Guide for the Selection, Application and Maintenance of Corrosion Prevention Systems for Ships' Ballast Tanks

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GENERAL CONDITIONS

Definitions:

"*Administration*" means the Government of the State whose flag the Ship is entitled to fly or under whose authority the Ship is authorized to operate in the specific case.

"IACS" means the International Association of Classification Societies.

"*Interested Party*" means the party, other than the Society, having an interest in or responsibility for the Ship, product, plant or system subject to classification or certification (such as the owner of the Ship and his representatives, the ship builder, the engine builder or the supplier of parts to be tested) who requests the Services or on whose behalf the Services are requested.

"*Owner*" means the registered owner, the ship owner, the manager or any other party with the responsibility, legally or contractually, to keep the ship seaworthy or in service, having particular regard to the provisions relating to the maintenance of class laid down in Part A, Chapter 2 of the Rules for the Classification of Ships or in the corresponding rules indicated in the specific Rules.

"Rules" in these General Conditions means the documents below issued by the Society:

- (i) Rules for the Classification of Ships or other special units;
- (ii) Complementary Rules containing the requirements for product, plant, system and other certification or containing the requirements for the assignment of additional class notations;
- (iii) Rules for the application of statutory rules, containing the rules to perform the duties delegated by Administrations;
- (iv) Guides to carry out particular activities connected with Services;
- (v) Any other technical document, as for example rule variations or interpretations.

"*Services*" means the activities described in Article 1 below, rendered by the Society upon request made by or on behalf of the Interested Party.

"Ship" means ships, boats, craft and other special units, as for example offshore structures, floating units and underwater craft.

"*Society*" or *"TASNEEF"* means Tasneef and/or all the companies in the Tasneef Group which provide the Services.

"*Surveyor*" means technical staff acting on behalf of the Society in performing the Services.

Article 1

1.1. The purpose of the Society is, among others, the classification and certification of ships and the certification of their parts and components. In particular, the Society:

- (i) sets forth and develops Rules;
- (ii) publishes the Register of Ships;
- (iii) issues certificates, statements and reports based on its survey activities.

1.2. The Society also takes part in the implementation of national and international rules and standards as delegated by various Governments.

1.3. The Society carries out technical assistance activities on request and provides special services outside the scope of classification, which are regulated by these general conditions, unless expressly excluded in the particular contract.

Article 2

2.1. The Rules developed by the Society reflect the level of its technical knowledge at the time they are published. Therefore, the Society, although committed also through its research and development services to continuous updating of the Rules, does not guarantee the Rules meet state-of-the-art science and technology at the time of publication or that they meet the Society's or others' subsequent technical developments.

2.2. The Interested Party is required to know the Rules on the basis of which the Services are provided. With particular reference to Classification Services, special attention is to be given to the Rules concerning class suspension, withdrawal and reinstatement. In case of doubt or inaccuracy, the Interested Party is to promptly contact the Society for clarification.
The Rules for Classification of Ships are published on the Society's website: www.tasneef.ae.

2.3. The Society exercises due care and skill:

- (i) in the selection of its Surveyors
- (ii) in the performance of its Services, taking into account the level of its technical knowledge at the time the Services are performed.

2.4. Surveys conducted by the Society include, but are not limited to, visual inspection and non-destructive testing. Unless otherwise required, surveys are conducted through sampling techniques and do not consist of comprehensive verification or monitoring of the Ship or of the items subject to certification. The surveys and checks made by the Society on board ship do not necessarily require the constant and continuous presence of the Surveyor. The Society may also commission laboratory testing, underwater inspection and other checks carried out by and under the responsibility of qualified service suppliers. Survey practices and procedures are selected by the Society based on its experience and knowledge and according to generally accepted technical standards in the sector.

Article 3

3.1. The class assigned to a Ship, like the reports, statements, certificates or any other document or information issued by the Society, reflects the opinion of the Society concerning compliance, at the time the Service is provided, of the Ship or product subject to certification, with the applicable Rules (given the intended use and within the relevant time frame).
The Society is under no obligation to make statements or provide information about elements or facts which are not part of the specific scope of the Service requested by the Interested Party or on its behalf.

3.2. No report, statement, notation on a plan, review, Certificate of Classification, document or information issued or given as part of the Services provided by the Society shall have any legal effect or implication other than a representation that, on the basis of the checks made by the Society, the Ship, structure, materials, equipment, machinery or any other item covered by such document or information meet the Rules. Any such document is issued solely for the use of the Society, its committees and clients or other duly authorised bodies and for no other purpose. Therefore, the Society cannot be held liable for any act made or document issued by other parties on the basis of the statements or information given by the Society. The validity, application, meaning and interpretation of a Certificate of Classification, or any other document or information issued by the Society in connection with its Services, is governed by the Rules of the Society, which is the sole subject entitled to make such interpretation. Any disagreement on technical matters between the Interested Party and the Surveyor in the carrying out of his functions shall be raised in writing as soon as possible with the Society, which will settle any divergence of opinion or dispute.

3.3. The classification of a Ship, or the issuance of a certificate or other document connected with classification or certificate on and in general with the performance of Services by the Society shall have the validity conferred upon it by the Rules of the Society at the time of the assignment of class or issuance of the certificate; in no case shall it amount to a statement or warranty of seaworthiness, structural integrity, quality or fitness for a particular purpose or service of any Ship, structure, material, equipment or machinery inspected or tested by the Society.

3.4. Any document issued by the Society in relation to its activities reflects the condition of the Ship or the subject of certification or other activity at the time of the check.

3.5. The Rules, surveys and activities performed by the Society, reports, certificates and other documents issued by the Society are in no way intended to replace the duties and responsibilities of other parties such as Governments, designers, ship builders, manufacturers, repairers, suppliers, contractors or sub-contractors, Owners, operators, charterers, underwriters, sellers or intended buyers of a Ship or other product or system surveyed.

These documents and activities do not relieve such parties from any fulfilment, warranty, responsibility, duty or obligation (also of a contractual nature) expressed or implied or in any case incumbent on them, nor do they confer on such parties any right, claim or cause of action against the Society. With particular regard to the duties of the ship Owner, the Services undertaken by the Society do not relieve the Owner of his duty to ensure proper maintenance of the Ship and ensure seaworthiness at all times. Likewise, the Rules, surveys performed, reports, certificates and other documents issued by the Society are intended neither to guarantee the buyers of the Ship, its components or any other surveyed or certified item, nor to relieve the seller of the duties arising out of the law or the contract, regarding the quality, commercial value or characteristics of the item which is the subject of transaction.

In no case, therefore, shall the Society assume the obligations incumbent upon the above-mentioned parties, even when it is consulted in connection with matters not covered by its Rules or other documents.

In consideration of the above, the Interested Party undertakes to relieve and hold harmless the Society from any third party claim, as well as from any liability in relation to the latter concerning the Services rendered.

Insofar as they are not expressly provided for in these General Conditions, the duties and responsibilities of the Owner and Interested Parties with respect to the services rendered by the Society are described in the Rules applicable to the specific Service rendered.

Article 4

4.1. Any request for the Society's Services shall be submitted in writing and signed by or on behalf of the Interested Party. Such a request will be considered irrevocable as soon as received by the Society and shall entail acceptance by the applicant of all relevant requirements of the Rules, including these General Conditions. Upon acceptance of the written request by the Society, a contract between the Society and the Interested Party is entered into, which is regulated by the present General Conditions.

4.2. In consideration of the Services rendered by the Society, the Interested Party and the person requesting the service shall be jointly liable for the payment of the relevant fees, even if the service is not concluded for any cause not pertaining to the Society. In the latter case, the Society shall not be held liable for non-fulfilment or partial fulfilment of the Services requested. In the event of late payment, interest at the legal current rate increased by 1.5% may be demanded.

4.3. The contract for the classification of a Ship or for other Services may be terminated and any certificates revoked at the request of one of the parties, subject to at least 30 days' notice to be given in writing. Failure to pay, even in part, the fees due for Services carried out by the Society will entitle the Society to immediately terminate the contract and suspend the Services.

For every termination of the contract, the fees for the activities performed until the time of the termination shall be owed to the Society as well as the expenses incurred in view of activities already programmed; this is without prejudice to the right to compensation due to the Society as a consequence of the termination.

With particular reference to Ship classification and certification, unless decided otherwise by the Society, termination of the contract implies that the assignment of class to a Ship is withheld or, if already assigned, that it is suspended or withdrawn; any statutory certificates issued by the Society will be withdrawn in those cases where provided for by agreements between the Society and the flag State.

Article 5

5.1. In providing the Services, as well as other correlated information or advice, the Society, its Surveyors, servants or agents operate with due diligence for the proper execution of the activity. However, considering the nature of the activities performed (see art. 2.4), it is not possible to guarantee absolute accuracy, correctness and completeness of any information or advice supplied. Express and implied warranties are specifically disclaimed.

Therefore, except as provided for in paragraph 5.2 below, and also in the case of activities carried out by delegation of Governments, neither the Society nor any of its Surveyors will be liable for any loss, damage or expense of whatever nature sustained by any person, in tort or in contract, derived from carrying out the Services.

5.2. Notwithstanding the provisions in paragraph 5.1 above, should any user of the Society's Services prove that he has suffered a loss or damage due to any negligent act or omission of the Society, its Surveyors, servants or agents, then the Society will pay compensation to such person for his proved loss, up to, but not exceeding, five times the amount of the fees charged for the specific services, information or opinions from which the loss or damage derives or, if no fee has been charged, a maximum of AED5,000 (Arab Emirates Dirhams Five Thousand only). Where the fees charged are related to a number of Services, the amount of the fees will be apportioned for the purpose of the calculation of the maximum compensation, by reference to the estimated time involved in the performance of the Service from which the damage or loss derives. Any liability for indirect or consequential loss, damage or expense is specifically excluded. In any case, irrespective of the amount of the fees charged, the maximum damages payable by the Society will not be more than AED5,000,000 (Arab Emirates Dirhams Five Millions only). Payment of compensation under this paragraph will not entail any admission of responsibility and/or liability by the Society and will be made without prejudice to the disclaimer clause contained in paragraph 5.1 above.

5.3. Any claim for loss or damage of whatever nature by virtue of the provisions set forth herein shall be made to the Society in writing, within the shorter of the following periods: (i) THREE (3) MONTHS from the date on which the Services were performed, or (ii) THREE (3) MONTHS from the date on which the damage was discovered. Failure to comply with the above deadline will constitute an absolute bar to the pursuit of such a claim against the Society.

Article 6

6.1. These General Conditions shall be governed by and construed in accordance with United Arab Emirates (UAE) law, and any dispute arising from or in connection with the Rules or with the Services of the Society, including any issues concerning responsibility, liability or limitations of liability of the Society, shall be determined in accordance with UAE law. The courts of the Dubai International Financial Centre (DIFC) shall have exclusive jurisdiction in relation to any claim or dispute which may arise out of or in connection with the Rules or with the Services of the Society.

6.2. However,

(i) In cases where neither the claim nor any counterclaim exceeds the sum of AED300,000 (Arab Emirates Dirhams Three Hundred Thousand) the dispute shall be referred to the jurisdiction of the DIFC Small Claims Tribunal; and

(ii) for disputes concerning non-payment of the fees and/or expenses due to the Society for services, the Society shall have the

INDEX

INDEX

INDEX

1 INTRODUCTION

Corrosion is one of the main causes of structural deterioration of a ship during its life. Corrosion is a natural phenomenon, therefore it is possible to prevent it or to slow it down, but not to eliminate it.

Ballast tank surfaces of any ship are certainly the area most subject to corrosion. The corrosive process is influenced and developed by many factors, like ship type, project, structural design, trading, use and many others.

The best method to prevent corrosion is the application of a protective coating. The life of this protection depends mainly on choices and procedures implemented during the construction of the ship. Therefore in this Guide some technical information and practical advice will be provided, which, if implemented, could ensure long-term corrosion protection of ballast tank surfaces.

This Guide gives the general requirements for the selection, application and maintenance of corrosion prevention systems for ships' ballast tanks.

In the case of discrepancies between the applicable classification Rules and statutory regulations indicated in the following items, the latter will prevail.

1.1 Rules

The reference Rules are briefly described below.

1.1.1 SOLAS CONVENTION

Regulation II-1/3-2: Protective coatings of dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers.

1 Paragraphs 2 and 4 of this regulation shall apply to ships of not less than 500 gross tonnage;

- 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
- the delivery of which is on or after 1 July 2012.

2 All dedicated seawater ballast tanks arranged in ships and double-side skin spaces arranged in bulk carriers of 150 m in length and upwards shall be coated during construction in accordance with 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 by the Maritime Safety Committee by resolution MSC.215(82) […].

3 All dedicated seawater ballast tanks arranged in oil tankers and bulk carriers constructed on or after 1 July 1998, for which paragraph 2 is not applicable, shall comply with the requirements of Regulation II-1/3-2 adopted by Resolution MSC.47(66).

4 Maintenance of the protective coating system shall be included in the overall ship's maintenance scheme. The effectiveness of the protective coating system shall be verified during the life of a ship by the Administration or an organisation recognised by the Administration, based on the guidelines developed by the Organisation.*

* Refer to Guidelines for maintenance under repair of protective coatings (MSC.1/Circ. 1330).

1.1.2 IMO Resolution MSC. 215 (82)

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", adopted by IMO on 8 December 2006 and entered into force on 1 July 2008.

This Standard provides technical requirements for protective coatings in dedicated seawater ballast tanks of all type of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of 150 m in length and upwards.

1.1.3 MARPOL Convention

Regulation 19 of Annex 1 of MARPOL Convention requires that all tankers (oil tankers, product carriers, chemical tankers when carrying oils) must have a double hull dedicated to seawater ballast.

1.1.4 IMO Resolution A.798(19)

Resolution A.798(19) "Guidelines for the selection, application and maintenance of corrosion prevention systems of dedicated seawater ballast tanks", adopted by IMO on 23 November 1995.

1.1.5 IMO Resolution A.744(18) as amended

Resolution A.744(18) "Guidelines on the enhanced programme of inspections during surveys of bulk carriers and oil tankers" (adopting the Enhanced Survey Program prepared by IACS and defined in Unified Requirements Z7, Z10.1, Z10.2 and Z11) as amended by IMO Resolution MSC.261(84) including Part B "Guidelines for the selection, application and maintenance of corrosion prevention systems of dedicated seawater ballast".

On the whole these unified requirements define that the frequency of periodic hull surveys, related to ballast tanks after the first five years, is connected to coating condition.

1.1.6 Tasneef Rules

Tasneef "Rules for the classification of ships" including requirements for the corrosion prevention of hull structures (see Part B, Ch 11; Part E; Part F, Ch 13, Sec 12 and App 5).

Tasneef Rules for the Certification of Coating Systems containing the requirements for the issuance of the Type Approval Certificate required by IMO Res. MSC.215(82) (see [1.1.2]).

2 CORROSION

2.1 Introduction

Corrosion is an electrochemical process by which materials deteriorate as a consequence of the reaction between the material itself and the environment.

The corrosion mechanism is very complex. A detailed study would be beyond the scope of this Guide. Therefore basic elements will be provided to understand the phenomenon, the causes and different typologies connected with steel corrosion, only.

2.2 Causes of corrosion

The main cause of steel corrosion is its chemical instability. Steel becomes stable by oxidation and has the tendency of returning to the natural condition of ore from which it was produced.

For corrosion to occur, the following four components must be present:

- An anode
- A cathode
- An electrolyte
- An electric path (circuit) connecting anode and cathode.

2.3 Corrosion cell

During the corrosive process, electricity passes from a negative area (called *anode*) of a piece of steel to a positive area (called *cathode*) through an external conductive vehicle (called *electrolyte*). The electric path is completed when electricity returns to the anode.

Metal loss (corrosion) occurs in the anodic area while the cathodic area is protected. Chemical reactions occurring in the anodic area are acid and those that occur at the cathode are alkaline with development of hydrogen gas. These reactions can be illustrated as follows:

Anode: $Fe \Rightarrow \underbrace{Fe^{2+}}_{\text{Ferrous Ions}} + \underbrace{2e^-}_{\text{Electrons}}$

The two free electrons cause the following two reactions:

Cathode: $\underbrace{2H^+}_{\text{Hydrogen Ion}} + 2e^- \Rightarrow \underbrace{2H}_{\text{Hydrogen atom}} \Rightarrow \underbrace{H_2}_{\text{Hydrogen gas}}$

or

$2H_2O + O_2 + 4e \Rightarrow \underbrace{4OH^-}_{\text{Hydroxyl Ions}}$

The Hydroxyl ions, extensively produced by water ionisation, react with ferrous ions producing various forms of rust (all of them detectable on ballast tank surfaces): brown rust (Fe_2O_3), black magnetite (Fe_3O_4) and green hydrated magnetite (Fe_3O_4 x H_2O).

An important factor affecting the corrosion rate is the cathode or anode electrical potential.

They are several tables listing the potential of metals (also named electro-negativity, namely their tendency to go in solution) in a particular environment. In Table 1 these potentials referred to seawater are listed.

If two metals of Table 1 are in contact in an electrolyte, the corrosion rate of the higher one in the table will increase, while that of the lower one will decrease. Similarly, a single piece of steel has a slight difference of chemical composition or physical proprieties in different areas. These differences act as anodes and cathodes and initiate a corrosion process. As occurs for metals of different composition, the greater the electronegative potentials in anode and cathode areas are on the same piece of metal, the greater the corrosion rate is.

Table 1
Galvanic Series in Sea Water

Less Noble	More anodic	Higher Corrosiveness	Potential mV
↑	Sodium (Na)	↑	- 2,300
	Magnesium (Mg)		- 1,400
	Zinc (Zn)		- 760
	Aluminium (Al)		- 530
	Steel-Iron (Fe)		- 400
	Nickel (not passivated) (Ni)		- 30
	Copper (Cu)		+ 40
	Mill scale		+ 45
	Nickel passivated (Ni)		+ 50
	Stainless steel (active)		+ 70
	Silver (Ag)		+ 300
	Stainless steel (passive)		+ 310
	Titanium (passive) (Ti)		+ 370
	Platinum (Pt)		+ 470
↓	Gold (Au)	↓	+ 690
More noble	More cathodic	Lower Corrosiveness	

2.4 Common forms of corrosion

There are many forms of corrosion. In the following items the common forms of corrosion usually observed in ballast tanks are briefly described.

2.4.1 Uniform corrosion

The anodic and cathodic areas on the same piece of steel can change with time, so that areas that were once anodes become cathodes and vice versa. This process allows the formation of a relatively uniform corrosion of steel in similar environments.

2.4.2 Galvanic corrosion

Galvanic corrosion occurs when two dissimilar metals are in contact in an electrolyte. The less noble metal (anode) will corrode at a higher rate compared to the more noble metal that will be protected or will corrode at a lower rate.

Potential difference can exist on a piece of similar metal and cause galvanic corrosion. The following factors can cause these differences:

- New steel is anodic to old steel
- Steel is anodic to mill scale
- Brightly cut surfaces are anodic to uncut surfaces
- Cold worked areas are anodic to less stressed areas.

2.4.3 Localised corrosion (pitting)

Pitting corrosion is one of more common forms that can be noted in ballast tanks. It is caused by the action of a localised corrosion cell on a steel surface due to the breaking of the coating, to the presence of contaminants or impurities on the steel (e.g. mill scale) or to impurities present in the steel composition.

Pitting occurs every time an electric current leaves the steel going into the electrolyte.

Furthermore, the defective areas of a coating or any other damage, can become anodic to the surrounding intact coated surface and cause a corrosion process.

Pitting is a very dangerous form of corrosion, which can have tremendous consequences, causing steel perforation in a short time.

2.4.4 Crevice corrosion

Crevice corrosion is also localised corrosion that appears as pitting. The most common case occurs in cracks and generally on steel surfaces covered by scales and deposits. Typical examples are skip welding seams, pipe supports and bolts.

The phenomenon is due to the fact that a small area of steel (i.e. the crevice, the crack or the area covered by debris) lacks oxygen and becomes the anode of a corrosion cell, while the remaining free surface, abundantly oxygenated, becomes the cathode. Since the anodic area is very small compared to the cathodic one, the corrosion process is extremely fast.

2.4.5 Bacterial corrosion

Bacterial Corrosion appears as scattered and/or localised pitting.

Micro-organisms contributing to this form of corrosion include aerobic and anaerobic bacteria, fungi and other organisms. Sulphate Reducing Bacteria (SRB) is the most important group of micro-organisms. These species are anaerobic in nature and obtain their needs of sulphur by a complex chemical reaction. During this reaction the organism assimilates a small amount of sulphur, while the majority is released into the immediate environment as sulphide ions, which are hydrolysed as free H_2S. In this way SRB give rise to a corrosive process that supports the anodic dissolution of the steel. When bacteria have started to produce sulphide, the environmental condition becomes more favourable for growth, resulting in a population explosion.

A ballasting operation can provide a source of microbiological infection or of nourishment. If, for example, these operations are carried out in the port, seawater and mud characteristics are extremely important.

2.4.6 Erosion corrosion

Corrosion due to erosion occurs when sand or other abrasives held in the water or a water flow impinges, with a certain velocity, an existing corrosion cell. The sand or the water flows remove the accumulation of corrosion products keeping the metal clean and the corrosion active. There are three forms of corrosion that can be connected to velocity:

a) impact caused by air bubbles
b) cavitation due to void formation or cavities in the water due to turbulence
c) erosion caused by the slime and mud present in the water

2.4.7 Stress Corrosion

Steel subject to stress or fatigue can be affected by fractures, even small. These areas act as a crevice and due to low aeration, will corrode as already described. Furthermore, a fracture can also cause micro cracking on the protective coating, giving rise to a very active corrosion cell.

2.5 Corrosion rate

Development of the corrosion process of steel in seawater is affected by many factors. A detailed analysis would be beyond the scope of this Guide. Seawater is a complex mixture containing several salts, suspended mud, gases, bacteria, various species of micro-organisms etc. All together or simply one may affect the corrosion process considerably making a situation already complicated at its origin even more complex.

In any case the following factors considerably influence corrosion rate: oxygen, temperature and salinity.

2.5.1 Oxygen

High oxygen content significantly affects the chemical reaction that occurs at the cathode (as shown in the equation of item 2.3 above) and consequently a more rapid metal loss at the anode (namely an increase of the corrosion rate).

2.5.2 Temperature

Like any other chemical reaction, the corrosion process rate increases when the temperature increases. For information only the relative corrosion rates at various temperatures are listed in Table 2, assigning the value 1 to the temperature of 0°C:

Table 2
Relative corrosion rate at various temperatures

TEMPERATURE	RELATIVE RATE
0°C	1
10°C	1,4
20°C	2
30°C	2,6
40°C	4

2.5.3 Salinity

Seawater is an excellent electrolyte since, containing a certain amount of salts, it is very conductive.

In oceans the average salt content is 3,2-3,7% for surface water. This concentration changes significantly in some specific areas, ranging for example from 8.000 PPM of the Baltic Sea to 41.000 PPM of the Mediterranean Sea.

The changes of total content of dissolved salts in various seas affect water conductivity. A higher amount of salts means greater conductivity, which is quite sufficient to cause an increase of the corrosion process.

Chloride ions, present in salts, tend to accelerate the corrosion rate due to the formation of permeable corrosion product layers.

2.5.4 Other factors affecting the corrosion process of ballast tanks

The corrosion process of ballast tank surfaces, besides being influenced by the above mentioned phenomena, is considerably influenced by a long series of other variables such as:

1) Ballasting frequency
2) Full or partial filling of the tank
3) Cleanliness of ballast water loaded
4) Frequency of sediment removal
5) Cargo temperature of adjacent tanks
6) Design and structure of the tank or double bottom
7) Coating type, application and related maintenance
8) Presence of sacrificial anodes

2.6 Corrosion control methods

There are several methods to control the corrosion process. Each method has its advantages and limitations. In this Guide those concerning ballast tanks will be considered, specifying that although each method will be separately described, the best solution in a total corrosion program, is a suitable combination of all methods.

2.6.1 Design

Corrosion prevention already starts during the design stage of the ship. A suitable structural design may control the corrosion by eliminating one or more components necessary for the corrosion reaction or by permitting an easier application of other methods of corrosion control and prevention. A good design must avoid:

1. Contact of dissimilar metals
2. Stagnation and water traps
3. Crevices (e.g. skip welds or irregular welding seams), that apart from the already described reasons, are difficult to protect with coating
4. Irregular and sharp surfaces, because they are difficult to coat with the correct film thickness
5. Difficult-to-reach-areas, since they can prevent the correct application of the coating

2.6.2 Cathodic protection

Cathodic Protection is a system of corrosion control by means of which a sufficient amount of direct current passing onto a metallic surface, converts the entire anodic surface to a cathodic area. Cathodic protection is effective only when the metallic surface is immersed.

A cathodic protection system can be carried out by means of impressed current equipment or by sacrificial anodes.

In ballast tanks the impressed current system is not permitted, due to the large amount of hydrogen gas produced by the process. Therefore only a system of sacrificial anodes (zinc or aluminium) is used. Anodes generate the necessary direct current so that they are corroded by their natural potential difference, protecting the surrounding steel.

Details of cathodic protection are described in Chapter 8.

2.6.3 Protective coating (paints)

Coatings can protect metals from corrosion by providing a barrier between the metal and the electrolyte, preventing or inhibiting the corrosion process or in some cases by a particular form of cathodic protection.

3 PAINTS AND PAINT SYSTEMS FOR BALLAST TANKS

3.1 What is paint?

The International Organization for Standardization (ISO) in the standard ISO 4618/1 (Paints and Varnishes - Vocabulary -Part 1: General terms) defines paint as follows:

"Paint is a product, liquid or in powder form, containing pigment(s), which, when applied to a substrate, forms an opaque film having protective, decorative or specific technical properties."

The main characteristic of a liquid paint is its capability of changing into a solid and adherent film, after its application on a substrate at a defined thickness. This can be obtained by selection of appropriate ingredients and fabrication processes.

3.2 The composition of paint

Paints consist of two main elements: the non-volatile part (which is successively acting to form the film) and the volatile part, outlined in Figure 1:

The following components form the non-volatile part:

- **Resin** or **Vehicle**: this determines the main properties: adhesion, flexibility, hardness, chemical and physical resistance. Generally, paints are identified according to resin (epoxy, alkyd, vinyl, polyurethane, acrylic etc.).
- **Pigment**: a solid, organic or inorganic substance that, reduced to a fine powder, gives the paint colour and coverage proprieties. Generally, it is insoluble in both the binder and the solvent.
- **Extender**: a solid substance, reduced to a fine powder with poor hiding power. It is added to give to the film particular mechanical or physical properties, such as: abrasion resistance, hardness, impermeability, chemical resistance etc.
- **Additives**: Liquid or solid substances that, added in small percentage to paint formulation, make manufacture easier and improve some properties like application, the drying process and stability of the finished product.

The volatile part is formed by the **Solvent** only.

Solvent is an organic volatile liquid or a mixture of organic liquids, which leads the resin to the desired viscosity, allowing the correct fabrication process. A solvent has to melt resins without modifying their chemical nature and gives homogeneous and unchangeable solutions. Furthermore, a solvent influences - by evaporation - the correct film formation.

The combination of resin and solvent is called **Binder**.

Based on the type of binder, paints can be divided in two categories: Thermosetting and Thermoplastic. Figure 2 shows, in a schematic form, various paint types related to their drying process:

Thermoplastic or ***Non Convertible*** are defined paints having the following properties:

a) film formation occurs by solvent evaporation without any polymer increase

b) final properties are the same as the original polymer

c) film can be redissolved

d) film is heat sensitive

Thermosetting or ***Convertible*** are defined paints having the following properties:

a) film formation occurs by chemical reaction with a polymer increase

b) final properties are the same as the new molecular structure formed after film formation

c) film cannot be returned to its original polymer by solvent or by heating

3.3 The properties and uses of paints

Since this Guide has been exclusively prepared for the corrosion protection of ballast tank surfaces, the properties of the paints that are mainly used for this purpose will be briefly described.

3.3.1 Thermoplastic paints

3.3.1.1 Vinyl paints

Vinyl paints are one-component, physical drying. In the marine industry, modified vinyl-tar products are mainly used.

- ***Properties***: Excellent humidity resistance. Good resistance to acids and base. Fair weathering resistance. Good mechanical properties. Limited resistance to temperature. Low solid content and high solvent content. Excellent covering characteristics. Quick drying. Excellent resistance to immersion service and good cathodic protection resistance.
- ***Uses***: Vinyl paints have low wetting properties. During application, they are extremely sensitive to humidity. Application on other paints requires particular attention, since strong solvents could cause the lifting of coats underneath.

3.3.1.2 Bitumen and Coal Tar paints

Bitumen paints are one-component, physical drying.

- ***Properties***: Excellent recoating proprieties, as well as water/humidity resistance. Poor resistance to solvents and temperature. Good adhesion on old coat residues. Limited covering properties due to tar presence. Tar has the tendency to migrate through the coat applied on it toward the surface of the paint system, modifying the colour and causing the phenomenon called "Bleeding". This happens to those systems, which are used for non-immersed areas.

- ***Uses***: Excellent wettability. They may be applied on non-abrasive blasted surfaces, provided that they are free of mill scale and wire brushed. The film, when cured becomes softened with temperature increase.

3.3.1.3 Emulsion paints

- ***Properties***: Emulsion paints cure by evaporation of the water contained in them. The most widely used are: vinyl, acrylic, as well as epoxy and polyurethane.

  When applied on a surface the water evaporates and the emulsionated resin particles come into contact. This process, called coalescence, allows the final formation of a continuous film. When cured, the film is insoluble in water.

- ***Uses***: Films obtained with this kind of paint have a lower resistance to water, to chemicals and to corrosion than other films formed by solvent based paints.
  However, the technology in development of these products is in progress, considering the strict rules related to environmental problems.

  Presence of water causes some limits e.g. storage and application temperature, evaporation rate etc.

3.3.2 Thermosetting paints

3.3.2.1 Epoxies

Epoxy paints are two-component, curing by chemical reaction between a base and a hardener, or curing agent. They may be formulated in an extended range of solvent content: from 0 to 50% of volume.

Formulations with high solvent content are usually used as primers and, in this case, overcoating property is less critical compared to high solid product. However, to avoid adhesion problems, it is a good practice to follow minimum and maximum overcoating times carefully, according to manufacturer's instructions.

- ***Properties***: Good resistance to chemicals, oils and solvents. Good resistance to water and humidity and to temperatures up to 80/120°C. Good resistance to weathering. Poor cosmetic property, since these paints have the tendency to become yellow and to chalk when exposed to the sun. Good mechanical properties. They allow the application of high coat thickness.

- ***Uses***: Epoxy paints are characterised by a low wettability. They require great attention during surface preparation. Solvent-based epoxy can be applied with a temperature higher than 5°C, while solvent free epoxy can generally be applied with a temperature higher than 10°C. At lower temperatures, the drying/curing process does not occur or it is slowed down.

  Strong solvent content means being prudent during application on old coatings to avoid risk of lifting of coats underneath and adhesion problems.

  The use of epoxy paints is ever increasing and the wide variability of their formulation may reduce any schematic definition.

  There are several heterogeneous formulations, which give hybrid properties: vinyl epoxy, coal tar epoxy, urethane-epoxy, surface tolerant, anti-abrasion etc. as briefly reported below.

3.3.1.1.1 Phenolic Epoxies

- ***Properties***: These resins are the result of a chemical reaction between the epoxy and a phenolic reactive resin. A suitable resin selection permits calibration of the required proprieties.

- ***Uses***: In the marine industry, phenolic epoxies, curing at ambient temperature, are generally used for cargo tank coating. They have a high chemical inertia and high resistance to temperature.

3.3.1.1.2 Coal Tar Epoxies

- ***Properties***: These are epoxy paints modified with pitch coal tar. They have a high water resistance, a good wetting property and good resistance to cathodic protection.

- ***Uses***: For many years this coating has been considered the best and widely used mainly for immersed areas of ships (Bottoms and Ballast Tanks). Due to the presence of tar, which could induce cancer, use of these paints is subject to greater restriction.

3.3.2.1.3 Epoxy Mastic or Surface Tolerant.

At present, there is a wide use of these recent paints, for their typical properties.

- ***Properties and uses***

  Good wetting power: These paints are formulated and produced for surfaces that have not received an adequate level of cleaning. They are mainly applied when the supports could not be abrasive blasted and, for this reason, have to tolerate a light rust.

Good adhesion: They can be applied on old, clean and adherent coatings, without lifting them.

Barrier Effect: It is their main property, for that reason they require high thickness application.

Advantages: Low solvent content, low environmental pollution, paint system maintenance is easier, reduction of operation times, reduction of surface preparation costs.

The surfaces to be coated with a surface tolerant, have in any case to be free of mill scale, salts, dusts, humidity and any other non-adherent material. Application on rust scale, even if apparently adherent, is not recommended.

3.3.2.2 Moisture Cured Polyurethanes

Moisture cured polyurethanes cure by water absorption (air humidity). They are one-component, chemical drying.

- ***Properties***: due to the presence of strong solvents, which could cause the lifting of coats underneath, precautions have to be taken before application on other existing coatings. They may be applied on humid surfaces. Good surface preparation is required (abrasive blasting is preferable). Good resistance to chemicals and to mechanical damage. They have the tendency to chalk when exposed to the sun.

3.3.2.3 Zinc Rich paints

- ***Properties***: These products are two-component, generally a zinc powder to which a liquid catalyst is added and cure chemically. The drying process depends on relative air humidity. They have to be applied directly on abrasive blasted steel to ISO 8501-1 Sa3 and suitable profile.

  The coating is extremely resistant to mechanical damage, to heat and to organic solvents. While organic paints with conventional anticorrosive pigment, contribute to the corrosion protection by a barrier effect that insulates the steel support from corrosion agents, Zinc-rich paints also protect the steel cathodically, following the principle of active cathodic protection. In this way corrosion protection is extended to uncoated areas adjacent the coating, avoiding risk of corrosion due to damage and pore formations.

  Zinc Rich paints can be divided into two types:

  - Zinc paint with organic binder (epoxy, vinyl, alkyd)
  - Zinc paint with inorganic binder (water soluble silicate or ethyl silicate soluble in solvents)

- ***Uses***: As single coat on paint systems for cargo tanks, mainly of chemical tankers. As first coat in paint systems for any type of steel construction subject to particular stresses and mechanical damage or exposed to aggressive environment and immersion. It is the best and longest lasting coating for ballast tanks, if overcoated with suitable epoxy system.

Figure 1 - The Composition of Paint

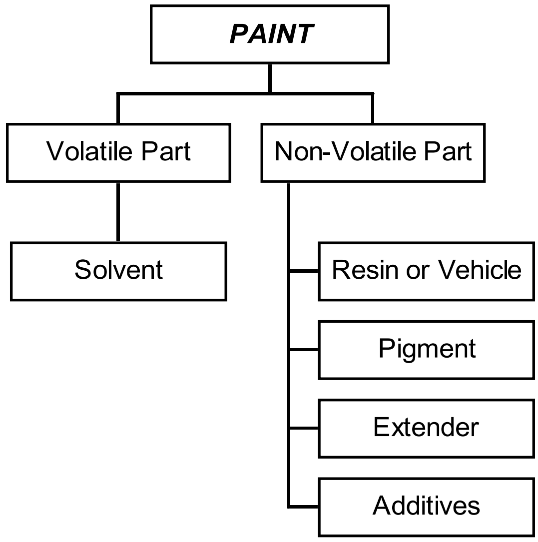
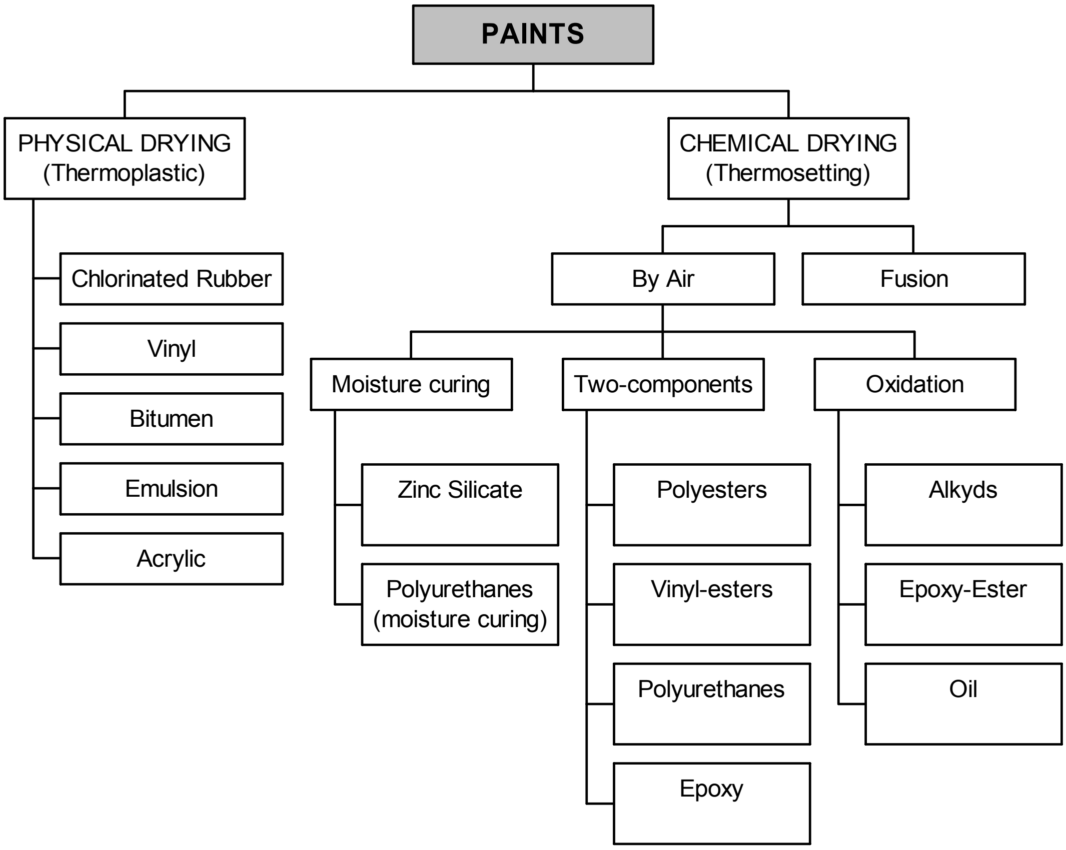


Figure 2 - Paint classification by drying/curing process



3.3.2.4 Shop-primers

Development of method of ship construction in blocks has considerably encouraged shop-primer use (also called prefabrication primer).

Shop-primers are particular paints expressly made to provide a temporary protection to the steel used for ship construction.

Steel and profiles used for ship construction, as well as any other industrial structure, are manufactured by a heat lamination process, which produces an iron oxide layer called mill scales on the surfaces. Mill scale looses its adhesion in the long run.

If a coating is applied on mill scale, the detachment of mill scale will cause the detachment of the coating as well.

The removal of mill scale by abrasive blasting allows application of paint systems with a long protection time, but above all, it improves the shipyard productivity, making faster welding and cutting operations.

Shop-primers must have several properties and satisfy numerous requirements that can be summarised as follows:

1) They must be approved by Tasneef, as required by Part D – Chapter 5 of the "Rules for classification of ships".
2) They must dry quickly, so the pieces can be handled within a few minutes of application.
3) They must have good adhesion on abrasive blasted steel.
4) They must be resistant to mechanical damage and high-temperature processes.
5) They must have a good resistance to the environment and maintain anticorrosive properties for some months.
6) They must not negatively affect the speed of cutting or welding operations and not produce toxic fumes during thermal treatment.
7) They must not negatively affect the quality of welding (e.g. cause no blowing or pores).
8) They must assure good adhesion for a wide range of paint systems.
9) They must be easily applied and permit thin and uniform film.
10) They must be resistant to cathodic protection action.
11) They must have good resistance to flame spreading.
12) They must have no pyrogenic properties (i.e. develop sparks).

Based on the type of binder, shop-primers can be categorised as follows:

- Polyvinyl butyral – phenolic
- Epoxy
- Inorganic zinc

At present, inorganic zinc ethyl-silicate shop-primers are the most widely used in shipyards. The development of these products has reached the "third generation" that, having reduced their zinc content, are called "Low Zinc". These types of shop-primers have considerably improved quality and speed of cutting and welding operations. Anticorrosive and overcoating properties are unchanged, while temperature resistance has increased up to 600/800°C, reducing thermal damage.

3.4 Paint systems

A paint system is formed by one or more coats of paint, each of which is applied at a specified film thickness. This sequence of coats, called paint system, provides corrosion control by means of one or more of the following mechanisms:

- Barrier protection (namely providing an insulating barrier between electrolyte and metal)
- Chemical inhibition of corrosion reaction
- Cathodic protection when a coat of zinc rich primer, acting as sacrificial anode, is applied.

Paint system is the logic and organic sequence of successive coats. It can be represented in a schematic generic form as: **Primer - Undercoats - Finishing**.

Primer is the first coat of the paint system. It has very important function such as, for example, to assure the adhesion of the whole system and to provide the required anticorrosive protection. It must be applied

- after a proper surface preparation, before which its quality could decay. Primer has to be overcoated according to the overcoating time and instructions recommended by the paint manufacturer.
- **Undercoats** are used to connect the primer with the finishing coat and to increase the total thickness of the system, as requested by the material to be protected and the location (e.g. Bottom, Topside etc.).
- **Finishing** provides specific characteristics to the area where it is applied: aesthetic appearance for Topside and other exposed areas, anti-fouling protection for the underwater etc.

On ballast tanks, the same paint is generally applied in more coats, providing more properties at the same time.

3.5 Paint systems for ballast tanks

There are a lot of paint systems available for the protection of ballast tank surfaces of new buildings. Each paint system proposed by the paint manufacturer has its number of coats and its specific film thickness. A schematic description of the various paint systems could result too vague and generic. For information only, on Table 3 the basic characteristics of the paint systems, until now more widely used for ballast tanks, are listed.

Epoxy paints form most of these systems, which according to type are called "HB Epoxy", "Mastic", "Surface Tolerant", "Solvent Less" (with a low solvent content), "Solvent Free" (without solvent, namely 100% volume solids).

Besides epoxy systems, moisture cured polyurethane, bituminous emulsion, vinyl-tar systems, as well as a system formed by a zinc rich primer followed by two or more coats of pure or modified epoxy, are available.

Amendment to SOLAS 1974 Convention (Reg. II-1/3.2) requiring that coating applied on ballast tanks has to be preferably in a light colour, reduced in practice the possibility of applying epoxy-tar systems or bituminous emulsions, which are usually black or brown.

Although bleached tar epoxies have a light colour, their use is expected to be reduced due to tar presence that, as already stated, could induce cancer. It is foreseeable that application of paints containing tar will be forbidden in future in many countries.

Table 3
TYPICAL PAINT SYSTEMS FOR BALLAST TANKS

PAINT SYSTEM	CHARACTERISTICS	No. OF COATS	TOTAL DRY FILM THICKNESS
PURE or MODIFIED EPOXY	Two-components Light colour	3	300/375 µm
SOLVENT LESS EPOXY	Two-components Light colour	2/3	300/450 µm
SOLVENT FREE EPOXY (100% volume solids)	Two-components Light colour	1	300/350 µm
EPOXY MASTIC and SURFACE TOLERANT	Two-components Light colour	2	350/400 µm
COAL TAR EPOXY	Two-components Dark colour	2	250/300 µm
BLEACHED TAR EPOXY	Two-components Light colour	2	250/300 µm
MOISTURE CURED POLYURETHANE	One-component Dark and light colour	2/3	300/375 µm
VINYL TAR	One-component Dark Colour	1/2	300/350 µm
NOTE: Listed data are average values worked out according to documentation published by paint manufacturers			

3.6 Soft coats

Amendment to SOLAS 1974 Convention, Reg. II-1/3.2, does not allow the use of Soft Coats for the corrosion prevention of ballast tanks of new buildings. However, since they are still available on the market and used for the maintenance of in-service vessels, their properties are listed below.

It is useful, first of all, to clarify some terms of recent use:

- **Hard Coatings**: Annex to IMO Resolution A.798(19) at item 2.6 defines Hard Coatings as "*...a coating which chemically converts during its curing process, normally used for new constructions or non-convertible air drying coating which may be used for the maintenance purposes. Hard coating can be either inorganic or organic.*" All conventional paints are included in this definition.
- **Semi-hard Coatings**: Are so defined the coatings that, after drying, remain flexible and hard enough to be touched and walked upon without damaging them and that are not affected by water erosion during deballasting operations.
- **Soft coatings**: Are so defined the coatings that not drying, remain permanently soft and can be removed by walking upon them and by contact.

Soft Coats are generally vegetable oils, petroleum oils or lanolin based. The liquid types can be applied with flotation method that, for the high risk of pollution, is not recommended. Others, the majority, can be applied by spray with a thickness ranging from 500 to 1.500 μm, according to the specific type.

It is necessary to point out that the border between Semi-hard and Soft coating definitions, is not very clean and in practice could cause some misunderstandings. In Part A of the Rules for Classification of ships Tasneef defines Hard Coatings and Soft coatings, only.

4 SURFACE PREPARATION AND PAINT APPLICATION

4.1 Surface Preparation

Surface preparation is one of the more, if not the most, important factor to ensure the good performance of the coating during its lifetime.

The best paint system applied on an insufficiently cleaned surface may rapidly deteriorate or failures may already occur a short time after application. Selection of the correct cleanliness standard may be more important than the selection of the paint system itself.

To avoid premature coating failures, any contaminant present on steel surfaces has to be removed. These contaminants are:

- Rust in any form, also as light oxidation,
- Mill scale,
- Grease and oil,
- Dust and dirt,
- Soluble salts,
- Water, condensation and humidity,
- Non-adherent paint scales or coating affected by defects.

To remove these contaminants and to prepare the surface ready to receive specified coat, there are various methods, summarised in Table 4.

Generally, abrasive blasting should be preferred to other surface preparation methods. Power tool cleaning can be performed on difficult-to-reach-areas for blasting or for repairs of limited extension. Hand preparation does not provide a suitable surface preparation and therefore is not advisable.

4.2 Surface preparation for new buildings

As already mentioned, in the ship building industry the method of construction in blocks is becoming more and more frequent. This has been possible thanks to technology and quality development of shop-primers. Consequently, surface preparation can be divided into two different steps:

1) Primary surface preparation,
2) Secondary surface preparation.

4.2.1 Primary surface preparation

Primary Surface Preparation is the operation carried out to remove mill scale, rust and other oxides. Steel plates and profiles are abrasive blasted, before the cutting and welding operations, in workshops. Grit blasting is an operation, similar to sandblasting, where more turbines, turning at high speed, blast a steel abrasive (grit or shots) against the surface to be cleaned.

The finishing degree of this preparation has always to be in accordance with the ISO Standard 8501-1 Sa2,5 while the roughness has always to be checked and measured in accordance with ISO Standard 8503. As reported in Appendix 2, there are other referential standards.

Immediately after grit-blasting, steel plates and profiles are shop-primed and then proceed to the shipyard prefabrication shop.

With the exception of those of large size, equipped with an internal shop-primer plant, shipyards generally buy plates and profiles already shop-primed. In this case, grit blasting and shop-priming operations are performed by the steel manufacturer or by others. Quality control by the buyer could result very difficult, since steel supplier and/or subcontractor plants can be located hundreds of kilometres away from the shipyard.

4.2.2 Secondary Surface Preparation

In the shipbuilding industry, *Secondary Surface Preparation* is the operation performed on shop-primed surfaces with the purpose of removing zinc salts (inorganic zinc shop-primers), welding smokes, of repairing damage caused by welding and steel works, burns and rusted spots, as well as of removing any other contaminants before the application of the specified paint system.

In most cases this preparation is performed by power tools (abrasive disks, wire brushes or other tools imbedded with abrasive materials), but, for certain ship areas, re-blasting is necessary to apply specific paint systems or when a coating with a long protection time is required.

No recognised international standard, ISO included, provides, as an initial condition, a contaminated or damaged shop-primed surface. For this reason many shipyards, or their associations, have prepared their own internal standards.

Among these, the so-called "Japanese Standard" prepared by the Shipbuilding Research Association of Japan (JSRA) and named SPSS, can be considered the most complete and suitable.

At a glance, the SPSS Standard seems to be complicated and too difficult to consult, since three different shop-primers and a high number of initial conditions and damage are assumed. Nevertheless, when the system is understood, it becomes easy and really useful.

4.2.3 Steel Imperfections

When steel works are completed and before secondary surface preparation, it is really important that the edges, corners, welds, welding shots, lamination defects and flame cuts are ground and rounded. In some countries this operation is improperly called "Steel preparation". If these imperfections, difficult to paint with the correct film thickness, are not removed, they will create rust formations in a short time. To ensure a good and lasting corrosion protection of the coating, mainly on ballast tanks, it is recommended that all imperfections are removed and sharp edges are rounded with a radius of 1 or 2 mm before the secondary surface preparation.

Requirements for this work can be specified according to two standards:

1) NACE RP0178 Standard issued by NACE International is made up of a descriptive part and by a plastic sample, showing various preparation levels depending on the area to treat. There are five levels; where "A" is the highest degree and "E" the lowest. This standard is particularly indicated for steel surfaces of tanks and vessels in general.
2) ISO/DIS 8501-3.2 (1999) Standard. This standard, issued by ISO, is a useful tool to define preparation and finishing degrees of welding, cuts and other imperfections before painting. The standard provides two levels of preparation, P1 the lower, P2 an intermediate and P3 the higher.

4.3 Paint application

4.3.1 Application methods

There are basically three paint application methods: by brush, by roller and by spray.

Brush application is used for small areas or touch-ups.

A roller generally has to be used to apply enamel and finishing coats. It is not recommended to apply primer on steel prepared by abrasive blasting or power tooling, since a roller slides on peaks not reaching the valleys of profile.

Application by spray is the most widespread method and technically the most suitable and effective. There are several types of equipment to apply paint by spray:

- Conventional (air spray)
- Airless
- Airless mix air
- Electrostatic
- Plural-components

Airless spray is the most widely used and widespread method in the shipping industry. The advantages of airless spray application can be summarised as follows:

- High production rate
- Possibility of applying paints with high viscosity and high solid content

- Limited formation of dry-spray
- Thickness uniformity

There are not really any disadvantages, apart from the operator having to be skilled and qualified to avoid, during application, sags, drops and film discontinuity (i.e. holidays).

4.3.2 Stripe-coating

Even for a skilled operator, weldings, edges and corners, backside of structures, bolts and nuts, flanges and generally all difficult-to-reach-areas are parts difficult to paint by spray with the correct film thickness. To ensure the right film thickness it is essential that these areas are painted, before the application of the full coat by spray, with an additional coat by brush. This operation is usually named "stripe-coating".

Stripe-coating is an important factor of the paint application process in order to ensure a suitable coating performance. Therefore, it is important that it is carried out before the first coat of paint system, as well as before each following coat.

Table 4
SURFACE PREPARATION METHODS

METHOD	CONTAMINANT	PROPERTIES
Degreasing	It removes grease and oil	It maybe performed with solvents, hot water or with suitable detergents.
Low pressure fresh water washing	It removes dust, dirt and soluble salts.	
High pressure fresh water washing	It removes dirt, soluble salts, fouling and non-adherent paint	Water jetting up to 35 MPa (350 bar).
Hydro-jetting	It removes dirt, soluble salts, fouling, paint, rust and mill scale	• Water jetting up to 200 MPa (2.000 bar) and more. • The method was introduced some years ago, and is performed when, for environmental and pollution problems, abrasive blasting is not possible. • It does not create a profile and leaves an oxidised surface. • It is not suitable for all paint systems. Coating must be selected with care and attention. • Production rate decreases with pressure increase. • It requires skilled operators.
Power tool preparation (with pneumatic and electric tools)	It removes paint, rust and, in some cases, the mill scale.	• It is not suitable for all paint systems. • With some tools only, a minimum profile is obtained, but generally it produces bright steel. • Low production. It is not recommended and expensive for wide surfaces.
Abrasive blasting	It removes paint, rust and mill scale.	• It does NOT REMOVE soluble salts, grease and oil. • It is the best surface preparation system, unavoidable when a long-term protection is required. • It produces an excellent steel profile. • Owing to dust development during the operation, it causes environmental and pollution problems and interferes with other activities.

4.3.3 Factors affecting application

To avoid premature coating failures (e.g. detachments, peeling, blistering etc.), in the application of any paint, it is essential to follow and carefully implement some basic rules.

1. **Storage**: To reduce risk of fire and to prevent deterioration, coating materials have to be stored in a safe room and not exposed to the weather. It is necessary to point out that all paints have a specific shelf life, reported on the Product Data Sheet. It is a good practice not to leave the containers in direct sun light or outdoors when the temperature is near 0°C. These factors could cause problems during application.
2. **Mixing**: During storage, heavy pigments tend to settle on the bottom of the can. Therefore, paint has to be restored to its original consistency before application, to achieve a complete drying after application. The two-component products have to be mixed carefully to ensure the correct mix of the base and curing agent.
3. **Dilution**: To allow a good application, paints are usually formulated and manufactured with the correct amount of thinner. It is not advisable to thin the paint, except in some particular circumstances and in any case always according to the paint manufacturer's recommendation.
4. **Thermo-hygrometric conditions**: Environmental conditions have to be carefully checked. As a general rule, before, during and after application, relative humidity has to be lower than 85%, minimum and maximum values of steel temperature have to be in accordance with paint manufacturer's recommendations for the specific paint system to apply and always 3°C minimum above the dew point.
5. **Ventilation**: The most important factor in the ventilation of a tank is not the air volume moved, but the air quantity that continuously flows over entire tank surfaces, from the ceiling to the bottom. It is essential that correct ventilation is maintained during and after the application of each coat. All coatings retain solvents in the film for a certain period of time after application. During film formation, heat is developed, which allows solvent evaporation (water included for water borne products); an insufficient air flow on the surface can make the film formation process too fast. When this happens, the film dries too quickly on the surface and part of the solvent is entrapped in the coating itself (phenomenon called "Solvent retention"), causing blistering.
   Good ventilation is also important for water based paints and for solvent free products (100% volume solids). Since no organic solvents are present in the process, many people believe that ventilation may be avoided or reduced. While from the safety point of view ventilation is not essential, on the other hand it is an extremely critical factor to ensure a suitable formation and curing of the coating.

All the information and recommendations that have to be followed for the correct storage, mixing, dilution, thermo-hygrometric condition and ventilation are usually reported in the Product Data Sheet.

4.4 Safety during painting operations

Safety rules have to be carefully followed during all painting operations. Safety becomes extremely important when paint application is carried out in closed and narrow spaces, such as ballast tanks. For information only, some aspects are briefly mentioned below:

1. **Scaffolding**: Staging has to be erected according to local authority rules. In ballast tanks, staging has to be erected in such a way that no areas to treat are covered by planks and pipes, supporting point excluded, and in the meantime to allow the operator to reach all surfaces easily.
2. **Surface preparation**: During any surface preparation a lot of powder and dust is developed. Therefore, it is essential that the operators are equipped with suitable safety equipment.
3. **Painting**: Most paints contain flammable solvents and dangerous products if they come into contact with the skin, eyes or if they are inhaled or ingested. For each product used, paint manufacturers provide Material Safety Data Sheets, listing all information concerning paint composition, necessary instructions and safety precautions.
   During spray application, a lot of solvent vapours are produced. To avoid risks of explosion or fire, it is essential that in the in tank there are enough air changes to maintain solvent vapours below the "Lower Explosive Limit" (LEL). Some paint manufacturers give useful information on the matter in product data sheets.

4.5 Coating Failures: Causes and prevention

4.5.1 Generic types of coating defects

Many coating defects are already visible during application or immediately after, others after a certain period of time. Most could be avoided with correct and suitable surface preparation and application procedure. Others, on the contrary, and blistering is the most significant, fall within the natural deterioration and decay of the coating. Therefore the development of these defects can be limited or postponed with preventive actions only.

Tables 5-A and 5-B show some of the most common coating defects usually detected in ballast tanks, related to surface preparation and application. Prevention and remedial actions are also reported.

During the ship's life, there are generally two other defects occurring on ballast tank coatings. Due to their complexity, they cannot be schematised, but described below.

4.5.1.1 Blistering

Blistering appears as a bubble formation scattered on the coating, with a diameter ranging from 3-4 mm to 20-30 mm. Osmosis is the main operative cause of blistering and the only one occurring in ballast tanks. No coating is totally impervious to water. The degree of transfusion is mainly the result of coating formulation related factors; a higher water absorption ratio will normally enhance the permeability, presence of water miscible species in the coating (such as inhibitors) sometimes enhance water absorption and transfusion.

For osmosis to occur a solvent, in this case water, and one or several solutes must be present. Since water cannot be eliminated from ballast tanks, it is clear that a reduction of solutes will diminish the risk of the osmotic process. Often the solute is substrate soluble salts contamination, but it can also be entrapped water miscible solvents etc., or anything else in the coating or on the coating/steel interface that is soluble in water.

The degree of blistering, and the size of the blisters are related to following main contributing factors:

1) the amount of solute. Concentration ratio between what is below (or in) the coating and what is in the water on the outside of the paint,
2) the amount of water absorbed into the coating,
3) the coating's wet adhesion (the wet adhesion is counter to the upwards force from the pressure generated by the osmosis),
4) the coating thickness (a higher thickness requires a higher osmotic force to force the dome to form).

Therefore to reduce the risk of blistering, it is necessary that adequate preventive actions are undertaken. These can be summarised as follows:

- ensure that fresh water washing is performed on substrate before surface preparation to remove soluble salts,
- ensure that tools and abrasives used are clean and soluble salts free,
- ensure that solvents/thinners are removed, by correct ventilation and air flow, from the coating to greatest possible degree during the "wet stage" of the curing process,
- use coatings with suitable water absorption.

4.5.1.2 Cracking

There are different types of cracking:

- Checking, which looks like a cobweb, involves the superficial part of the coating, not reaching the steel.
- Cracking, similar to checking, but cracks reach the steel.
- Alligatoring, with a wide and spaced cracks, which cannot reach the steel.

All these forms of cracking can be caused by:

1) internal or superficial stress occurs in the coating during polymerisation reaction,
2) thermal contraction and expansion of the structure,
3) migratory components of the coating leaving the film,
4) excessive film thickness.

Some of these causes are inherent to the coating type and formulation, but high film thickness is related to the way the coating is applied.

To reduce or avoid the risk of cracking it is necessary that suitable prevention actions are undertaken. They can be summarised as follows:

a) choose a coating with low initial reaction shrinkage,

b) make sure, implementing a suitable ventilation and air flow, that the solvents leave the film at greatest extent during the early phases after the application, before the coating is hard,

c) limit the use of solvents containing fast curing organic products designed for application in low temperature conditions,

d) avoid application of high film thickness.

5 SELECTION OF CORROSION PROTECTION

5.1 Factors affecting the protective coating life

As for the corrosion process, also the protective coating life of ballast tanks is affected by several factors.

Frequency of ballasting operation, partial or complete filling of each tank, ballasting duration, temperature of cargo transported in adjacent cargo tanks, surface preparation and paint system selected. All these factors, separately or combined, can considerably affect the coating life.

The selection of a paint system must take into consideration, firstly, the expected and intended life of the coating. The surface preparation and paint system have to be selected accordingly. These choices can considerably affect the cost of construction; therefore it is advisable that the Owner makes the right evaluations on the investment, according to his requirements and on the basis of a suitable Life Cycle Cost.

5.2 Painting specification related to coating life

In the Table 6 the suggested procedures and paint systems for the corrosion protection of ballast tanks of new buildings related to an estimated life are shown.

The data given are based on direct experience and acquired information. The main scope of different procedures is to achieve at the end of the expected life, a coating condition judged "Fair", according to the Tasneef definition given in Part A - Periodical Surveys of hull of the Rules for classification of ships.

Concerning the data listed in Table 6, it is necessary to take the following points into due consideration:

1) *To reach the intended life, it is necessary in any case, to program and carry out periodic coating maintenance during the ship's service. In Chapter 9 of this Guide, some recommendations for suitable maintenance are reported.*

2) *To achieve the expected specified life, it is essential that specifications, procedures and related working steps, described in each column, are carefully applied and followed, in order to avoid premature decay and/or deterioration of the coating*

3) *The suggested paint systems have to be considered as examples of those most widely used in shipyards. Therefore they do not intend to exclude other systems, currently applied, or suitable alternatives that can be developed in the future.*

4) *Only total dry film thickness has been reported. The thickness can be applied in single or multiple coats, according to type of paint and paint manufacturer's recommendations. A stripe-coat before each full coat is recommended to achieve the proper film thickness.*

5.2.1 Criteria for the selection of protective coating

IMO Resolution MSC.47(66), adopting the Amendment to Chapter II-1 of SOLAS 1974 Convention, requires that the scheme for the selection, application and maintenance of the paint system shall comply with IMO Resolution A.798(19) requirements.

In practice this means that, the owner, paint manufacturer and shipyard have to agree in advance the scheme for the selection, application and maintenance of the paint system. They have to give evidence of the agreement to Tasneef, before ship's construction. In detail, following documents have to be collected and forwarded to RINA:

1) The owner's, coating manufacturer's and shipyard's explicit agreement to the scheme for coating selection, application and maintenance.

2) List of seawater ballast tanks identifying the coating system for each tank, including coating colour and whether coating system is a hard coating.

3) Details of anodes, if used.

4) Manufacturer's technical product data sheet for each product.

5) Manufacturer's evidence of product quality and ability to meet owner's requirements.

6) Evidence of shipyard's and/or its subcontractor's experience in coating application.

7) Surface preparation procedures and standards, including inspection points and methods.

8) Application procedures and standards, including inspection points and methods.

9) Format for inspection reports on surface preparation and coating application.
10) Manufacturer's product safety data sheets for each product and owner's, coating manufacturer's and shipyard's explicit agreement to take all precautions to reduce health and other safety risks, which are required by the authorities.
11) Maintenance requirements for the coating system.

In addition and to better clarify that stated above, the following criteria have to be satisfied:

a) Give evidence that factors mentioned in item 5.1 of this Guide were duly considered.
b) Paint manufacturer has to provide necessary documentation evidencing the good performance of the proposed paint system and adequate technical assistance.
c) Concerning required documentation, it would be advisable that paint system selection is supported by performance tests carried out by independent laboratories, according to international standards (e.g. ISO, ASTM or similar). As a general rule, and for information only, cyclic tests, immersion tests, water absorption tests, temperature resistance and any other test proving the paint system suitability for a continuously or intermittent immersion service may be considered suitable.
d) Reports and evaluations of paint system conditions, after at least two (2) years of effective and continuous ship service, made by organisations, independent companies or by a Tasneef surveyor will be taken into primary consideration.

5.3 Suggestions for the preparation of a painting specification

A technical specification is the starting point of any paintwork. It is the document, in which procedures, methods to carry out the work and materials to be used, are described. Therefore the specification has to satisfy some fundamental requirements:

a) It must be a practical document, clearly describing, without ambiguity, what is needed, how it is needed and what is expected from the protective coating.
b) It must be a working document, or better a working tool. The specification should be easily understood by everyone: superintendent, production manager, foreman and so on.
c) Since the technical specification is a part of the contract, it is also a legal document. Therefore, in case of dispute, each detail of the document becomes very important.

Owing to numerous variables, a painting specification is often quite complicated. However, for new buildings and mainly for ballast tank coating, a suitable painting specification should be made up of the following sections:

1) **General Information**: this contains the description of work to be performed, the area or areas to be treated, scope of the work and level of protection required. It is useful to include paragraphs reporting, briefly and clearly the following points: reference standards, application steps related to general planning, storage of paints and materials, weather protection, safety and meetings.
2) **Products and Paint systems**: required paint systems and related characteristics should be described in this section. For ballast tank coatings it is advisable to define some requirements, e.g. maximum value of water absorption according to ASTM D570 Standard, adhesion test on the steel and between coats, temperature resistance both for dry and wet condition and performance test.
3) **Execution and Application**: this is the most detailed and complicated section, because it describes how the work has to be performed. Details concerning surface preparation, thermo-hygrometric conditions, application methods, film thickness, cleaning of equipment etc. have to be given.
4) **Inspection**: this describes inspection procedures for the different working steps. Inspection, of ballast tank coating, is very important to ensure that work is performed in a proper manner and according to the specification. It would be better for inspectors as well as all personnel to be qualified and skilled.

Table 5-A - Coating defects and its prevention

DEFECT	RELATED TO	APPEARANCE	CAUSE	PREVENTION/REMEDIAL
Pinpoint rusting	Application	Small points of rust spread or localised.	Insufficient and low film thickness. Dry-spray between the coats of paint system	Check film thickness during application. Remove dry-spray before the application of the next coat.
Rust on edges, corners and angles	Preparation Application	Rust on edges, corners and drain holes, which is spreading underneath the coating parallel to the edge itself.	Poor borders and edges rounding. Poor film thickness on these areas.	Round edges and corners before the surface preparation. Apply additional coats by brush on corners and edges before each full coat.
Rust on welds	Preparation Application	Rust on welding seams, which is spreading underneath the coating parallel to the welding.	Slag not removed. Manual welding not rounded. Welding shots not removed. Poor film thickness on welds.	Remove slag, welding spatters and sharp irregularities, before surface preparation. Apply additional coats by brush on welding seams before each full coat.
Holidays	Application	Unpainted areas, generally difficult to reach and back of structural elements.	Lack of care during paint application	Apply paint with care and correctly.
Pinholing	Application	Small holes in the coating, usually concentrated.	Spray gun too close to the surface. Steel temperature too high.	Apply paint with care and with spray gun at the right distance. Check the temperature. Sandpaper the defective area and apply one more coat.

Table 5-B - Coating defects and its prevention (Cont.)

DEFECT	RELATED TO	APPEARANCE	CAUSE	PREVENTION/REMEDIAL
Sagging	Application	Paint drops pouring along the vertical sides and from ceilings	Excessive film thickness. Spray gun too close to the substrate. Paint too thinned	During the application, when the paint is still fresh, remove stains with the brush. After the application, according to overcoating time, remove sags by sandpapering and re-apply.
Overspray or Dry-Spray	Application	Very rough coating surface. Dry paints on the surface look like dust.	Spray gun too far from substrate. Incorrect pump pressure.	Apply paint with care and with spray gun at the right distance. Adjust the pump pressure. Sandpaper defective area before application of next coat. For zinc reach primers, surfaces have to be re-blasted and re-coated.
Detachments from substrate	Preparation	Coating is completely detached from the steel.	Poor surface preparation. Oily, dirty or wet surface	Re-blast and re-coat. If there is oil, before the re-blasting, surfaces have to be degreased and washed.
Detachments	Preparation Application	One or more coats are detaching from previous one	Oily, dirty or wet surface Coat apply when the overcoating time of previous one was expired	Re-blast and re-coat.

Table 6 - Painting specification for ballast tanks related an estimated coating life

Design intent:	*5 - 7 years*	*8 - 12 years*	*13 - 17 years*	*Over 18 years*
Steel treatment	Remove lamination defects, loose spatter and scale, slag etc. Edge treatment only of hand-gas cut edges.	Remove lamination defects, spatters and scale, slag etc. according to degree P2 standard ISO 8501-3.2. Edges chamfered in two passes.	Remove lamination defects, spatters and scale, slag etc. according to degree P2 standard ISO 8501-3.2. Edges ground to 2 mm radius.	Remove lamination defects, spatters and scale, slag etc. according to degree P3 standard ISO 8501-3.2. Edges ground to 2 mm radius.
Oil, grease, zinc salts	Clean according to SSPC-SP 1	Clean according to SSPC-SP 1	Clean according to SSPC-SP 1	Clean according to SSPC-SP 1
Fresh water washing	No	Low pressure fresh water washing	H.P. (15 MPa) washing	H.P. (15 MPa) hot water washing.
Water soluble salt limit	None specified	3 μg/cm^2 maximum	3 μg/cm^2 maximum	3 μg/cm^2 maximum
Primary surface preparation and Shop primer requirement	Grit-blasting to ISO 8501-1 Sa 2,5 No specific choice of shop-primer, PVB excluded.	Grit-blasting to ISO 8501-1 Sa 2,5 and zinc silicate shop-primer	Grit-blasting to ISO 8501-1 Sa 2,5 and zinc silicate shop-primer	Grit-blasting to ISO 8501-1 Sa 2,5 and zinc silicate shop-primer
Secondary surface preparation	Power tooling ISO 8501-1 St 2-3 (SPSS Pt 2 –Pt 3) of welding, mechanical damage, and shop-primer decay.	Abrasive blasting to ISO 8501-1 Sa 2,5 of welding, mechanical damage and shop-primer decay, leaving the intact clean shop-primer.	Abrasive blasting to ISO 8501-1 Sa 2,5 of welding, mechanical damages and shop-primer decay. Sand-sweeping of intact shop-primer.	Full abrasive blasting to ISO 8501-1 Sa 2,5
Coating system	200 μm in total of Epoxy. No specific test required	300 μm in total of Epoxy. No specific test required	400 μm in total of Epoxy. Performance tests certified by independent laboratory	375/450 μm in total of Epoxy. Performance tests certified by independent laboratory
Thermo-Hygrometric condition control	Usual condition required during paintwork, (steel temp. 3 °C above dew point, R.H. 85% max, etc.)	Usual condition required during paintwork, (steel temp. 3 °C above dew point, R.H. 85% max, etc.)	Usual condition required during paintwork, (steel temp. 3 °C above dew point, R.H. 85% max, etc.). No paint application with temp. below 15°C.	Usual condition required during paintwork, (steel temp. 3 °C above dew point, R.H. 85% max, etc.). No paint application with temp. below 15°C.
Modified paint curing at low temperature	Allowed	Allowed	Allowed, but standard systems with normal cure temperatures preferred.	No low temperature systems. Only standard, well-known systems to be used and applied well.

5.4 Specific treatments

In all ships, ballast tanks are usually built of carbon steel. Chemical tankers, in most cases, can have a structure both in stainless steel and carbon steel.

To achieve a suitable corrosion protection, it is necessary even for stainless steel to be coated with the paint system, as reported in Part E – Chapter 8 – Section 6 – 1.1.1 (e) Tasneef Rules for the classification of ships. This, besides ensuring the correct continuity of the coating, forms an insulating barrier, that avoids the galvanic process owing to the presence of two differentmetals.

Stainless steel has to be abrasive blasted, with a non-metallic abrasive, to create a suitable superficial roughness and allow adhesion of the coating. Generally, roughness must not be lower than 50 μm and in accordance with the paint manufacturer's recommendations.

After abrasive blasting and before application of the specified paint system, the stainless steel has to be coated with a specific primer, usually an epoxy zinc free primer, at low thickness (40-50 μm) that ensures correct adhesion of the coating on it.

In the same way, possible galvanised outfittings mounted in ballast tanks have to be treated.

6 COATING INSPECTION

6.1 General

The best available paint system may give unsatisfactory results if not applied correctly. Statistical data show that premature coating failures and deterioration are, in most cases, related to an unsuitable application (both surface preparation and paint application), a small percentage is caused by coating material anomalies and rarely by unsuitable specification. Therefore it is clear that the inspection and the quality control of paintwork, during all steps, takes on a very important and essential function to ensure the good result of corrosion protection.

6.2 Inspector tasks and duty

The purpose of inspection is to ascertain that during painting operations the work is performed fully in compliance with the requirements of the contractual specification.

Inspection procedures are usually defined in the technical specification and in any case have to be agreed in advance between shipyard an/or sub-contractor, owner and paint manufacturer. Each of them may appoint a coating inspector, forming an inspection team of 3-4 people.

It is necessary for the following items to be defined and agreed:

- Inspection methods
- Work acceptability criteria
- Inspector's powers and authority
- Forms for reports and records

It is advisable that an inspector has good experience in ships' painting, has a good knowledge of paint systems and of their application and is an active member of the production process.

A useful inspectors' guide is the ASTM D3276 "Standard Guide for Painting Inspectors (Metal Substrates).

6.3 Inspection procedures

Before beginning his work, an inspector has to:

1) Collect and study all technical and contractual documentation concerning the work
2) Ensure that he has all necessary instruments to perform the work
3) Define and agree with the counter-parties a working-plan.

6.3.1 Documentation

The inspector has to know the specified standards for surface preparation and painting, checks to perform and the characteristics of coating material to apply very well. Therefore, the inspector must collect and study the following documents:

- Specifications, modifications included, amendments and enclosures
- Rules and standards related and required by the specification
- Paint manufacturer's recommendations (Product Data Sheets)
- Procedures recommended by the paint manufacturer.

6.3.2 Instruments

The instruments, that an inspector must have to perform his job, can be divided into two sections: basic standard instruments for any kind of job and advanced instruments, that have to be used for a specific and qualitative task, which require good knowledge and experience to be used.

Standard instruments are as follows:

- Hygrometer or psychrometer
- Dew Point and relative humidity table or calculator
- Digital thermometer
- Surface roughness gauge or comparator
- Photographic standards for surface preparation
- Magnifiers
- Inspection mirrors
- Wet film gauge
- Digital dry film thickness gauge
- Flash light (halogen and rechargeable is better)
- Camera
- Knife or cutter
- Scraper
- Abrasive paper
- Sample bags
- Felt-pens or chalks
- Adhesive tape or paper

Advanced instruments are:

- Kit for the determination of chlorides on surfaces before painting
- Litmus charts
- Conductivity gauge
- Kit for the adhesion test
- Hypodermic gauge
- "Blotter Test" to check compressed air cleanliness.

6.3.3 Planning

Before starting any work, it is of primary importance to hold a meeting with the attendance of all parties. This is an opportunity for the inspector to ascertain that all persons know the content, the procedures, the standards and the paint systems required by the specification. It is during the pre-job meeting that inspection procedures, timing, as well as the working steps intended to be checked, are agreed.

In paintwork the working steps to be inspected, namely quality control interventions to ascertain the level of quality, should be as follows:

1) Work Conditions and Safety:
   a) Scaffolding
   b) Lighting
   c) Ventilation of closed spaces
2) Before surface preparation:
   a) Completion of steel works
   b) Removal of steel imperfections
   c) Cleanliness and type of abrasive materials
   d) Suitability, cleanliness and operation of the applicator's equipment
   e) Paint storage
3) After surface preparation:
   a) Surface cleanliness
   b) Blasting profile (roughness)
   c) Thermo-hygrometric conditions
   d) Presence of chlorides on abrasive blasted surface
4) Immediately before application of each coat of paint system
   a) Thermo-hygrometric conditions
   b) Substrate temperature
   c) Cleanliness of the surface to be painted
   d) That coating material is defect free
   e) Mixing, thinning of the paint
   f) That the operator knows the paint manufacturer's instructions
5) After each coat application:
   a) Film drying
   b) Film thickness
   c) Film continuity, namely coating is free from defects
   d) Presence of dry-spray, sags and other visible defects
6) After the curing of paint system:
   a) Film drying
   b) Film thickness
   c) Film continuity and adhesion
7) If in ballast tanks, besides the protective coating (passive protection), a cathodic protection system by sacrificial anodes (active protection) is provided:
   a) Number of anodes

b) Type of anodes

c) Assembly of anodes

d) That anodes are not damaged or painted.

Generally, destructive tests are to be avoided and only carried out if strictly necessary.

6.4 Inspection reports

The utility of a detailed working report, besides being a continuous up- dating of work progress, becomes of great importance when a summary of performed work sequence, is necessary.

The report has to be prepared as a diary where all events are reported in a concise and clear way. It is recommended that the starting and the end of each operation is listed, as well as weather and thermo-hygrometric conditions, overcoating times, film thickness, non-conformities detected during inspections and related remedial actions implemented. All data concerning the surface preparation, the tests and checks performed and minutes of meetings, have to be included in the report. Use of printed forms will make the preparation of the report and data in-put easier.

These reports, with the documentation reported in the item 5.2.1 of this Guide, must be forwarded to all interested parties and put at Tasneef disposal.

7 WORK ORGANISATION AND PLANNING

7.1 Planning

The shipyard shall suitably plan and program the paintworks to ensure that work, considerably interfering with other activities, is carried out according to the technical specification.

The development of construction in blocks of ships makes painting easier and improves its general quality. The best results are achieved when the shipyard is equipped with a closed shop for painting. Upon completion of construction, the block already pre-outfitted, is carried into a shop to perform the specified paintworks, in a controlled environment. This is an undoubted advantage to achieve a good qualitative result. During this step it is possible to carry out the secondary surface preparation and the application of the complete paint system, or of a part of it, excluding the conjunction areas of the blocks.

After painting, the block can be erected on the slipway or in dry-dock and joined with others. After that, it will be possible to complete the paint application of the joint areas and of damage.

The construction program has to be regularly checked and up- dated, in order to allow the inspector of each party to follow all paintwork steps.

7.2 Quality System

To assure that paintwork is carried out according to the requirements of the contractual specification, it is preferable that the Shipyard establishes and maintains a suitable quality system.

The quality system should provide for written procedures of the following items:

- organisation
- documentation check
- procurement and supply
- product identification and tracing
- control of the productivity process
- inspections and tests
- inspections, measurements and related instruments
- non-conformities, and related management, preventive and corrective remedial actions
- internal audits.

7.3 Samples

Unlike other industries, in the shipping industry the sampling of paint batch is not a common practice.

On the contrary the importance of the identification and the sampling, at least at spot, of the paint batches could be really useful in the eventuality of anomalies and failures during the guarantee period or during the coating life.

8 CATHODIC PROTECTION

8.1 General

A cathodic protection system by sacrificial anodes may be installed in ballast tanks only in conjunction with a protective coating. The scope of this additional corrosion protection is to prevent or reduce the corrosion rate of the steel if coating defects and/or damage occur.

Anodes can be of zinc or aluminium alloys. Magnesium anodes are not permitted. Composition of alloys, which in any case requires a high zinc or aluminium content, is an essential factor to avoid the formation of an insulated layer on the anode surface, inhibiting the dissolution process.

It is necessary to underline that cathodic protection is effective only when the tank is full of water and no empty spaces are left. In this way the process is active on the ceiling, too.

Furthermore when a ballast tank is filled, sacrificial anodes need a certain time (1 or more days) to become effective and active (polarisation time).

8.2 Design of a cathodic protection system

To design a protection cathodic system in a ballast tank in conjunction with a protective coating, the following factors have to be considered:

1) Dimensions, surface and shape of the tank
2) Ballasting frequency
3) Percentage of the period in which the tank is full
4) Type of ballast water to be used: sea water, fresh water and related cleanliness.
5) Water temperature

For new buildings, the coating is considered intact and without defects, while for ships in service, it is necessary to consider the coating conditions, namely percentage of defects and of damage.

8.3 Calculation of the sacrificial anode number

To calculate the necessary number of sacrificial anodes, additional elements have to be considered:

1) Current density
2) Electrochemical capacity

8.3.1 Current density

The potential of the surface to be protected has to be maintained between -0,750 V and -0,850V, measured with a Silver/Silver-Chloride electrode (Ag/AgCl). Values below -0,750V (under-protection) denote an insufficient protection, while higher values (over-protection) could damage the coating, causing blistering.

Necessary current density for a suitable protection is shown in Table 7.

In case of short voyages in ballast, the figures listed in the table have to be increased. This involves an increase of the anode number.

The current density of 5 mA/m² for surface with an intact coating has to be increased by 10 mA/m² for every 10% of coating damage that may occur. Therefore, assuming that the paint system is affected by 20% defects, the current density has to be of 25 mA/m².

Table 7 - Current density for cathodic protection of ballast tanks

Ballast Tank type	Recommended current density	
	Bare steel	Intact coating
Top side tanks	120-130 mA/m²	5 mA/m²
Peaks	100-110 mA/m²	5 mA/m²
Double Bottom	100-110 mA/m²	5 mA/m²
Segregated Tanks	100-110 mA/m²	5 mA/m²

8.3.2 Electrochemical capacity

Another factor to consider in the calculation is the electrochemical capacity of the anode. This capacity, expressed in Ah/kg is shown in Table 8.

Table 8 - Electrochemical capacity of anodes	
Anode type	**Capacity**
Zinc anodes:	760 Ah/kg
Aluminium anodes:	2.400 Ah/kg

In the presence of mud and/or sediments, the capacity decreases to 750 Ah/kg for zinc anodes and to 1.300 Ah/Kg for aluminium anodes.

8.3.3 Calculation of anode quantity

For an easy calculation of the necessary amount of anodes, the following formula can be used:

$$P = \frac{A\,H\,I}{1000\,K}$$

Where:

- **P:** is the amount in weight of necessary anodes
- **A**: is the surface in m² of the ballast tank
- **H**: is the effective life of the anodes expressed in hours
- **I**: is the current density in mA/m², as reported in Table 7
- **K**: is the current capacity of the anodes expressed in Ah/kg, as shown in Table 8.

8.4 Anodes distribution

When the calculation of the type and mass of anodes for expected protection time is completed, anodes have to be suitably distributed and fitted in the ballast tank. Although the fitting by welding ensures the proper continuity of the electric path, in coated tanks it is recommended to mount bolted clamps, avoiding damage to the coating during fitting and further replacements.

Anodes have to be distributed uniformly all over the tank surface according to the supplier's instructions and located nearest the bottom that is usually never completely dry.

9 MAINTENANCE

9.1 General and definitions

The maintenance of ballast tank corrosion protection has to be included in the general maintenance program of a ship.

During periodic hull surveys, the coating condition will be ascertained according to Part A of Tasneef Rules for the classification of ships.

Coating conditions are defined as follows:

- **Good**: condition with only minor spot rusting.
- **Fair**: condition with local breakdown at edges of stiffeners and weld connections and/or light rusting over 20% or more of areas under consideration, but less than as defined for POOR condition.
- **Poor**: condition with general breakdown of coating over 20% or more of areas or hard scale at 10% or more of areas under consideration.

The Tanker Structure Co-operative Forum schematised the definitions as reported in Table 9.

Under the term "breakdown", any coating defect that may limit or reduce its efficiency, has to be included. These defects are: blistering, detachments, peeling, cracking and obviously any form of rust.

The main scope of the periodic maintenance is to maintain the coating above the "Fair" condition during the ship service or however within the limit of "Poor" condition at the end of defined ship service life.

As a general rule, it is a good practice to repair and touch-up the coating before the extension of defects reaches 3% of the surface.

Periodic cleaning of surfaces (i.e. removal of mud and sediments from the bottom, decks and all horizontal surfaces) ensures a better performance of the coating, avoiding corrosion caused by bacterial attacks, poor ventilation etc. as well as making inspections easier.

9.2 Coating maintenance

Coating defects usually start on borders, edges, welds, difficult-to-reach-areas etc., spreading quickly to the nearby areas. The speed at which the damaged area deteriorates and corrodes is faster compared to the time necessary for the defect itself to form.

9.2.1 Paint system selection

Coating maintenance should be carried out using the same paint system applied during construction. Generally, application of these paint systems requires abrasive blasting of the surface and furthermore they have a poor adhesion on the existing intact coating. This makes coating maintenance, mainly when the extension of defects is limited, an expensive operation both for the cost itself and for the time necessary to perform it.

Over the last years, paint manufacturers have developed paints called "surface tolerant" or "epoxy mastic". These products have several advantages compared with conventional epoxy paints that can be summarised as follows:

- Lower degree of cleanliness
- Extended overcoating times
- Compatibility with other existing coatings
- Can be applied at temperatures below 10°C.

To avoid incompatibility problems of paint systems and to avoid possible detachments, if it is not possible to apply the original paint system, the selection of maintenance paint system has to be evaluated and agreed between owner, paint manufacturer and shipyard.

The selection of a soft-coat for the maintenance of ballast tank surfaces has to be carefully considered. Although these products provide several advantages for application (minimal surface preparation, compatibility with existing coating, solvent free, possibility of being applied on humid surfaces), during service they can cause many problems, summarised below, that discourage their use:

- Risk of pollution during deballasting operations, mainly after application
- Limited corrosion protection period. For some of them, it is necessary to reapply the product after 1 or 2 years
- Difficult to perform safe periodic inspection due to slippery surfaces
- Are easily damaged by walking on them
- Poor resistance to temperature (max. 50°C)
- It must be removed in areas interested by steel work
- Great difficulties, mainly in surface preparation, if reapplication of a hard coating is required.

Where soft coating is applied, safe access is to be provided for the surveyor to verify the effectiveness of the coatings and carry out an assessment of the condition of internal structures which may include spot removal of the coating; when safe access cannot be provided, the soft coating should be removed.

9.2.2 Surface preparation

As in any paintwork, surface preparation is extremely important for the performance and the life of the protective coating.

For the coating maintenance of ballast tanks, one or more of the following methods can be used:

- abrasive blasting,
- power tool cleaning,
- hydro-jetting,
- electrolytic descaling.

9.2.2.1 Abrasive blasting

As already mentioned, abrasive blasting is the best method for surface preparation and the only one that ensures a long life of the coating.

Generally, and according to the paint system selected, the cleanliness degree should not be lower than standard ISO 8501-1 Sa2 and in any case as recommended by the paint manufacturer.

Before abrasive blasting, surfaces have to be washed with fresh water, using if possible a pressure of 25 MPa and oily and grease areas are to be cleaned.

Table 9 – Definition of coating conditions

CONDITION	GOOD	FAIR	POOR
Spot rust Light rust	Minor Minor	 >20	
Edges and welds	<20%	>20%	
Hard scale	Minor	<10%	>10%
General breakdown	Minor	<20%	>20%
Other references			
ISO 4628/3	Ri 3	Ri 4	Ri 5
European Rust Scale	Re 3	Re 5	Re 7

9.2.2.2 Mechanical preparation

Power tool cleaning of the surface is recommended when the extension of defects is localised and limited. Cleanliness degree should not be lower than standard ISO 8501-1 St3.

This degree can be achieved using pneumatic tools such as descalers, needle guns and rotary abrading tools.

As for abrasive blasting, the surfaces have to be previously washed with fresh water.

Hand tool cleaning is not recommended, since this preparation method is insufficient to apply any type of paint.

9.2.2.3 Hydro-jetting

Over the last few years, the surface preparation method named “hydro-jetting” has been used more and more in painting maintenance. The development of surface tolerant paints has certainly increased its use.

The advantages of hydro-jetting are the following:

- No abrasive materials are used, therefore a smaller amount of waste for disposal
- Soluble salts are completely removed

However, in ballast tank work, some difficulties may be encountered and summarised as follows:

- Due to the very high pressure of the water, the job must be performed by skilled and qualified operators
- It is difficult to clean all areas. Reverse side of structural elements, narrow spaces and structures can result untreated
- The production rate decreases with pressure increase
- Flash rust occurs in a short time.

Equipment reaching a pressure of 250 MPa (2.500 bar) is currently available on the market. It is necessary to point out that satisfactory results are achieved with a pressure over 150 MPa (1.500 bar).

A suitable standard, defining surface cleaning by hydro-jetting, has been prepared by NACE International and the SSPC, The Society for Protective Coating named SSPC-SP12/NACE No. 5 "*Surface Preparation and Cleaning of Steel and Other Hard Material by High- an Ultrahigh-Pressure Water Jetting Prior to Recoating".*

This standard is descriptive and provides four preparation degrees related to the water pressure used. The photographic standard, based on definitions, is near to being published. In the meantime, some paint manufacturers have prepared their own photographic standards.

Apart from definition of surface cleanliness, it is important to define the flash rust degree before application of the first coat. This subject has to be defined and agreed between owner, paint manufacturer and shipyard.

9.2.2.4 Electrolytic descaling

An electrolytic descaling system can be implemented when ballast tank surfaces are very rusted and heavy scales are present. The system is based on the galvanic principle and uses a strong electric current that causes the detachment of heavy rust scales from the steel.

Magnesium strips mounted in the ballast tanks usually produce the required electric current. Magnesium is used because, compared to steel, its difference of electrochemical potential is very high when the tank is filled with seawater. Magnesium strips act as an extremely active anode.

Recently, a system using the principle of impressed current cathodic protection has been introduced on the market. In this case, external equipment produces the required direct current. The positive pole is connected to one or more anodes (made from special alloys) appropriately placed in the tank, while the negative pole is connected to the ship's hull.

The final result is similar for both systems, but while the magnesium strips require one or two weeks in immersion, 3-4 days are sufficient for the impressed current system.

For both systems, the following aspects have to be taken into due consideration:

1) In the electrolytic process a great amount of hydrogen gas is produced. Therefore, to reduce the risk of explosion it is necessary to take suitable precautions, such as additional air vents and good ventilation.
2) The electrolytic process causes the formation of a soft layer of carbonate on the steel. This calcareous deposit, having a grey/white colour, is soft, gelatinous and easily removable when surfaces are wet. When the surfaces dry, the layer becomes hard and very difficult to remove. Therefore the surfaces have to be high pressure washed before the surfaces become dry. This operation is not always possible especially for large ballast tanks. It is advisable not to apply the coating on surfaces covered with calcareous deposits.
3) Electrolytic descaling cannot be considered as the only method for surface preparation, but rather as an aid to other methods (i.e. abrasive blasting or hydro-jetting). Abrasive

blasting or hydro-jetting performed on a steel surface with hard and heavy rust scales will result in more difficulties, be expensive and take longer.

REFERENCES

- Tasneef - Rules for the classification of ships
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APPENDIX 1

GLOSSARY OF WIDELY USED COATING TERMS

- **Abrasive** — Material used for blast cleaning. An abrasive is characterised by a specific physical property allowing steel roughness to be obtained.
- **Abrasive Blasting** — Surface preparation method that uses sand, metallic or other abrasives, propelled by air pressure, to clean a steel surface before painting.
- **Absorption** — Process by which a coating soaks up or absorbs water or other liquid.
- **Adhesion** — Resistance offered by a coating to the detachment action from a previous coat or from the substrate.
- **Ageing** — Progressive degradation of a coating in the long run.
- **Air Spraying** — An application method by which paint is atomised by compressed air and transported to the surface.
- **Airless Spraying** — An application method by which the paint is forced to a great pressure (up to 350 kg/sq. cm.) and is atomised by forcing it through a tiny nozzle.
- **Anode** — Positive pole of an electrolytic cell at which a corrosive reaction occurs.
- **Anticorrosive** — Generic term defining paint used to protect metals from corrosion.
- **Batch** — The amount of paint produced in a single production process and identified by a number assigned by manufacturer.
- **Binder** — Non-volatile part of paint vehicle.
- **Bleeding** — The appearance of a coloured substance on a newly painted surface from a previously painted substrate. The soluble substances causing this defect are for example: bituminous paint, specific organic pigments, etc.
- **Blistering** — Defect of a coating that retains air bubbles inside the film, solvent or reaction products causing an osmotic process. The defect may occur during coating life of immersed areas.
- **Blushing** — Development of a milky appearance on a coating surface during drying process caused by humidity and/or from the precipitation of one or more solid components of the paint.
- **Body** — Improper term to indicate the high percentage of volume solid of a paint.
- **Bubbling** — Coating defect, temporary or permanent, in which small bubbles of air or solvent or both are present in the applied film.
- **Cathode** — Negative pole of an electrolytic cell at which corrosion does not occur.
- **Cathodic Protection** — A technique to prevent corrosion of a metal surface by making an electrochemical contact between the substrate and a metal easier to be corroded, i.e. zinc, magnesium, aluminium, which in this case is sacrificed to preserve the less noble metal such as steel.
- **Chalking** — Formation of powder on a coated surface as a result of weathering.
- **Chipping** — Cleanliness method of steel by removing paint, rust and mill scale, or other material by mechanical tools.

APPENDIX 1

- **Clotted** — Irreversible gelatinisation of a paint that becomes unusable.
- **Coat** — Single coat of paint applied on a surface.
- **Coating Material** — Compound generally liquid, mastic or powder, forming a solid, filling protective and/or decorative coating.
- **Coating, Lining** — Term used to define various products that are applied on steel to protect it from corrosion and/or to decorate it.
- **Cohesion** — The force holding the molecules forming a coating together.
- **Compatibility** — Attitude of a paint to be applied on another already dry coating.
- **Corrosion** — Degradation of a metal, reacting with the environment through an electrochemical process.
- **Corrosion Rate** — Percentage indicating the increase of the corrosive process.
- **Cracking** — The splitting of a dry paint film, usually as a result of ageing or defect of the paint, or application procedure.
  It can be found in different forms such as:
  - Checking
  - Cracking
  - Crocodiling
- **Cross Application** — System of application by airless spraying and by brush consisting of crossing the various coats at right angles.
- **Cross Hatch Test** — A method for testing adhesion of a coating, performed by a parallel series of crosshatch cuts near each other.
- **Curing** — Complex of chemical phenomena which cause the polymerisation of the binder of the paint with formation of a tridimensional molecular structure insoluble in the original solvents of the binder.
- **Curing Time** — Time required by a coating to reach its complete properties and mechanical characteristic.
- **Curtaining** — Special form of sagging by which the film appears locally with high thickness and with flakes similar to drape curtains.
- **Dew Point** — The temperature at which air becomes saturated with water.
- **Discing** — Surface preparation method carried out with an abrasive disc assembled on a pneumatic or electric tool.
- **Discoloration** — Colour change of a coating after application, normally caused by exposure to sunlight or chemical atmospheres.
- **Dry Film Thickness** — The thickness of the paint film, after drying and curing.
- **Dryers** — Substances that incorporated in relatively small percentages in the paint accelerate the drying process.
- **Drying** — Process by which coatings change from a liquid to solid state due to evaporation of the solvent, physical/chemical reactions of the binder or a combination of these factors.
- **Drying Time** — Time required for an applied film to reach a determined state of drying.
- **Dulling or Tarnishing** — Loss of gloss of a coating.

• **Elasticity**	Term improperly used to indicate the flexibility of the coating, corresponding to a permanent plastic deformation.
• **Enamel**	A finish coat of paint thatshows a smooth, gloss surface after drying.
• **Erosion**	Gradual and irregular destruction of coating surface caused by a mechanical or also by a chemical-physical action.
• **Extender**	Inert substance, for certain characteristics similar to pigments, but without or of low hiding power, used as a paint component for technical needs or for economic reasons (filling) (see "Pigments").
• **Film**	A layer of coating material applied on a surface. The film just applied, before evaporation of the solvents is called "wet film"; the dry paint film, after solvent evaporation, "dry film".
• **Finish**	Term used to define indifferently the final coat in a paint system or the general aspect of a painted surface after drying.
• **Flaking**	Detachment of a coating from the surface, in the form of flakes.
• **Flash off**	Starting stage of drying process, during which most of the solvents evaporate from the coating.
• **Flash Point**	The lowest temperature at which a liquid gives off sufficient vapour to form an ignitable mixture with the air near the surface of the liquid.
• **Flexibility**	Attitude of a coating to follow the movement or deformation of the support, without breaking or cracking.
• **Flooding-Floating**	Differentiated separation of pigments on a coating surface
• **Galvanising**	Anticorrosive system which consists in dipping a steel structure, into melted zinc at a temperature of approximately 450°C.
• **Gelling**	Partial or complete transformation of a paint into a mass similar to a gelatine.
• **Glazing**	Coat intentionally applied with a small thickness.
• **Gloss**	Aptitude of a surface to reflect the light in certain conditions.
• **Hard Coatings**	Coatings that convert chemically during their drying process or a non-convertible coating that dries with air. In general it is typical of paint.
• **Hardener, Curing agent, Catalyst**	Component of a two-pack paint that mixed with a binder creates a chemical reaction forming a harder and resistant film.
• **Hardness**	Resistance of a dry coating to scratching or to superficial deformation due to pressure.
• **Hiding Power**	The ability of a coating material to hide, after drying, the colour of surface underneath.
• **Holidays**	Coating defect characterised by areas of a painted surface with low film thickness or by areas completely unpainted.
• **Hot Spraying**	Spray application of a coating that has been heated to reduce its viscosity in special equipment.
• **Impressed current**	Cathodic protection system in which the current is supplied at the anode from an external source.

- **Inhibitor** — Additive used, usually in small percentage, to stop or delay a chemical reaction.
- **Light Colour** — Colour of a coating different from the colour of rust making identification of it easier.
- **Material Safety Data Sheet** — Document published by paint manufacturer in which components of the paints and all the safety requirements are given.
- **Orange peel** — Appearance similar to orange peel, that can be seen on a film applied by airless spraying due to incomplete levelling.
- **Paint System** — Sequence of the various coats, listing type of paints and of the number of coats applied.
- **Peeling** — Disbonding of particles of a coating from substrate in the form of strips, due to loss of adhesion.
- **Pigments** — Insoluble coloured particles dispersed in a coating material in order to define appearance, structure and functionality of the final film.
- **Pinholes** — Presence of small holes in a coating that are formed during application or drying.
- **Pitting** — Cavity in a metallic surface, due to localised corrosion.
- **Pot Life** — Time limit within which a coating material can be applied after catalyst is added.
- **Power Tool Preparation** — Surface preparation method carried out by mechanical tools, pneumatic or electric such as abrasive discs, wire brush, sandpaper etc.
- **Primer** — General term used to define the first coat of a paint system applied to provide adhesion and/or corrosion protection.
- **Product Data Sheet** — Document published by paint manufacturer in which the characteristic of the product, the method to use, the instructions for application and storage are indicated.
- **Resin** — Solid or semisolid organic compound, of natural or synthetic origin, used as binder of the paints to form a non-crystalline film.
- **Roller Application** — Hand application of a coat of paint udsing an absorbing roller on a surface.
- **Sacrificial anode** — Anode made from less noble metal than steel in the galvanic series, (usually zinc or aluminium). When immersed, the anode protects the steel by coming into solution.
- **Sag** — Downward flow of a wet coat and consequent formation of irregular amount of paint: drops, curtains etc. Sagging is due to the prevalence of the force of gravity on those of adhesion and of cohesion and happens on vertical or inclined surfaces.
- **Sandpapering** — Generic term identifying various methods used to smooth or in some cases to roughen a coating surface. In particular, sandpapering is a smoothing carried out with abrasive paper.
- **Semi-Hard Coatings** — Coatings that, after drying, remain flexible and hard enough to be touched and walked upon without damaging them and that are not affected by water erosion during deballasting operations.
- **Settling** — Accumulation of pigments and fillers in the bottom of a paint container.

- **Shop-primer** — Specific type of paint applied at low thickness (15-20 microns) after shot-blasting and in automatic plant for the temporary protection of steel plate, before cutting, welding and other fabrication phases.
- **Shot Blasting** — Abrasive blasting operation usually performed in shops using a spherical or grit metallic abrasive.
- **Skinning** — Solidification process of the superficial part of paint in the can due to oxidation, evaporation, coagulation etc.
- **Soft-Coatings** — Coatings, that not drying, remain permanently soft and can be removed by walking on and by contact.
- **Solid Content** — Non-volatile part of a paint, see also solids by volume.
- **Solvent** — Volatile liquid, used to dissolve the binder, which evaporates during the drying stage.
- **Solvent-Free** — Paint without volatile binder (also called 100% volume solid).
- **Solvent-Less** — Paint containing a small percentage (generally 10/15%) of volatile binder.
- **Spreading Rate** — Surface in square metres covered by one litre of paint at a specified thickness.
- **Stripe Coating** — Painting method used before a general coat on positions (weld, back, edge, corner etc.) where it is not easy to achieve the final thickness with the simple airless spray application.
- **Thermo-Hygrometric Condition** — The environmental conditions that are present during surface preparation and paint application.
- **Thinner** — In commercial language it means a mixture of solvents and not volatile solvents, perfectly compatible with the paint, added to reduce its viscosity.
- **Thinning Ratio** — Property of a paint to englobe a determined percentage of suitable thinner, to reach the right consistency for application by brush, airless spray or roller.
- **Thinning Ratio** — Percentage of solvents to add to a paint, to make it suitable for a defined application system.
- **Thixotropy** — Characteristic of a coating material to reach a viscosity reduction when shaken, stirred or other mechanical operations and that readily recovers its original viscosity when allowed to stand.
- **Touch drying** — Drying is the stage of film formation in which, when exercising a light pressure with the finger, no sign remains and it is not sticky.
- **Touch-up** — Operation of repair of spot damage coated surface.
- **Two-Pack Paints** — Paints stored in two separate containers and that have to be mixed in the correct proportion before application.
- **Varnish, Lacquer** — Non-pigmented coating material.
- **Vehicle** — The liquid portion of paint in which the pigment is dispersed. It is made up of resin and solvent.
- **Volume Solids** — Non-volatile part of a coating compound, which after drying forms the coating.

APPENDIX 1

- **Wet Film Thickness** The thickness of paint film just applied and before evaporation of the volatile part.

- **Wet-on-Wet** Paint technique consisting of the application of a coat on a previous one not yet dry. The result is of one film that dries as a whole. The process requires specific paints.

- **Wrinkling** Coating defect due to a non-homogeneous solidification of the paint film with wrinkling of the surface coat.

Reference Standards mainly used in paint work

1. GENERAL

Standards and rules are reference documents, descriptive and photographic, which regulate the execution and control of paint work.

- Many standards issued by organisations and international associations exist which were applied to paint work or to activities connected to them. Like the type of activity there are standards which regulate:
- The surface finishing of welds and edges
- The surface preparation for painting
- The choice of the paint system
- Laboratory test on the paint
- The evaluation and the extension of failure of a paint system
- The systems and the procedures for measuring a dry paint film.

In the following only the number and name of the standards mainly used in the paint field, divided by application sector, will be listed. A detailed explanation of each standard is not the purpose of this guide. The complete books of the standards may be bought from the organisation or association that issued them.

All the standards are written in the English language (the French language is used as an alternative for some ISO standards). To avoid mistakes of translation and interpretation we prefer to leave the title of the standards in the original English form.

2. SURFACE FINISHING OF WELDS AND EDGES

- **NACE RP0178** Fabrication details, surface finish requirements and proper design considerations for tanks and vessels to be lined for immersion services
- **ISO/DIS 8501-3.2 (1999)** Preparation of steel substrates before application of paints and related products. Visual assessment of surface cleanliness.

  Part 1: Preparation grades of welds, cut edges and other area with surface imperfections

3. SURFACE PREPARATION BEFORE PAINTING

3.1 Standards ISO

- **ISO 8501** Preparation of steel substrates before application of paints and related products. Visual assessment of surface cleanliness.

  Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after removal of previous coatings.

  Part 2: Preparation grades of previously coated steel substrates after localised removal of previous coatings.
- **ISO 8502** Preparation of steel substrates before application of paints and related products. Test for the assessment of surface cleanliness

  Part 1: Field test for soluble iron corrosion products

  Part 2: Laboratory determination of chloride on cleaned surfaces

  Part 3: Assessment of dust on steel surfaces preparaed for painring (pressure-sensitive tape method)

  Part 4: Guidance on the estimation of the probability of condensation prior to paint application

Part 5: Measurement of chloride on steel surfaces prepared for painting (ion detection tube method)

Part 6: Extraction of soluble contaminants for analysis. The Bresle method.

Part 9: Field method for conductometric determination of water-soluble salts.

Part 10: Field method for the titrimetric determination of chloride.

- **ISO 8503** Preparation of steel substrates before application of paints and related products. Surface roughness characteristics of blast-cleaned steel substrates.

  Part 1: Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces.

  Part 2: Method for the grinding of surface profile of abrasive blast-cleaned steel. Comparator procedure.

  Part 3: Method for the calibration of ISO surface profile comparators and for the determination of surface profile. Focusing microscope procedure.

  Part 4: Method for the calibration of ISO surface profile comparators and for the determination of surface profile. Stylus instrument procedure.

- **ISO 8504** Preparation of steel substrates before application of paints and related products. Surface preparation methods.

  Part 1: General principles.

  Part 2: Abrasive blast-cleaning.

  Part 3: Hand- and power-tool cleaning.

3.2 Standards SSPC/NACE

- **SSPC-SP 1** Solvent Cleaning
- **SSPC-SP 3** Power Tool Cleaning
- **SSPC-SP 5/NACE No. 1** White Metal Blast Cleaning
- **SSPC-SP 6/NACE No. 3** Commercial Blast Cleaning
- **SSPC-SP 7/NACE No. 4** Brush-off Blast Cleaning
- **SSPC-SP 10/NACE No. 2** Near-White Blast Cleaning
- **SSPC-SP 11** Power Tool Cleaning to Bare Metal
- **SSPC-SP 12/NACE No. 5** Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating
- **SSPC-VIS-1** Visual Standard for Abrasive Blast Cleaned Steel
- **SSPC-VIS-3** Visual Standard for Power and Hand Tool Cleaned Steel
- **NACE RP0178** Fabrication Details, Surface Finish Requirements, and Proper Design Considerations for Tanks and Vessels to be Lined for Immersion Service.
- **NACE RP0287** Field Measurement of Surface Profile Abrasive Blast Cleaned Steel Surfaces Using a Replica Tape

3.3 Standard SPSS

As already said in the Guide *Secondary preparation* is the operation that is carried out on a surface with shop-primer with the purpose of eliminating salt zinc and preparing the damage due to welding and burning.

The only standard that defines this type of preparation in a suitable way is the so called "Japanese Standard" prepared by the Shipbuilding Research Association of Japan (JSRA), denominated SPSS - Standard for the Preparation of Steel Surface prior to Painting.

3.4 Comparative initials of the standards

In the following schedule the relative correspondences of the degree of finish of the surface preparation of the above-mentioned standards are given for information only:

METHOD	SSPC/NACE	ISO	SPSS
Mechanical preparation	SP 11	None	None
	SP 3	St 3	Pt 3
	SP 2	St 2	Pt 2
	None	None	Pt 1
Abrasive blasting	SP 5	Sa 3	Sh(d) 3
	SP 10	Sa 2,5	Sh(d) 2
	SP 6	Sa 2	Sh(d) 1
	SP 7	Sa 1	Sh(d) 1

3.5 Other standards related to surface preparation

- **ISO 11127** Preparation of steel substrates before application of paints and related products. Test methods for non-metallic blast-cleaning abrasives.

  Part 6: Determination of water-soluble contaminants by conductivity measurement

  Part 7: Determination of water-soluble chlorides
- **ASTM D-4940** Test Method for Conductimetric Analysis of water Soluble Ionic Contamination of Blasting Abrasives
- **ASTM D-4285** Standard Test Method for Indicating Oil or Water in Compressed Air

4. CHECKS AND TESTS ON THE PAINT FILM

4.1 Paint film measurement

- **SSPC-PA 2** Measurement of Dry Coating Thickness with Magnetic Gages
- **ISO 2808** Paints and varnishes - Determination of film thickness

4.2 Check of adhesion of paint film

- **ASTM D-3359** Standard Test Methods for Measuring Adhesion by Tape Test
- **ASTM D-4541** Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers
- **ISO 2409** Paints and varnishes - Cross-cut test
- **ISO 4624** Paints and varnishes - Pull-off test for adhesion

4.3 Check of continuity of paint film

- **ASTM D 5162** Practice for Discontinuity (Holiday) Testing of Non-destructive Protective Coating on Metallic Substrate
- **NACE RP0188** Standard Recommended Practice - Discontinuity (Holiday) Testing of Protective Coatings

4.4 Defect evaluation of paint film

- **ISO 4628** Paints and varnishes - Evaluation of degradation of paint coatings - Designation of intensity, quantity and size of common types of defect

  Part 1: General principles and rating schemes

  Part 2: Designation of degree of blistering

  Part 3: Designation of degree of rusting

  Part 4: Designation of degree of cracking

  Part 5: Designation of degree of flaking

  Part 6: Rating of degree of chalking by tape method
- **European Rust Scale**
- **ASTM D-714** Evaluating degree of blistering of paints
- **ASTM D-660** Evaluating Degree of Resistance to Checking
- **ASTM D-661** Evaluating Degree of Resistance to Cracking of Exteriors Paints