, are treated as confidential. However:

- "Clients have access to the data they have provided to the Society and, during the period of classification of the Unit for them, to the **classification file** consisting of survey reports and certificates which have been prepared at any time by the Society for the classification of the Unit ;
- "copy of the documents made available for the classification of the Unit and of available survey reports can be handed over to another Classification Society, where appropriate, in case of the Unit's transfer of class;
- "the data relative to the evolution of the Register, to the class suspension and to the survey status of the Units, as well as general technical information related to hull and equipment damages, may be passed on to IACS (International Association of Classification Societies) according to the association working rules;
- "the certificates, documents and information relative to the Units classed with the Society may be reviewed during certificating bodies audits and are disclosed upon order of the concerned governmental or inter-governmental authorities or of a Court having jurisdiction.

The documents and data are subject to a file management plan.

ARTICLE 10

10.1. - Any delay or shortcoming in the performance of its Services by the Society arising from an event not reasonably foreseeable by or beyond the control of the Society shall be deemed not to be a breach of contract.

ARTICLE 11

11.1. - In case of diverging opinions during surveys between the Client and the Society's surveyor, the Society may designate another of its surveyors at the request of the Client.

11.2. - Disagreements of a technical nature between the Client and the Society can be submitted by the Society to the advice of its Marine Advisory Committee.

ARTICLE 12

12.1 - Disputes over the Services carried out by delegation of Governments are assessed within the framework of the applicable agreements with the States, international Conventions and national rules.

12.2. - Disputes arising out of the payment of the Society's invoices by the Client are submitted to the Court of Nanterre, France, or to another Court as deemed fit by the Society.

12.3. **- Other disputes over the present General Conditions or over the Services of the Society are exclusively submitted to arbitration, by three arbitrators, in London according to the Arbitration Act 1996 or any statutory modification or re-enactment thereof. The contract between the Society and the Client shall be governed by English law.**

ARTICLE 13

13.1. **- These General Conditions constitute the sole contractual obligations binding together the Society and the Client, to the exclusion of all other representation, statements, terms, conditions whether express or implied. They may be varied in writing by mutual agreement. They are not var- ied by any purchase order or other document of the Client serving similar purpose.**

13.2. - The invalidity of one or more stipulations of the present General Conditions does not affect the validity of the remaining provisions.

13.3. - The definitions herein take precedence over any definitions serving the same purpose which may appear in other documents issued by the Society.

RULE NOTE NR 530

NR 530

Coating Performance Standard

SECTION 1 GENERAL

SECTION 2 COATING PERFORMANCE STANDARD CPS (WBT)

SECTION 3 COATING PERFORMANCE STANDARD CPS (VSP)

SECTION 4 COATING PERFORMANCE STANDARD CPS (COT)

SECTION 5 COATING SYSTEM APPROVAL

July 2013

Section 1 General

Section 2 Coating Performance Standard CPS(WBT)

Section 3 Coating Performance Standard CPS(VSP)

Section 4 Coating Performance Standard CPS(COT)

Section 5 Coating System Approval

NR 530, Sec 1

SECTION 1

GENERAL

1 Application

1.1 General

1.1.1 This Rule Note is related to protective coatings in:

- dedicated seawater ballast tanks of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of length greater than or equal to 150 m
- void spaces in bulk carriers and oil tankers
- cargo oil tanks of crude oil tankers of 5,000 tones deadweight and above.

1.1.2 It applies to ships complying with the requirements of the IMO Performance Standard for Protective Coating for dedicated seawater ballast tanks (IMO PSPC WBT), according to the procedure described in Sec 2.

1.1.3 It applies to bulk carriers and oil tanker complying with the requirements of the IMO Performance Standard for Protective Coating for void spaces (IMO PSPC VSP), according to the procedure described in Sec 3.

1.1.4 It applies to crude oil tankers complying with the requirements of the IMO Performance Standard for Protective Coating for cargo oil tanks of crude oil tankers (IMO PSPC COT), according to the procedure described in Sec 4.

1.2 Additional service feature CPS(WBT)

1.2.1 The additional service feature CPS (WBT) is to be assigned to ships complying with the requirements of the Common Structural Rules for Bulk Carriers or the Common Structural Rules for Double Hull Oil Tankers, contracted for construction on or after the 8th December 2006, for which the requirements of this Rule Note are to be applied.

(Refer to NR467 Rules for the Classification of Steel Ships Part A, Ch 1, Sec 2, [4.3.2] and [4.4.2]).

1.3 Additional class notation CPS (WBT)

1.3.1 The additional class notation CPS(WBT) may be assigned to ships, other than those subject to [1.2] above, complying with the requirements of this Rule Note.

(Refer to NR467 Rules for the Classification of Steel Ships Part A, Ch 1, Sec 2, [6.15]).

1.4Additional class notation CPS (VSP)

1.4.1 The additional class notation CPS(VSP) may be assigned to bulk carriers and oil tankers complying with the requirements of this Rule Note.

(Refer to NR467 Rules for the Classification of Steel Ships Part A, Ch 1, Sec 2, [6.15]).

1.5 Additional class notation CPS (COT)

1.5.1 The additional class notation CPS(COT) may be assigned to crude oil tankers complying with the requirements of this Rule Note.

(Refer to NR467 Rules for the Classification of Steel Ships Part A, Ch 1, Sec 2, [6.15]).

2 General

2.1 Reference documents

2.1.1 IMO PSPC WBT

IMO PSPC WBT is the "Performance Standard for Protective Coatings for dedicated seawater ballast tanks", in all types of ships and double-side skin spaces of bulk carriers, adopted on 8 December 2006 by IMO Maritime Safety Committee under Resolution MSC.215(82).

A general view flow chart, pointing out items and tasks that are included inside of the PSPC WBT, is presented in Fig 1.

2.1.2 IMO PSPC VSP

IMO PSPC VSP is the "Performance Standard for Protective Coatings for void spaces on bulk carriers and oil tankers", adopted on October 2007 by IMO Maritime Safety Committee under Resolution MSC.244(83).

A general view flow chart, pointing out items and tasks that are included inside of the PSPC VSP, is presented in Fig 1.

2.1.3 IMO PSPC COT

IMO PSPC COT is the "Performance Standard for Protective Coatings for cargo oil tanks of crude oil tankers", adopted on 14 May 2010 by IMO Maritime Safety Committee under Resolution MSC.288(87).

A general view flow chart, pointing out items and tasks that are included inside of the PSPC COT, is presented in Fig 1.

2.1.4 IMO MSC.1/Circ.1279

IMO MSC.1/Circ.1279 is the "Guidelines for corrosion protection of permanent means of access arrangements", adopted on 23 May 2008 by IMO Maritime Safety Committee.

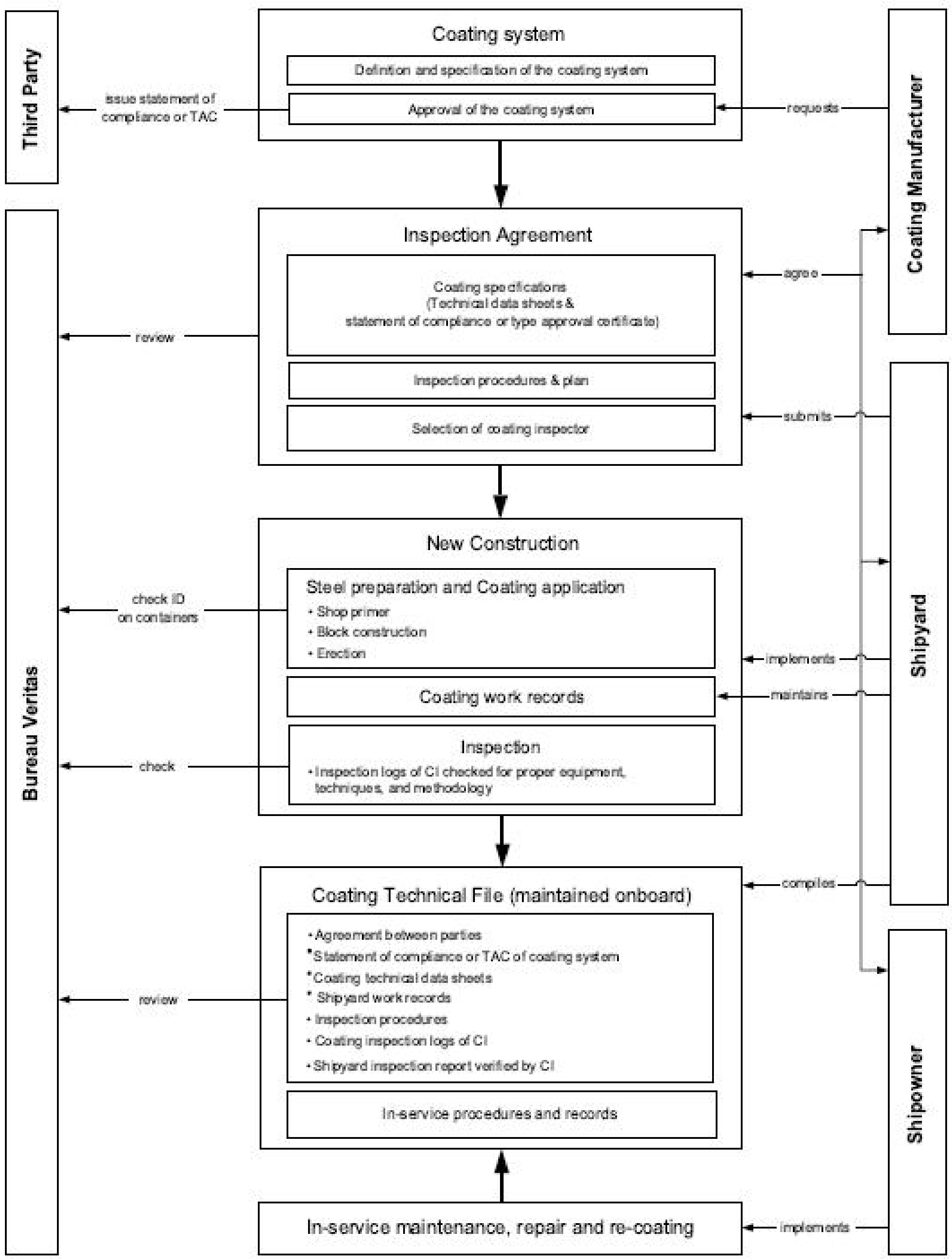
2.1.5 IACS UI SC223

IACS UI SC223 is the Unified Interpretation "For application of SOLAS regulation II-1/3-2 Performance Standard for Protective Coatings (PSPC) for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers, adopted by resolution MSC.215(82)".

2.1.6 IACS UI SC227

IACS UI SC227 is the Unified Interpretation for "The dedicated seawater ballast tanks in SOLAS Chapter II-1 (Regulation 3-2)".

Figure 1 : PSPC Flow Chart



2.1.7 IACS UI SC 259

IACS UI SC 259 is the Unified Interpretation for "application of SOLAS Regulation II-1/3-11".

2.1.8 IACS Recommendation 87

IACS Recommendation is the Guidelines for coatings maintenance and repairs.

2.1.9 IACS Recommendation 101

IACS Recommendation 101 is the "IACS Model Report for IMO Resolution MSC.215 (82) Annex 1 Test Procedures for Coating Qualification".

2.1.10 IACS Recommendation 102

IACS Recommendation 102 is the "IACS Model Report for IMO Resolution MSC.215 (82) Annex 1 Test Procedures for Coating Qualification, Section 1.7 - Crossover Test".

2.1.11 IACS Recommendation 116

IACS Recommendation 116 is the "Performance Standard for Protective Coatings for Cargo Oil Tanks of Crude Oil Tankers - 5 years field exposure test in accordance with MSC.288(87)".

2 Definitions

2.2.1 Seawater ballast tank

Seawater ballast tank is a tank which is used solely for salt water ballast.

It includes:

•segregated ballast tanks

•side ballast tanks

•ballast double bottom spaces

•topside tanks

•hopper side tanks

•peak tanks.

Holds of bulk carriers used for both cargo and salt water ballast are not considered as seawater ballast tanks in the scope of this Rule Note.

Moreover, the following tanks are not considered to be dedicated seawater ballast tanks:

•ballast tank identified as "Spaces included in Net Tonnage" in the 1969 ITC Certificate

•seawater ballast tanks in passenger ships also designated for the carriage of grey water or black water

•seawater ballast tanks in livestock carriers also designated for the carriage of the livestock dung.

2.2.2 Double side skin space

Double side skin space is a space for which boundaries are side and inner side, and, if any, bottom of topside tank and top of hopper side tank.

2.2.3 Totally enclosed space

Totally enclosed space is a space which has no means of access and no ventilation.

2.2.4 Void space

Void space is an enclosed space below the bulkhead deck, within and forward of the cargo area of oil tankers or the cargo length area of bulk carriers, excluding:

•dedicated seawater ballast tank

•space for the carriage of cargo

•space for the storage of any substance (e.g., oil fuel, fresh water, provisions)

•space for the installation of any machinery (e.g., cargo pump, ballast pump, bow thruster)

•any space in normal use by personnel

•double-side skin space of bulk carriers of 150 m in length and upwards complying with the PSPC WBT adopted by resolution MSC.215(82).

a) In bulk carriers:

•double bottom pipe passages/pipe tunnels

•small void spaces located behind gusset or shedder plates at the bottom of corrugation bulkheads with the exception of totally enclosed spaces

•other small voids spaces in cargo spaces, with the exception of totally enclosed spaces

•lower transverse stool of transverse bulkheads, with the exception of totally enclosed spaces

•upper transverse stool of transverse bulkheads, with the exception of totally enclosed spaces.

b) In oil tankers:

•forward cofferdam/cofferdam separating cargo from forepeak

•cofferdam in cargo area/cofferdam separating incompatible cargoes

•aft cofferdam

•duck keel/pipe tunnels

•lower bulkhead stools

•upper bulkhead stools.

c) The following void spaces in bulk carriers and oil tank- ers are not covered by this Rule Note:

•totally enclosed spaces located behind gusset or shedder plates at the bottom corrugation bulkheads and other small totally enclosed spaces in cargo tanks

•lower transverse stool of transverse bulkheads that are totally enclosed spaces

•upper transverse stool of transverse bulkheads that are totally enclosed spaces

•transducer voids.

2.2.5 Cargo oil tank of crude oil tanker

Crude oil tanker means an oil tanker engaged in the trade of carrying crude oil, according to Annex I of MARPOL 73/78.

2.4 Documents to be submitted to the Society

2.3.1 Inspection agreement

The inspection agreement is the document defining the inspection of surface preparation and coating processes.

The inspection agreement is to be agreed upon between the shipowner, the shipyard and the coating manufacturer.

This inspection agreement is making reference to or including:

•the coating specification and/or the technical data sheets

•the certification of the coating system

•the assignment and the qualification of the coating inspector

•the assignment and the qualification of the assistant to the coating inspector, if relevant

•inspection procedures and plan.

The inspection agreement may also make reference to tem- plates of inspection documents to be included in the coating technical file (CTF).

2.3.2 Coating specification

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.

2.3.3 Certification of the Coating system

The statement of compliance or the type approval certificate of the relevant coating system(s) is (are) to be made available by the shipyard.

2.3.4 Qualification of coating inspector(s)

The assigned coating inspector is to provide the evidence of his/her qualification level, in accordance with [2.4].

2.3.5 Qualification of assistant inspector(s)

The assistant inspector, if any, is to provide the evidence of his/her qualification level, in accordance with [2.5].

2.3.6 Inspection documents

Inspection documents showing that the inspectors are using the inspection equipment, techniques and reporting methods as described in the inspection agreement are to be sub- mitted on a regular basis during the course of its inspection.

2.3.7 Coating Technical File

The coating technical file (CTF) is to be delivered by the shipyard to the Society for review.

2.4 Coating inspector qualification

2.4.1 The coating inspector is to be qualified to NACE coating inspector Level 2, or FROSIO inspector Level III, or to equivalent qualification as defined below under [2.4.2].

In addition, the coating inspector is to have at least 2-years experience as a coating inspector, to be allowed to write and/or authorise procedures, or to decide upon corrective actions to overcome non-compliances.

2.4.2 Equivalent qualification

Individuals can obtain equivalent qualifications:

- either by passing theoretical and practical examination. This case applies to individuals with a minimum of 5-years practical work experience as a coating inspector of ballast tanks during new construction within the last 10 years
- or by attending a training course and by passing theoretical and practical examinations.

The course tutors are to 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.

The coating inspector training course is to be reviewed to make sure that it covers IMO PSPC topics. This course is to cover the following items:

- 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 courses may be internal courses run by the coating manufacturers or shipyards.
Training course, theoretical and practical examinations are to be approved by the Society.

2.5 Assistant to coating Inspectors

2.5.1 If the coating inspectors require assistance from other persons to do the part of the inspections under the coating inspector's supervision, those persons are to be trained to the coating inspector's satisfaction.

2.5.2 Such training courses are to be recorded and endorsed either by the inspector, the yard's training organisation or inspection equipment manufacturer to confirm competence in using the measuring equipment and confirm knowledge of the measurements required by the PSPC.
Training records are to be available for verification if required.

SECTION 2 COATING PERFORMANCE STANDARD CPS(WBT)

1 Procedure for CPS(WBT)

1.1 General

1.1.1 The additional service feature or additional class notation **CPS(WBT)** is granted after satisfactory assessment of the procedure described in [1.1.2].

1.1.2 The steps of the procedure for **CPS(WBT)** are the following:

- review of the inspection agreement
- verification of the IMO PSPC WBT implementation
- review of the coating technical file (CTF).

1.2 Review of the inspection agreement

1.2.1 The inspection agreement signed by the shipyard, the shipowner and the coating manufacturer is to be presented by the shipyard to the Society to check its compliance with the IMO PSPC WBT, prior to commencement of any coating works, on any stage of a new building.

1.2.2 For the review of this agreement, the following from the CTF, are to be available:

- coating specification including selection of areas (spaces) to be coated, selection of coating system, sur- face preparation and coating process
- statement of compliance or type approval certificate of the coating system.

1.2.3 The inspection agreement is to cover:

- the assignment of coating inspector(s), and assistant inspector(s), if any
- areas of responsibilities of coating inspector(s), in case of more than one coating inspector is assigned (for example, multiple construction sites)
- qualification of coating inspector(s), and assistant inspector(s)
- inspection process, including scope of inspection, mini- mum inspection requirements, inspection methods
- language to be used for documentation.

The inspection agreement is to be included in the coating technical file.

1.2.4 Deviations in the procedure relative to the IMO PSPC WBT noted during this checking are raised with the ship- yard, which is responsible for identifying and implementing the corrective actions.

1.3 Verification of the PSPC WBT implementation

1.3.1 Prior to reviewing the coating technical file and during the performance of coating works, the Society is to carry out the following checking:

a) check that the relevant technical data sheet and statement of compliance or type approval certificate are made available

b) check, on a sampling basis, 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

c) check the document which evidences the qualification of the coating inspector(s), who is(are) assigned in the inspection agreement

d) check, on a sampling basis, that the inspector's reports of surface preparation and the coating's application indicate compliance with the technical data sheet and statement of compliance or type approval certificate; and

e) check, on a sampling basis, that the inspectors are using the correct equipment, techniques and reporting methods as described in the inspection agreement.

Deviations found for items d) and e) are raised initially with the coating inspector, who is responsible for identifying and implementing of the corrective actions.

1.3.2 Any other deviations found under [1.3.1] are raised with the shipyard, who is responsible for the implementation of the corrective actions.

1.4 Review of the Coating Technical File (CTF)

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

1.4.2 The Coating Technical File is to be reviewed, at random, to ascertain it contains the information required in [1.4.3].

1.4.3 The Coating Technical File is to contain at least the following information:

- Copy of Statement of Compliance or Type Approval Certificate
- Copy of Technical Data Sheet, including:
  - product name and identification mark and/or number
  - materials, components and composition of the coating system, colours
  - minimum and maximum dry film thickness
  - application methods, tools and/or machines
  - condition of surface to be coated (de-rusting grade, cleanliness, profile)
  - environmental limitations (temperature and humidity)
- Shipyard work records of coating application, including:
  - applied actual space and area of each compartment
  - applied coating system
  - time of coating, thickness, number of layers
  - ambient condition during coating
  - method of surface preparation
- Procedures for inspection and repair of coating system during ship construction
- 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
- Shipyard's verified inspection report, including:
  - completion date of inspection
  - result of inspection
  - remarks
  - coating inspector's signature
  - Procedures for in-service maintenance and repair of coating system.

1.4.4 Deviations found under [1.4.3] are raised with the shipyard, who is responsible for identifying and implementing the corrective actions.

1.4.5 The Coating Technical File prepared by the shipyard is to be kept on board and maintained by the shipowner throughout the life of the ship.

SECTION 3 COATING PERFORMANCE STANDARD CPS(VSP)

1 Procedure for CPS(VSP)

1.1 General

1.1.1 The additional class notation **CPS(VSP)** is granted after satisfactory assessment of the procedure described in [1.1.2].

1.1.2 The steps of the procedure for **CPS(VSP)** are the following:

- review of the inspection agreement
- verification of the IMO PSPC VSP implementation
- review of the coating technical file (CTF).

1.2 Review of the inspection agreement

1.2.1 The inspection agreement signed by the shipyard, the shipowner and the coating manufacturer is to be presented by the shipyard to the Society to check its compliance with the IMO PSPC VSP, prior to commencement of any coating works, on any stage of a new building.

1.2.2. For the review of this agreement, the following from the CTF, are to be available:

- coating specification including selection of areas (spaces) to be coated, selection of coating system, sur- face preparation and coating process
- statement of compliance or type approval certificate of the coating system.

1.2.3 The inspection agreement is to cover:

- the assignment of coating inspector(s), and assistant inspector(s), if any.
- areas of responsibilities of coating inspector(s), in case of more than one coating inspector is assigned (for example, multiple construction sites)
- qualification of coating inspector(s), and assistant inspector(s)
- inspection process, including scope of inspection, mini- mum inspection requirements, inspection methods
- language to be used for documentation.

The inspection agreement is to be included in the coating technical file.

1.2.4 Deviations in the procedure relative to the IMO PSPC VSP noted during this checking are raised with the shipyard, which is responsible for identifying and implementing the corrective actions.

1.3 Verification of the PSPC VSP implementation

1.3.1 Prior to reviewing the coating technical file and during the performance of coating works, the Society is to carry out the following checking:

a) check that the relevant technical data sheet and statement of compliance or type approval certificate are made available

b) check, on a sampling basis, 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

c) check the document which evidences the qualification of the coating inspector(s), who is(are) assigned in the inspection agreement

d) check, on a sampling basis, that the inspector's reports of surface preparation and the coating's application indicate compliance with the technical data sheet and statement of compliance or type approval certificate; and

e) check, on a sampling basis, that the inspectors are using the correct equipment, techniques and reporting methods as described in the inspection agreement.

Deviations found for items d) and e) are raised initially with the coating inspector, who is responsible for identifying and implementing of the corrective actions.

1.3.2 Any other deviations found under [1.3.1] are raised with the shipyard, who is responsible for the implementation of the corrective actions.

1.4 Review of the Coating Technical File (CTF)

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

1.4.2 The Coating Technical File is to be reviewed, at random, to ascertain it contains the information required in [1.4.3].

1.4.3 The Coating Technical File is to contain at least the following information:

- Copy of Statement of Compliance or Type Approval Certificate
- Copy of Technical Data Sheet, including:
  - product name and identification mark and/or number
  - materials, components and composition of the coating system, colours
  - minimum and maximum dry film thickness
  - application methods, tools and/or machines
  - condition of surface to be coated (de-rusting grade, cleanliness, profile)
  - environmental limitations (temperature and humidity)
- Shipyard work records of coating application, including:
  - applied actual space and area of each compartment
  - applied coating system
  - time of coating, thickness, number of layers
  - ambient condition during coating
  - method of surface preparation
- Procedures for inspection and repair of coating system during ship construction
- 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.
- Shipyard's verified inspection report, including:
  - completion date of inspection
  - result of inspection
  - remarks
  - coating inspector's signature
- Procedures for in-service maintenance and repair of coating system.

1.4.4 Deviations found under [1.4.3] are raised with the shipyard, who is responsible for identifying and implementing the corrective actions.

1.4.5 The Coating Technical File prepared by the shipyard is to be kept on board and maintained by the shipowner throughout the life of the ship.

SECTION 4 COATING PERFORMANCE STANDARD CPS(COT)

1 Procedure for CPS (COT)

1.1 General

1.1.1 The additional class notation **CPS(COT)** is granted after satisfactory assessment of the procedure described in [1.1.2].

1.1.2 The steps of the procedure for **CPS(COT)** are the fol- lowing:

- review of the inspection agreement
- verification of the IMO PSPC COT implementation
- review of the coating technical file (CTF).

1.2 Areas of application

1.2.1 At least, the following areas shall be protected according to the IMO PSPC COT:

- Deckhead with complete internal structure, including brackets connecting to longitudinal and transverse bulk- heads. In tanks with ring frame girder construction the underdeck transverse framing to be coated down to level of the first tripping bracket below the upper faceplate.
- Longitudinal and transverse bulkheads are to be coated to the uppermost means of access level. The uppermost means of access and its supporting brackets to be fully coated.
- On cargo tank bulkhead is without an uppermost means of access the coating to extend to 10% of the tanks height at centreline but need not extend more than 3 m down from the deck.

1.3 Review of the inspection agreement

1.3.1 The inspection agreement signed by the shipyard, the shipowner and the coating manufacturer is to be presented by the shipyard to the Society to check its compliance with the IMO PSPC COT, prior to commencement of any coating works, on any stage of a new building.

1.3.2 For the review of this agreement, the following from the CTF, are to be available:

- coating specification including selection of areas (spaces) to be coated, selection of coating system, sur- face preparation and coating process.
- statement of compliance or type approval certificate of the coating system.

1.3.3 The inspection agreement is to cover:

- the assignment of coating inspector(s), and assistant inspector(s), if any
- areas of responsibilities of coating inspector(s), in case of more than one coating inspector is assigned (for example, multiple construction sites)
- qualification of coating inspector(s), and assistant inspector(s)
- inspection process, including scope of inspection, mini- mum inspection requirements, inspection methods
- language to be used for documentation.

The inspection agreement is to be included in the coating technical file.

1.3.4 Deviations in the procedure relative to the IMO PSPC COT noted during this checking are raised with the ship- yard, which is responsible for identifying and implementing the corrective actions.

1.4 Verification of the PSPC COT implementation

1.4.1 Prior to reviewing the coating technical file and during the performance of coating works, the Society is to carry out the following checking:

a) check that the relevant technical data sheet and statement of compliance or type approval certificate are made available

b) check, on a sampling basis, 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

c) check the document which evidences the qualification of the coating inspector(s), who is(are) assigned in the inspection agreement.

d) check, on a sampling basis, that the inspector's reports of surface preparation and the coating's application indicate compliance with the technical data sheet and statement of compliance or type approval certificate; and

e) check, on a sampling basis, that the inspectors are using the correct equipment, techniques and reporting methods as described in the inspection agreement.

Deviations found for items d) and e) are raised initially with the coating inspector, who is responsible for identifying and implementing of the corrective actions.

1.4.2 Any other deviations found under [1.4.1] are raised with the shipyard, who is responsible for the implementation of the corrective actions.

1.5 Review of the Coating Technical File (CTF)

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

1.5.2 The Coating Technical File is to be reviewed, at random, to ascertain it contains the information required in [1.4.3].

1.5.3 The Coating Technical File is to contain at least the following information:

- Copy of Statement of Compliance or Type Approval Certificate
- Copy of Technical Data Sheet, including:
  - product name and identification mark and/or number
  - materials, components and composition of the coating system, colours
  - minimum and maximum dry film thickness
  - application methods, tools and/or machines
  - condition of surface to be coated (de-rusting grade, cleanliness, profile)
  - environmental limitations (temperature and humidity)
- Shipyard work records of coating application, including:
  - applied actual space and area of each compartment
  - applied coating system
  - time of coating, thickness, number of layers
  - ambient condition during coating
  - method of surface preparation
- Procedures for inspection and repair of coating system during ship construction
- 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.
- Shipyard's verified inspection report, including:
  - completion date of inspection
  - result of inspection
  - remarks
  - coating inspector's signature
- Procedures for in-service maintenance and repair of coating system.

1.5.4 Deviations found under [1.5.3] are raised with the shipyard, who is responsible for identifying and implementing the corrective actions.

1.5.5 The Coating Technical File prepared by the shipyard is to be kept on board and maintained by the shipowner throughout the life of the ship.

SECTION 5 COATING SYSTEM APPROVAL

1 General

1.1 Scope

1.1.1 This Section provides requirements for coating sys- tem type approval by the Society in compliance with IMO PSPC WBT, IMO PSPC VSP and IMO PSPC COT. When several performance standards are considered, reference is made to IMO PSPC.

1.2 Definitions

1.2.1 Coating system

Coating system means the coating product (CP1), which could be an epoxy-based system or an alternative system, and/or the associated shop primer(s) (SP1).

1.2.2 Alternative system

Alternative system can be coating systems which are:

- Epoxy-based systems, but not applied according to table 1 of IMO PSPC
- Non epoxy-based systems applied according to table 1 of IMO PSPC, or
- Non epoxy-based systems, but not applied according to table 1 of IMO PSPC.

1.2.3 Shop primer

Shop primer is the prefabrication primer coating applied to steel plates, often in automatic plants.

Shop primer is intended to provide a temporary corrosion protection. It is in general to be associated to a coating product.

1.2.4 Alternative shop primer

Shop primers not containing zinc or not silicate based are considered to be “alternative systems” and therefore equivalency is to be established in accordance with Section 8 of the IMO PSPC WBT with test acceptance criteria for “alter- native systems” given in section 3.1 (right columns) of Appendixes 1 and 2 to ANNEX 1 of MSC.215(82).

1.2.5 DFT and NDFT

DFT is the dry film thickness.

NDFT is the nominal dry film thickness.

1.2.6 TDS

TDS is the technical data sheet provided by the coating manufacturer, which contains detailed technical instructions and information relevant to the coating and its application.

1.2.7 MSDS

MSDS is the material safety data sheet provided by the Coating Manufacturer, which contains chemical information and safety instructions relevant to the coating.

2 Recognition of testing laboratory

2.1 General

2.1.1 This section gives the procedure for recognition by the Society of laboratory engaged in testing coating system according to IMO PSPC.

2.1.2. First-time application for recognition of testing laboratory is to be made using the appropriate form made available by the Society.

The application for recognition of testing laboratory is to be made by the laboratory to the Bureau Veritas Local Office.

2.2 Documentation

2.2.1 The following documents are to be submitted by the laboratory to the Society:

- outline of laboratory, e.g. organization and management structure
- experience of the laboratory in the specific testing activities
- list of operators, technicians, inspectors documenting training and experience within the relevant testing activities, and qualifications according to recognized national, international or industry standards, as relevant
- a detailed list of the laboratory test equipment for the IMO PSPC coating approval
- a guide for operators of such equipment
- check list and format of testing records
- quality manual and/or documented testing procedures covering the requirements in [2.3.4]
- accreditation certificate by national accreditation body, when available
- 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
- a detailed list of reference documents comprising as minimum those referred to IMO PSPC.

The Society may request additional documentation while the recognition process is under progress.

2.3 Audit general requirements

2.3.1 The laboratory shall demonstrate, as required by items a) - h), that it has the competence and control needed to perform the testing activities for which the certification is sought:

a) Training of personnel - The laboratory 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 laboratory 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.

b) Supervision - The laboratory shall provide supervision for all testing activities provided. The responsible super- visor shall have had minimum two (2) years experience as an operator/technician/inspector within the testing activities for which the laboratory is certified.

c) Personnel records - The laboratory shall keep records of the approved operators/technicians/inspectors. The record shall contain information on age, formal education, training and experience for the testing activities for which they are certified.

d) Equipment and facilities - The laboratory shall have the necessary equipment and facilities for the testing activities to be supplied. A record of the equipment used shall be kept. The record shall contain information on maintenance and calibration.

e) Procedures - The laboratory shall have documented work procedures covering all testing activities supplied.

f) Subcontractors - The laboratory shall give information of agreements and arrangements if any parts of the testing activities provided are subcontracted. Particular emphasis shall be given to quality management by the laboratory in following-up of such subcontracts. Subcontractors providing anything other than subcontacted personnel or equipment shall also meet the requirements of sections [2.3.1] and [2.3.4].

g) Verification - The laboratory shall verify that the testing activities provided are carried out in accordance with approved procedures.

h) Reporting - The report shall be prepared in a form acceptable to the Society. The report shall include a copy of the Certificate of Approval.

The Society's requirements for attendance of the Surveyor to the tests and examinations for coating systems to be certified by the Society are given in the recognition certificate.

2.3.2 Auditing of the laboratory

Upon reviewing the submitted documents with satisfactory result, the laboratory's arrangements are audited in order to ascertain that the laboratory is dully organised and man- aged in accordance with the submitted documents, and that it is considered capable of conducting the testing activities for which certification is sought.

2.3.3 Certification is conditional on a partical demonstration of the specific testing activities performance as well as satisfactory reporting being carried out.

2.3.4 Quality system

The laboratory 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/inspec- tors
- 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, com- plaints, corrective actions, and issuance, maintenance and control documents.

A documented Quality system complying with the most current version of ISO 9000 series and including the above items, would be considered acceptable.

2.4 Recognition certificate

2.4.1 Initial certification

Upon satisfactory completion of the recognition process, a recognition certificate is issued by the Society to the laboratory.

The recognition certificate contains the scope of testing activities considered for the recognition process and the requirements for the attendance by a Surveyor.

Normally the recognition certificate will be given a time validity of 4 years.

The laboratory is to apply for periodical assessment during the validity of the recognition certificate, as agreed with the Society.

2.4.2 Application for modification of the recognition certificate

When necessary, the laboratory may apply for a modification of an existing recognition certificate, using the appropriate form made available by the Society.

Details of the requested modification are to be submitted to the Society. Upon satisfactory completion of the recognition process, the modified certificate is issued by the Society to the laboratory.

Normally the term of validity is not changed.

2.4.3 Application for renewal of the recognition certificate

As necessary, the laboratory is to apply for renewal of an existing recognition certificate, using the appropriate form made available by the Society.

In case of modification, details of the requested modification are to be submitted to the Society.

Upon satisfactory completion of the recognition process, the renewed recognition certificate is issued by the Society to the laboratory. Normally the renewed recognition certificate will be given a time validity of 4 years

2.4.4 Reconsideration and cancellation of the recognition certificate

During the period of validity, the recognition certificate may be cancelled by the Society when an irregular situation brought to the knowledge of the Society has not been corrected by the laboratory to the satisfaction of the Society, and, in the particular following cases:

- where the service was improperly carried out or the results were improperly reported
- where a Surveyor finds deficiencies in the approved service operating system of the laboratory and appropriate corrective action is not taken
- where the testing laboratory fails to inform of any alteration to its certified service operating system to the Society
- where intermediate audit, if prescribed, has not been carried out
- where willful acts or omissions or grossly negligent act or omission are ascertained.

The Society reserves the right to cancel the recognition certificate and to inform the International Association of Classification Societies (IACS) Members accordingly.

A laboratory whose recognition has been cancelled may apply for re-approval after a period of 6 months 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. This possibility is not open if the cancellation is based on a grave fault such as violation of ethics.

3. Type approval coating system procedure

3.1 General

3.1.1 Application for type approval of coating system and/or shop primer is to be made using the appropriate form made available by the Society.

The application for type approval of coating system and/or shop primer is to be made by the coating manufacturer to the Bureau Veritas Local Office.

The type approval coating system procedure consists of the verification of type approval documentation listed in [3.2], and, the assessment of coating manufacturers and their individual works described in [3.5].

3.2 Type approval documentation

3.2.1 The type approval documentation to be submitted consists in:

- Technical Data Sheet (TDS) for each coating product and each shop primer showing all the information required by IMO PSPC § 3.4.2.2.
- Material Safety Data Sheet (MSDS) for each coating product and each shop primer.
- Infrared (IR) and specific gravity (SG) identification of winter and summer type coating, to demonstrate they are the same.
- Infrared (IR) and specific gravity (SG) identification of the coating product for each manufacturing site.
- Type testing documentation listed in [3.3].

3.3 Coating system type testing methods

3.3.1 Type testing of coating system consist of one following methods:

- Testing laboratory carried out either within IMO PSPC tests procedures as per [3.3.2], or, "Marintek B1" laboratory test as per [3.3.3], or
- Five years field exposure as per [3.3.4].

3.3.2 IMO PSPC laboratory tests

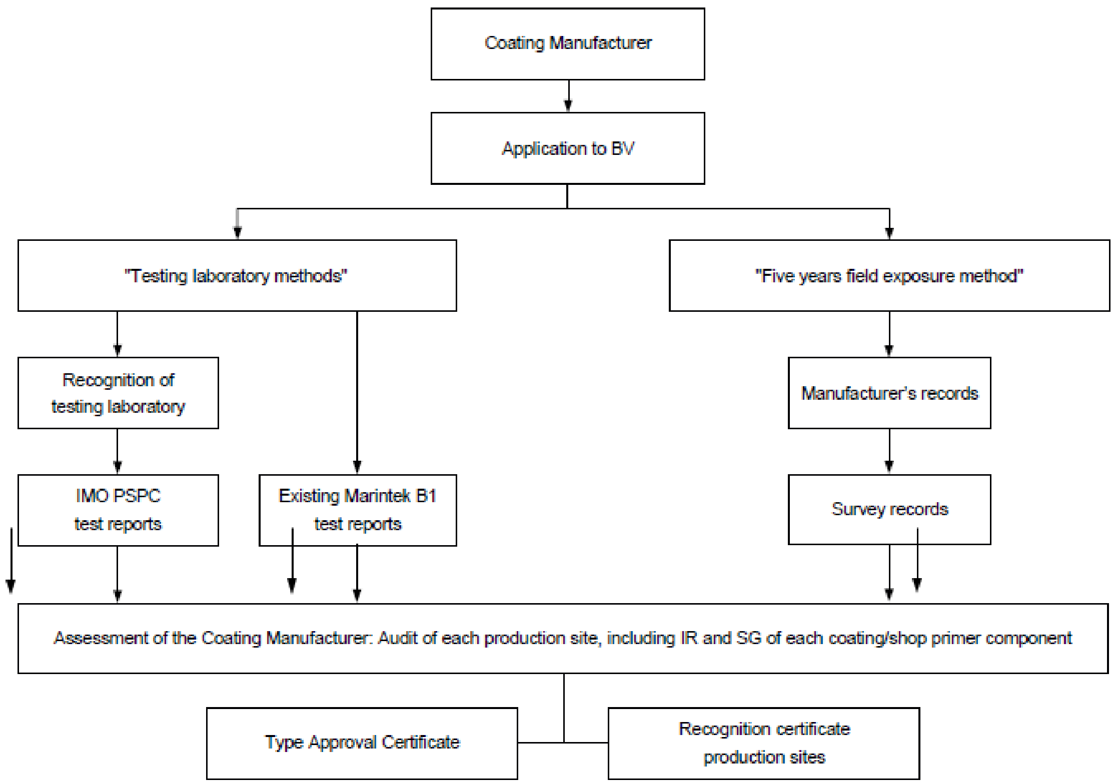
The testing laboratory is to be recognised as per procedure described in [2].

For each coating system (coating product (CP1) plus its associated shop primer (SP1), if any):

- Seawater ballast tanks: tests reports edited for "the simulated ballast tank conditions" and for "the condensation chamber test" in accordance with requirements indicated in IMO PSPC WBT Annex1 have to be submitted.
- Void spaces: tests reports edited for "the condensation chamber test" in accordance with requirements indicated in IMO PSPC VSP Annex1 have to be submitted.
- Crude oil tankers: tests reports edited for "gas-tight cabinet test" and for "the immersion test" in accordance with requirements indicated in IMO PSPC COT Annex1 have to be submitted.

For model test reports reference is made to IACS Recommendation 101 "Model Report for IMO Resolution MSC.215 (82) Annex 1 Test Procedures for Coating Qualification" for IMO PSPC WBT approval.

Figure 1 : Type approval procedure



3.3.3 "Marintek B1" laboratory test

This method only applies to test reports for IMO PSPC WBT epoxy-based system, issued before 8 December 2006.

For each coating system (coating product (CP1) plus its associated shop primer (SP1), if any):

- Marintek test reports, at a minimum level B1, including relevant IR identification and SG, have to be submitted.

If original SG and IR documentation cannot be provided, then a statement is to be provided by the coating manufacturer confirming that the readings for the current product are the same as those of the original.

3.3.4 Five years field exposure

For each coating system (coating product (CP1) plus its associated shop primer (SP1), if any) manufacturer's records and class survey records detailed thereafter have to be sub- mitted.

Manufacturer's Records consist of:

- Original application records
- Original coating specification
- Original technical data sheet
- Current formulation's unique identification (Code or number)
- If the mixing ratio of base and curing agent has changed, a statement from the manufacturer confirming that the composition mixed product is the same as the original composition. This is to be accompanied by an explanation of the modifications made
- Current technical data sheet for the current production site
- SG and IR identification of original product

- SG and IR identification of the current product
- If original SG and IR cannot be provided then a statement from the manufacturer confirming the readings for the current product are the same as those of the original.

Either class survey records from the Society or a joint (coating manufacturer / Society) survey is to be carried out:

- For all seawater ballast tanks of a selected ship. The selected ship is to have ballast tanks in regular use, of which:
  - at least one tank is approximately 2000m3 or more in capacity
  - At least one tank shall be adjacent to a heated tank
  - At least one tank contains an underdeck exposed to the sun.
- For void spaces of a selected ship in accordance with the requirements of IMO PSPC VSP
  - For cargo tanks of a selected ship. The selected ship is to have cargo tanks in regular use, of which:
    - At least one tank is exposed to minimum temperature of 60°C plus or minus 3°C.
    - For field exposure the ship should be trading in varied trade routes and carrying substantial varieties of crude oils including highest temperature and lowest pH limits to ensure a realistic sample: for example, three ships on three different trade areas with differ- ent varieties of crude cargoes.

In the case that the selected ship does not meet the requirements listed above, then the limitations will be stated on the type approval certificate. For cargo tanks of crude oil, the limitations on lowest pH and highest temperature of crude oils carried will be stated.

The shop primer shall be removed prior to the application of the approved coating system, unless it can be confirmed that the shop primer applied during construction, is identical in formulation to that applied in the selected ship used as a basis of the approval.

All ballasts are to be in “GOOD” condition excluding mechanical damages, without touch up or repair in the period of 5 years.

“GOOD” is defined as: Condition with spot rusting on less than 3% of the area under consideration without visible failure of the coating. For cargo tank the threshold limit of 5% is considered. Rusting at edges or welds, must be on less than 20% of edges or welds in the area of consideration.

Examples of coating condition evaluation report with respect to areas under consideration should be those given in IACS Recommendation 87.

If the applied NDFT is greater that required by IMO PSPC, the applied NDFT will be the minimum to be applied during construction. This will be reported on the type approval certificate.

3.4 Cross-over tested shop primers

3.4.1 A shop primer (SPi) that has been type approved with a coating product (CP1), according to [3.3.2], [3.3.3] or [3.3.4], may also be certified with another type approved coating product (CPi) if it passes cross-over tests, as described below:

- For seawater ballast tanks and void spaces: cross over test in accordance with the requirements stated in IMO PSPC WBT Appendix 1 § 1.7, without wave movement. For model crossover test report, reference is made to the IACS Rec102.

For crude oil tankers: cross over test in accordance with the requirements stated in IMO PSPC COT Appendix 2.

3.5 Assessment of the Coating Manufacturer

3.5.1 General

Coating manufacturers and their individual works are to be recognised by the Society through recognition scheme (known as BV Mode II) described in Rule Note NR 320.

This section gives the requirements for assessment of each individual work to be stated in the type approval certificate.

3.5.2 Documentation

The following documentation is to be submitted by each coating and/or shop primer manufacturer to the Society:

- outline of company, e.g. organisation and management structure, including subsidiaries to be included in the approval/certification
- names and location of raw material suppliers
- a detailed list of the test standards, equipment, quality manual, quality control and test procedures and records

- quality system certification to ISO 9001 or equivalent
- details of any sub-contracting agreements
- where relevant, list and documentation of licenses granted by manufacturer.

3.5.3 Audit

The audit of the manufacturer's arrangements for production and testing aims at verifying that the following items are documented and operated by the coating and/or shop primer manufacturer to the satisfaction of the Society:

- management of type approval with the Society
- training and qualification of personnel
- purchasing of components subject to certification requirements
- traceability of product
- management of equipment including maintenance and calibration
- testing standards and procedures
- management of non-conform products
- management of complaints.

The audit of the manufacturer's arrangements is to be based on the requirements of IMO PSPC, by taking into consideration the following items:

- with the exception of early 'scale up' from laboratory to full production, adjustment outside the limitations listed in the quality control instruction referred to below is not acceptable, unless justified by trials during the coating system's development programme, or subsequent test- ing. Any such adjustments must be agreed by the formulating technical centre
- if formulation adjustment is envisaged during the production process the maximum allowable limits is to be approved by the formulating technical centre and clearly stated in the quality control working procedures
- the manufacturer's quality control system ensures that all current production is the same formulation as that supplied for the type approval certificate. Formulation change is not permissible without testing in accordance with the IMO PSPC test procedures
- whenever possible, raw material supply and lot details for each coating batch are to be traceable. Exceptions may be where bulk supply such as solvents and pre-dis- solved solid epoxies are stored in tanks, in which case it may only be possible to record the supplier's blend
- batch records including all quality control test results such as viscosity, specific gravity and airless spray characteristics are to be accurately recorded. Details of any additions are also to be included
- dates, batch numbers and quantities supplied to each coating contract are to be clearly recorded
- all raw material supply must be accompanied the sup- plier's certificate of conformance. The certificate includes all requirements listed in the coating manufacturer's quality control system
- in the absence of a raw material supplier's certificate of conformance, the coating manufacturer must verify conformance to all requirements listed in the coating manufacturer's quality control system
- drums must be clearly marked with the details as described on the type approval certificate
- the quality control system ensures that the technical data sheets referenced in the type approval certificate(s) are current
- quality control procedures of the originating technical centre ensure that all production units comply with the above stipulations and that all raw material supply is approved by the technical centre.

A1.4.3 Det Norske Veritas: Coating Performance Standard

In this subchapter, the Det Norske Veritas Coating Performance Standard is provided, following the exact chapter division and formulation it has in the formal papers (Det Norske Veritas, 2020).

CLASSIFICATION NOTES

No. 33.1

Protective Coatings

JULY 2013

The electronic pdf version of this document found through http://www.dnv.com is the officially binding version

DET NORSKE VERITAS AS

FOREWORD

DNV is a global provider of knowledge for managing risk. Today, safe and responsible business conduct is both a license to operate and a competitive advantage. Our core competence is to identify, assess, and advise on risk management. From our leading position in certification, classification, verification, and training, we develop and apply standards and best practices. This helps our customers safely and responsibly improve their business performance. DNV is an independent organisation with dedicated risk professionals in more than 100 countries, with the purpose of safeguarding life, property and the environment.

Classification Notes

Classification Notes are publications that give practical information on classification of ships and other objects. Examples of design solutions, calculation methods, specifications of test procedures, as well as acceptable repair methods for some components are given as interpretations of the more general rule requirements.

Any comments may be sent by e-mail to *rules@dnv.com*

CHANGES – CURRENT

General

This document supersedes Classification Notes No. 33.1, July 1999.

Text affected by the main changes in this edition is highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

Main Changes

- General
  — The document has been completely revised, based on new IMO requirements for coating of tanks and holds.

Editorial Corrections

In addition to the above stated main changes, editorial corrections may have been made.

CONTENTS

1 Introduction

1.1 General

This Classification Note describes the quality levels in regard to coating systems and their applicability in ballast tanks, cargo tanks, holds and spaces. The Classification Note is, in general, referred to in the Rules, when applicable.

The regulations contained in the International Convention for Safety of Life at Sea (SOLAS) and in the guidelines issued by the International Maritime Organisation (IMO) and the International Association of Classification Societies (IACS) include:

— SOLAS Amendment, Regulation II-1/3-2 (December 2006).
— SOLAS Amendment, Regulation II-1/3-11 (May 2010).
— IMO Resolution MSC.215(82) (IMO PSPC-WBT) *Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers*.
— IMO Resolution MSC.244(83) (IMO PSPC-VS) *Performance standard for protective coatings for void spaces on bulk carriers and oil tankers*.
— IMO MSC.1/Circ.1279 (IMO PMA-Guideline) *Guidelines for Corrosion Protection of Permanent Means of Access Arrangements*.
— IMO Resolution MSC.288(87) (IMO PSPC-COT) *Performance standard for protective coatings for cargo oil tanks of crude oil tankers*.

Note that the requirements of IMO Resolution MSC.244(83) are made voluntary by IMO.

This Classification Note supports and further elaborates the requirements related to optional class notations **COAT-PSPC(X)**. The code for the application of the different coating systems is given in the DNV Rules for Classification of Ships Pt.6 Ch.31 for the optional notations. This Classification Note is intended to be a supplement to the Rules.

1.2 Limitation

This Classification Note covers protection of common carbon steel structures against seawater and the marine environment, limited to seawater ballast tanks, cargo oil tanks, void spaces and holds. The mentioned tanks and holds are known to be most susceptible to corrosion and are thus of prime concern.

The Classification Note does not address protection against corrosive cargoes or chemicals.

1.3 Definitions

Coat: A continuous film of paint from a single application.

CTF: Coating Technical File

Dry film thickness, DFT: The thickness of the coating remaining on the surface when the coating has hardened, usually measured in micrometre (m) (microns (1 m = 0.001 mm).

Nominal dry film thickness, NDFT: The dry film thickness specified for a coat or a coating system.

Maximum dry film thickness: The highest acceptable dry film thickness without impairing the coating quality, which is to be stated in the Technical Data Sheets from the coating manufacturer.

PSPC: Performance Standard for Protective Coatings

Shop primer (pre-construction primer): Primer coating applied as a thin film (approximately 15 to 25 microns) to provide temporary corrosion protection of steel plates and structures while plates and beams are stored and during the construction phase. IMO PSPC recommends using zinc containing inhibitor free zinc silicate based or equivalent shop primer. The compatibility with the main coating system shall be confirmed by the coating manufacturer prior the application of the main coating system.

Epoxy primer: Epoxy based primer coating usually without or low Zinc content. The compatibility with the main coating system shall be confirmed by the coating manufacturer, otherwise the primer has to be removed prior the application of the main coating system.

Sa 1: Light blast cleaning. Loose mill scale, rust and foreign matter shall be removed. The appearance shall correspond to the standard photos designated Sa 1. (ISO standard 8501-1; It is a pictorial surface preparation standard for painting steel surfaces. Grades Sa 1 - Sa 3 describe blast-cleaned surfaces.)

Sa 2: Thorough blast cleaning. Almost all mill scale, rust and foreign matter shall be removed. Finally, the surface is cleaned with a vacuum cleaner, clean, dry compressed air or a clean brush. It shall then be greyish in colour and correspond in appearance to standard photos designated Sa 2. (See Sa 1.)

Sa 2,5 (Sa 2½): Very thorough blast cleaning. Mill scale, rust and foreign matter shall be removed to the extent that the only traces remaining are slight stains in the form of spots or stripes. Finally, the surface is cleaned with a vacuum cleaner, clean, dry compressed air or a clean brush. It shall then correspond to standard photos designated Sa 2½. (See Sa 1. It should be noted that Sa 2½ is closer to Sa 3 than to Sa 2. Sa 2½ corresponds to NACE grade No. 2 (near white) and SSPC grade SP 10 (near-white).)

Sa 3: Blast cleaning to pure metal. Mill scale, rust and foreign matter shall be removed completely. Finally, the surface is cleaned with a vacuum cleaner, clean, dry compressed air or a clean brush. It shall then have a uniform metallic colour and correspond in appearance to standard photos designated Sa 3. (See Sa 1. Sa 3 corresponds to NACE grade No. 1 (white metal) and SSPC grade SP 5 (white).)

St 2: Thorough scraping and wire brushing - machine brushing - grinding - etc. The treatment shall remove loose mill scale, rust and foreign matter. Finally, the surface is cleaned with a vacuum cleaner, clean, dry compressed air or a clean brush. It should have a faint metallic sheen. The appearance shall correspond to standard photos designated St 2. (ISO standard 8501-1; It is a pictorial surface preparation standard for painting steel surfaces. Grades St 2 - St 3 describe mechanically cleaned surfaces.)

St 3: Very thorough scraping and wire brushing - machine brushing - grinding - etc. The surface preparation is as for St 2, but much more thoroughly. After removal of dust, the surface shall have a pronounced metallic sheen and correspond to standard photos designated St 3 (See St 2).

2 Class Notation COAT-PSPC(X) – an optional class notation.

The class notation **COAT-PSPC(X)** series will document compliance with the IMO PSPCs, where the '**X**' in the parentheses will denote corrosion prevention of different tanks and spaces/areas, as follows:

- **(B)** IMO PSPC requirements for dedicated seawater ballast tanks of all types of vessels [1],[5].
- **(D)** IMO PSPC requirements for double side-skin spaces of bulk carriers [1],[5].
- **(V)** IMO PSPC for void spaces on bulk carriers and oil tankers [7].
- **(C)** IMO PSPC for cargo oil tanks of crude oil tankers [9],[13].

The notations may be combined, e.g. a Bulk Carrier may have a class notation **COAT-PSPC(B;D;V)**. The class notation **COAT-PSPC(X)** is an Optional Class Notation intended for:

- use before the SOLAS requirements enter into force, or
- vessels with Gross Tonnage (GT) below the limits set in the different SOLAS regulations, or
- vessels that are not required to follow SOLAS (non-SOLAS vessels), or
- vessels that shall follow MODU Code (Code for the Construction and Equipment of Mobile Offshore Drilling Units).

The application of the class notation **COAT-PSPC(X)** is voluntary although it may be used to document or visualize compliance with both mandatory and non-mandatory SOLAS regulations:

- The class notation **COAT-PSPC(X)** is mainly intended for vessels where the IMO PSPCs are not SOLAS requirements.
- The class notation **COAT-PSPC(X)** may be ordered also for vessels following the SOLAS requirements, however, this will then be more for visualisation purpose as compliance is already documented by issuance of the vessels' safety certificate.
- From 2006-12-08 until 2012-07-01 all Common Structural Rules (CSR) vessels contracted for construction had to follow the IMO PSPC-WBT, and the compliance is documented through the class notation **CSR**, but some vessels may also have assigned the class notation **COAT-PSPC(B)** or **COAT-PSPC(B;D)**.

The documentation requirements are outlined in the DNV Rules Pt.6 Ch.31 Sec.2 A102.

3 Coating Technical File (CTF)

All the IMO PSPCs require the shipyard to compile a Coating Technical File (CTF) either in paper or electronic format, or a combination of the two. If more than one of the three IMO PSPCs are to be complied with, the required documentation shall be gathered in one CTF, with separate sections describing each of the IMO PSPCs.

The CTF shall contain all the information required by the IMO PSPCs and shall be reviewed by the DNV Responsible Approval Centre (RAC) for content in accordance with the IMO PSPCs.

3.1 Inspection Agreement

Inspection of surface preparation and coating processes shall be agreed upon, between the ship owner, the shipyard/builder and the coating manufacturer. The signed Inspection Agreement shall be presented to DNV by the shipyard for review and, as a minimum; it shall comply with the IMO PSPCs. It is to be included to the CTF.

The Inspection Agreement, when a ship owner is known and a building contract exists, shall include the signature of that ship owner.

In cases where there are no building contract, and thereby no ship owner the shipyard will also take the role as the "ship owner" until a real ship owner takes over the vessel constructed. The yard will then have to sign the Inspection Agreement also as the ship owner.

In cases where a ship owner, originally having signed the Inspection Agreement, cancels the contract with the shipyard and there is no longer a ship owner, the shipyard may either have a get new ship owner in place that can take over the obligations from the previous ship owner, or the shipyard may elect to stay as the ship owner until the vessel is eventually sold. In such case the shipyard may either issue a letter confirming their new obligations (as an attachment to the Inspection Agreement and the CTF) or the Inspection Agreement may be revised to have the shipyard as the ship owner as well.

3.2 Specifications, Procedures and Approvals

3.2.1 Specifications

- specification of the coating systems to be applied.
- coating technical specification (application procedure, acceptance criteria, inspection procedures etc.).
- Technical Data Sheets for all parts of the coating systems.
- Material Safety Data Sheets for all parts of the coating systems.

3.2.2 Procedures

For the surface preparation, coating application and inspections:

- inspection agreement between builder, owner and the coating manufacturer, including coating inspectors' qualifications.
- detailed criteria for coating selection, job specifications, inspection, maintenance and repair.
- record of the shipyard's coating work.
- procedures for inspection of coating system during ship construction.
- procedures for repair of coating system during ship construction.
- coating forms for coating logs to be issued by the coating inspector.
- shipyard's verified inspection report.
- procedures for in-service maintenance and repair of coating system.

3.2.3 Approvals/Reports

- DNV Type Approval Certificates for the main coating system, listing the relevant shop primers to be used.
- DNV Type Approval Certificates for the shop primers (related to weldability / pore-forming tendency) (voluntary).
- The Technical/Test Reports for the coating systems to be used (voluntary).
- DNV Approval of Service Supplier Certificate for the coating test laboratory (voluntary).

3.3 Coating Inspectors

3.3.1 Coating Inspectors

Coating Inspectors shall inspect surface preparation and coating application during the coating process by carrying out, as a minimum, those inspection items identified in IMO PSPC to ensure compliance with the PSPC. Coating Inspectors shall be qualified to NACE Coating Inspector Level 2, FROSIO Inspector Level III, or an equivalent qualification. In addition to the NACE or FROSIO certificates, Coating Inspectors shall also have at least 2 years relevant experience.

Equivalent qualification: DNV offers review of such equivalent qualifications with basis in IACS UI SC223, PSPC 6, Section 3 and IACS UI SC259, PSPC-COT 6, Section 3 to confirm that the training programme, including exams etc., is considered equivalent to:

- NACE CIP Level 2/CIP Level 2, maritime emphasis and
- FROSIO Inspector Course,

when applied to IMO PSPC / Resolution MSC.215(82) / Resolution MSC.288(87). A Certificate of Compliance is issued, having 3 years validity.

3.3.2 Assistant Coating Inspectors

If the Coating Inspector requires assistance from other persons to do the part of the inspections under the Coating Inspector's supervision, those persons shall be trained to the Coating Inspector's satisfaction. Such training should be recorded and endorsed either by the Coating Inspector, the yard's training organisation or inspection equipment manufacturer to confirm competence in using the measuring equipment and confirm knowledge of the measurements required by the PSPC. Training records shall be available for verification if required.

4 Verification

4.1 Initial review of CTF

The initial CTF including the Inspection Agreement, the specifications and the procedures shall be reviewed by DNV RAC and approved before the project starts. The technical- and material safety data sheets, coating system approval (the DNV Type Approval Certificate) and the Coatings Inspectors' qualifications shall be included to the CTF.

4.2 Inspection requirements

During the project, the implementation of PSPC will be monitored by the DNV Surveyor (Project Manager or a Project Team Member). This implies checking on a sampling basis that the Coating Inspector uses correct equipment, techniques and reporting methods. Similarly, the results from the surface preparation, coating logs and other inspection reports are checked on a sampling basis.

The attending DNV Surveyor will not verify the application of the coating system, but will (on a sampling basis) review the reports of the Coating Inspector to verify that the specified procedures have been followed.

4.3 Final review of CTF

The final CTF, issued as a new revision to the initial CTF, shall be stamped with "Reviewed" and "And found to comply with:

- IMO Resolution MSC.215(82) and/or
- IMO Resolution MSC.288(87) and/or
- IMO Resolution MSC.244(83) and/or
- IMO MSC.1/Circ.1279".

The final CTF shall be kept on board the vessel as either electronic copy, paper copy or combination of both and be updated, when relevant, see Sec.5.

5 Vessels in Operation

During operational phase any maintenance or repair of the applied coating system shall be documented and added to the CTF on board the vessel.

Please refer to IMO MSC.1/Circ.1330 [12] for Guidance.

6 References

[1] IMO Resolution MSC.215(82) *Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin space of bulk carriers*, adopted 8 December 2006.

[2] SOLAS Amendments, Regulation II-1/3-2, *Protective coating of dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers*, adopted by resolution MSC.216(82) 8 De-cember 2006.

[3] IMO MSC.1/Circ.1378 *Unified interpretations of the performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers (res-olution MSC.215(82))*, 8 December 2010.

[4] IMO DE 51/14/1 *Guideline for implementation of performance standard for protective coatings for ded-icated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers (resolution MSC.215(82))*, 16 November 2007.

[5] IACS Unified Interpretation (UI) SC223, *For Application of SOLAS Regulation II-1/3-2 Performance Standard for Protective Coatings (PSPC) for Dedicated Seawater Ballast Tanks in All Types of Ships and Double-side Skin Spaces of Bulk Carriers, adopted by Resolution MSC.215(82)*, July 2011.

[6] IACS Unified Interpretation (UI) SC227, *The dedicated seawater ballast tanks in SOLAS Chapter II-1 (Regulation 3-2)*, May 2011.

[7] IMO Resolution MSC.244(83) *Performance standard for protective coatings for void spaces on bulk carriers and oil tankers*, October 2007.

[8] SOLAS Amendment, Regulation II-1/3-11, 21, *Corrosion protection of cargo oil tanks of crude oil tank- ers* adopted by resolution MSC.216(82), 11 May 2010

[9] IMO Resolution MSC.288(87), *Performance standard for protective coatings for cargo oil tanks of crude oil tankers*, 21 May 2010

[10] DNV's sample Coating Technical File (Ballast Tanks and Cargo Oil Tanks), Rev 1, March 2011

[11] Det Norske Veritas Rules for Classification of Ships (July 2012 or later edition).

[12] IMO MSC.1/Circ.1330 *Guidelines for Maintenance and Repair of Protective Coatings*, 11 June 2009.

IACS Unified Interpretations SC259. For Application of SOLAS Regulation II-1/3-11 Performance Standard for Protective Coatings for Cargo Oil Tanks of Crude Oil Tankers (PSPC-COT), adopted by Resolution MSC.288(87)

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