BUREAU VERITAS

GUIDELINES

FOR

CORROSION PROTECTION

OF

SEAWATER BALLAST TANKS

AND

HOLD SPACES

NI 409 DNC R00E
September 1995

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The Society :
- sets forth and develops Rules, Guidance Notes and other documents ;
- publishes Registers ;
- issues Certificates, Attestations and Reports following its interventions.

1.2. - BUREAU VERITAS also participates in the application of National or International Regulations or Standards, in particular, by delegation from different Governments.

1.3. - BUREAU VERITAS can also carry out Technical Assistance missions and provide special services exceeding the scope of classification, to which Particular Conditions will then apply.

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2.2. - The documents issued pursuant to surveys carried out by the Society's surveyors according to the methods and modalities mentioned in articles 3 and 4 reflect the condition of the ship at the time of the survey. It is the Owner's or his Agent's responsibility to maintain that condition until the next survey required by the Rules.

ARTICLE 3

BUREAU VERITAS
- appraises specifications and drawings for the construction of ships by reference to its Rules,
- inspects materials, machinery, equipment, fittings and other items used in the construction of ships, by reference to its Rules,
- surveys the construction of ships to ensure that they are built in accordance with approved drawings and the Society's published Rules,
- classes ships in accordance with its Rules and publishes the ships' names in its Register,
- carries out periodic surveys of ships in service in order to ensure that the requirements for the specified class are met. It is the owner's duty to report to the Society any incident or event affecting the condition of the ship or the need for repairs, whatever their nature or extent.

ARTICLE 4

4.1. - The Rules, Guidance Notes and other documents published by the Society endeavour to meet the state of the art and technology at the time they are published.

Committees, consisting of personalities from the International Maritime Industry, contribute to the development of these documents.

The Society is not responsible for any inadequacy or failure of such Rules, Guidance Notes or other documents as a result of future development of techniques which could not reasonably have been foreseen at the time of their publication.

4.2. - BUREAU VERITAS is sole qualified to decide upon the meaning, the interpretation and application of the documents mentioned above. Any reference to them is of no value if it does not involve, accompany or follow a Society's intervention.

4.3. - The Society exercises due care and skill and acts in a professional and workmanlike manner :
- in the selection of its surveyors,
- in the performance of its services, considering the state of the art and technology in existence at the time the services are being performed.

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ARTICLE 5

5.1. - No report, statement, notation on a plan, review, certificate of class or any document or information issued or given as part of the services provided by the Society shall be given any legal effect or implication other than a representation that the ship, structure, item of material, equipment or machinery or any other item covered by such document or information has met one or more of the Society's Rules. Any such representation is issued solely for the use of the Society, its committees and clients or other duly authorized entities and for no other purpose.

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In particular, the Society does not declare the acceptance or commissioning of a ship, that being the exclusive responsibility of the owner.

The validity, application, meaning and interpretation of a Classification Certificate or any similar document or information issued by the Society in connection with, or in furtherance of the performance of its services, is governed by the Rules of the Society which shall be the sole judge thereon, in its absolute discretion.

ARTICLE 6

6.1. - In providing services, information or advice, neither the Society nor any of its servants or agents warrants the accuracy of any information or advice supplied. Furthermore, all express and implied warranties are specifically disclaimed. Except as set out herein, and also in the case of the surveys mentioned in Article 1.2., neither the Society, nor any of its servants or agents, shall be liable for any loss, damage or expense of whatever nature sustained by any person, in tort or in contract, due to any act or omission or error of whatever nature, whether or not negligent, and howsoever caused in any information or advice given in any way whatsoever by or on behalf of the Society.

6.2. - Nevertheless, if any person uses the Society's services, and suffers loss, damage or expense thereby, which is proved to have been due to any negligent act, omission or error of the Society, its servants or agents, or any negligent inaccuracy in information or advice given by or on behalf of the Society, then the Society will pay compensation to such person for his proved loss, up to, but not exceeding, five times the amount of the fee - if any - charged by the Society for the particular service, information or advice and, if no fee is charged, FRF 50,000.

Where the fees are related to a number of services, the amount of fees shall be apportioned for the purpose of the calculation of the maximum compensation, by reference to the estimated time involved in the performance of each service.

Any liability for consequential damages is specifically excluded.

In any case, whatever the amount of the fees, the maximum damages payable by the Society shall be not more than FRF 5,000,000.

6.3. - Any claim for damages of whatever nature by virtue of the provisions set forth herein must be made in writing, and notice must be provided to the Society within six months of the date the services were first supplied or the damages first discovered. Failure to provide such notice within the time set forth herein will constitute an absolute bar to the pursuit of such claim against the Society.

ARTICLE 7

Requests for interventions shall, in principle, be submitted in writing. They entail the acceptance without reservation, of the present General Conditions and of Particular Conditions which may be attached thereto.

ARTICLE 8

8.1. - Any intervention of BUREAU VERITAS, whatever its nature, whether completed or interrupted for any cause whatsoever, shall involve the payment of fees upon receipt of the invoice and the reimbursement of the expenses incurred. Interests may be demanded in case of late payment.

8.2. - The class of a ship may be withheld or, if granted, suspended or withdrawn, in the event of non-payment of fees.

ARTICLE 9

9.1. - All plans, drawings, specifications and information provided to the Society, or of which the Society may become reasonably aware in connection with the performance of its services, shall be treated as confidential by the Society and shall not, without the prior consent of the party furnishing such document, be used for any purpose other than that for which they are furnished.

9.2. - Records and other documents whatsoever relating to ships classed with the Society shall not be disclosed or communicated by the Society to any third party but with the prior approval of the owner, unless it is in pursuance of an order of the flag authorities or an injunction of a Court having jurisdiction.

ARTICLE 10

Should a technical disagreement arise between the requesting party and the BUREAU VERITAS surveyor, the Society may, at the request of that party, designate another of its surveyors.

ARTICLE 11

Any dispute over the interpretation, or the enforcement of these General Conditions of services, or the performance of BUREAU VERITAS's services, shall be submitted to arbitration in London. Arbitration proceedings will be conducted according to the English law on arbitration. The arbitrator shall be selected by the parties and, in case they could not reach an agreement, he would then be nominated by the President of the Law Society of England and Wales upon request of any party.

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FOREWORD

This guide is intended to provide shipyards and shipowners with information and recommendations concerning various systems of protection against corrosion, so that they can make the proper choice and draw up a contractual specification. The guide applies mainly to new buildings of ships, and also to ships in service.

The guide is concerned mainly with protection of seawater ballast tanks of all types of ships and hold spaces on bulk and ore carriers. It concerns only the protection of such structures made from carbon steel. Some chapters (in particular chapter 3) give general information on corrosion protection.

The recommendations set out in this guide to protect seawater ballast tanks assume a life expectancy of approximately twelve years in case of new buildings coated with hard coating.

The guide does not come within the framework of BUREAU VERITAS Classification Rules. As its name indicates, it is merely a guide for the use of shipyards and shipowners.

The Classification Society is concerned with corrosion protection from two standpoints:

- For new ships at the building stage, to check that zones requiring protection, as specified in the BUREAU VERITAS Rules, are protected.

- For ships in service at the maintenance stage, in relation to the frequency of surveys (Refer to 1.2.2. and Appendix 2).

The particular requirements of BUREAU VERITAS concerning corrosion protection are appended to this guide.

The guide has been drawn up following the work of the *ad hoc* workgroup "Coatings to protect seawater ballast tanks and hold spaces against corrosion". Shipyards, shipowners, painters, paint manufacturers and BUREAU VERITAS all took part in this workgroup.

Users of this guide are reminded of the fact that the subjects dealt with are not examined in detail. The guide is primarily a practical handbook for users.

A glossary of the main terms is given in Appendix 1, for the purpose that the same language is spoken by the users of this guide.

CHAPTER 1 - INTRODUCTION

1.1. General

Corrosion is one of the main causes of structural problems encountered on ships in service.

Large areas of ship structures can be subject to severe corrosion:

- seawater ballast tanks,
- bulk carrier holds, especially when carrying cargoes of corrosive nature of (e.g. coal with high sulphur content),
- cargo tanks, following washing operations.

Many factors contribute to the spread of corrosion, including:

- severe stress on certain zones,
- water retained on horizontal surfaces,
- condensation and streaming of water,
- corrosive cargoes,
- flexibility of sideplating
- inadequate cleaning of bulker holds.

Some of these factors can be taken into account at the design stage, by examining the behaviour of the structure in relation to corrosion.

However, such measures are not sufficient to prevent or reduce the effects of corrosion. The durability of a structure subject to corrosion depends mainly on corrosion protection applied to the new building.

1.2. Regulations

1.2.1. International Regulations

THE IMO will amend the chapter II-1 of the SOLAS 74 Convention by adding a new regulation 14.1. This new regulation will ask for an efficient system of corrosion protection in water ballast tanks of oil tankers and bulk carriers.

1.2.2. BUREAU VERITAS Rules for Classification of ships

Given these changes in International regulations, BUREAU VERITAS has introduced the following IACS Unified Rules and IMO Regulations into its own Rules:

1) In April 1992 (for ships more than 65 m in length) and in August 1991 (for ships less than 65 m in length):

   Salt water ballast spaces having boundaries formed by the hull envelope shall have an efficient protection coating (BUREAU VERITAS Rules and IACS Unified Rule Z8).

2) In May 1993:

The frequency of inspections of ballast tanks on all ships and of holds in bulk carriers after the first five years depends on the condition of the protective coating (BUREAU VERITAS Rules, IACS Unified Rules Z7, Z10.1 and Z10.2, and IMO Resolution A744 (18)).

3) In September 1993:

Sensitive areas in holds of bulk carriers under construction must be protected by a suitable coating (BUREAU VERITAS Rules and IACS Unified Rule Z9).

Appendix 2 contains the parts of the BUREAU VERITAS Rules concerning the protection of seawater ballast tanks and holds (new buildings and maintenance).

1.3. Economic aspect

1.3.1. Extent of surface areas to be protected during construction

The new regulations (Rule 13F of 1992 amendments to Annex 1 of MARPOL Convention 73/78), requiring a double hull for oil tankers and product carriers, means that the surface areas of ballast tanks to be protected on such ships are now very large.

For information, table 1.I below shows the surface area of seawater ballast tanks on oil tankers and product carriers, in the case of a single hull and in the case of a double hull.

Table 1.I

Deadweight	Single hull	Double hull
40000 t	20000 m^2	70000 m^2
250000 t	50000 m^2	250000 m^2

The change from a single to a double hull means that the area of ballast tanks to be protected against corrosion is increased 3.5 to 5 times.

1.3.2. Cost of corrosion protection

In addition to the cost of applying protection to the new building, allowance must be made for the cost of maintenance and long-term repairs (immobilisation of the ship, painting, scaffolding, possible replacement of plates). This means that the cost of restoring the paint protection can be approximately eight to ten times the cost during building.

Therefore, it is preferable to invest at the construction stage in the best possible protection against corrosion.

CHAPTER 2 - CORROSION OF STEEL

2.1. General

Corrosion is the process of deterioration of metallic materials and their properties, following a reaction with the surrounding environment.

The metals tend to return to a more stable thermodynamic state: iron oxide (rust) for steel.

2.2. Unprotected steel

2.2.1. Types of corrosion

2.2.1.1 Galvanic corrosion

This type of corrosion occurs when two metals or alloys are electrically in contact in a corrosive environment (electrolyte). The less noble metal, in other words the one with the greater electronegative potential is attacked ; it is called anode. The most noble metal is protected ; it is called cathode. This process is known as galvanic corrosion. A more detailed explanation of the processes involved is given in Appendix 3.

This type of corrosion is affected by the following factors:

- difference in potential between the two metals or alloys,
- relative surface areas of anodic and cathodic zones,
- distance between anode and cathode,
- electrical resistance of the galvanic circuit (which depends, in particular, of the electrolytic conductivity and of the coating protection).

2.2.1.2 General corrosion

This involves an almost uniform attack over the surface of the material. In this type of corrosion, the galvanic process extends uniformly over the whole surface.

This form of corrosion is not particularly dangerous, because it can be predicted by tests, and wear on the material is proportional to time and easily measurable.

2.2.1.3 Pitting corrosion

This involves a localised attack, which can result in perforation of the metal or alloy. It is one of the most insidious forms of corrosion.

This form frequently occurs on damaged parts of non-conducting layers on the surface of the metal (oxide films).

In particular, pitting often occurs on stainless steels, and is usually caused by surface contamination.

2.2.1.4 Crevice corrosion

This is an intense localised form of corrosion, usually associated with small volumes of stagnant solution resulting from holes, masked surfaces or crevices.

The mechanism can be explained by the fact that the stagnant solution inside the crevice prevents the diffusion and migration of ions, and that access of oxygen to the metal surface area at corrosion bottom is inadequate to keep the protective oxide layer intact (case of stainless steels).

2.2.1.5 Stress corrosion

In this type of corrosion, fractures occur in the material exposed to a corrosive environment and subject to stresses, the levels of which would not be regarded as dangerous if they were applied outside the corrosive environment. For example these stresses can be residual stresses of welding or thermal stresses.

Such fractures are also not easily detectable.

2.2.1.6 Bacterial corrosion

This form of corrosion is caused by certain bacteria, particularly sulphate-reducing anaerobic bacteria. Such corrosion develops under corrosion deposit product, or in deaerated seawater circuits.

2.2.2. Principal corrosion factors

2.2.2.1 Electrolyte salinity

Seawater contains a high level of salinity (about 3,5 %) and therefore of conductivity. This encourages galvanic corrosion and localised attacks.

In addition, chlorides present in seawater produce breakings in the protective oxide films responsible for corrosion resistance of many materials.

Finally, as regards general corrosion, the rate of corrosion increases in proportion to the salt content.

2.2.2.2 Oxygen

Oxygen is one of the most important factors in corrosion. A decrease in oxygen concentration causes a rise in corrosion rates.

In addition, variations in oxygen concentration on the surface of the same material result in corrosion by differential aeration: surfaces with the lowest oxygen concentration undergo accelerated corrosion.

2.2.2.3 Electrolyte temperature

In general, and if there is no modification in the environment, corrosion increases with temperature. In the same way, it increases with the speed of circulation.

2.2.2.4 Bacteria

Bacteria present in seawater can cause local changes in corrosive conditions, and are therefore dangerous for most metallic materials. The mechanisms of bacterial attack are still unknown. However, efforts are made to combat it by trying to limit the deposits beneath which such bacteria develop, and by using bactericides.

2.2.3. Corrosion rates

For information, the following Table 2.I gives some corrosion rates, in mm/year, on structures of oil tankers in service. These figures refers to uncoated platings.

Table 2.1

Plating	Segregated Ballast Tank	Cargo / Ballast Tank	Cargo Oil Tank
Deck	0,10 - 0,50	0,05 - 0,30	0,03 - 0,10
Side shell	0,05 - 0,10	0,05 - 0,10	-
Bottom	0,05 - 0,25	0,05 - 0,25	0,04 - 0,10
Longitudinal bulkhead	0,10 - 0,30	0,03 - 0,50	0,03 - 0,10
Transverse bulkhead	0,30 - 0,50	0,02 - 0,10	0,03 - 0,10

2.3. Steel protected by paint coating

In the case of surfaces protected by coats of paint, corrosion can develop in one of the following ways:

1) Local cracks in the paint film

In this case, corrosion is galvanic, and highly active.

These local cracks in the surface can result from mechanical wear or defects in the paint film which have not been checked and repaired on the new building stage (e.g. absence of grinding to smooth the sharp edges of cutouts).

Such cracks may also result from localised fatigue stresses, caused by design errors, or from plastic structural deformations, exceeding the elongation properties of the paint film.

2) Lack of thickness of paint film

A dry film of paint is never completely impermeable to liquid and gas, and full protection requires a certain thickness in order to provide a proper barrier against corrosion.

This type of corrosion is slower than in the case of a local crack in the paint film, but it is generally more extensive.

3) Premature ageing of paint film

Premature ageing of the paint film, particularly of the top coat, will mean less protection for lower layers, and consequently greater permeability to liquid and gas. For this purpose, the film should have a homogeneous thickness in any point.

Premature ageing of the top coat may result from the incorrect choice of type of the paint for its resistance to chemicals, UV or heat, for example.

CHAPTER 3 - CORROSION PROTECTIONS

3.1. General

3.1.1. Application

This chapter is devoted to protection of steel structures against corrosion. This chapter gives general information applying also to other structures than water ballast tanks and hold spaces.

3.1.2. Paint system

A good protection system by painting depends on the following parameters:

- the choice of types of paint, which is to be suitable for the surface to be protected, the environment and required useful life,
- the surface preparation, which is to be suitable for the paint,
- the thickness of the film,
- the conditions of application,
- the work planning,
- the conditions of survey and inspection.

Moreover, it should also be remembered that paint manufacturer's recommendations must be respected under all circumstances.

3.2. Hard coatings

3.2.1. Definition

Generally, a hard coating is a paint. This is in liquid form prior to application and dries after application. A dry, hard coat of paint then remains on the surface, hence the term "hard coating".

3.2.2. Types of paints

Before considering types of paints, the main components of any paint should be recalled:

- the binder, providing internal cohesion in the paint film and the bond with the substrate, and giving the chemical resistance,

- the pigments, which give the paint its colour, covering power, correct consistency and resistance to abrasion,

- the fillers, which allow the paint to be applied in thick layers, without the risk of breaking caused by cracking of the film,

- the additives which, for example, confer thixotropic or fongicidal properties to the paint,

- the solvents, in which the paint binder is diluted in the liquid state, and which evaporate as the paint dries.

Paints are classified in relation to their binders and the way in which they dry and harden.

There are three main ways in which paints cure:

- drying by oxidation,
- physical drying,
- chemical curing.

Paints which dry by oxidation, in addition to evaporation of solvents, require oxygen to provide a bond for the molecular chains which will form the continuous film of paint. Oil paints and alkyd paints form part of this group.

Physical drying paints are dissolved before application in very strong solvents, which prevent strong bonds in molecular chains. When these solvents have evaporated, bonds form and the paint cures.

In general, paints in this second group are based on the following binders:
- chlorinated rubber,
- vinyl,
- bitumen,
- tar.

Chemical curing paints contain two components: the base and the hardener. Curing is obtained by mixing the base and hardener in clearly defined proportions. A chemical reaction then occurs, causing crosslinking of the molecular chains. Once cure, these paints provide a very hard film.

In general, paints in this third group are based on the following binders:
- epoxy,
- tar epoxy,
- polyurethane,
- polyester,
- zinc silicate.

3.2.3. Criteria for the selection of paint systems

In order to select the paints for a particular application, it is important to know their main properties and the particular conditions for their application and maintenance.

They are given hereafter:

1) Surface preparation

   The quality of the necessary surface preparation varies in degree. Requirements shall be respected, in order to ensure that the paint adheres properly to the material. This factor has a fairly high impact on the total application cost.

2) Two-components or one-component paint

   There are obviously risks of mixing two-components paints incorrectly, or using the wrong proportions.

3) Percentage solvents

   A paint containing a high percentage of solvent will be easy to apply, but solvent evaporation will be more intense, and precautions are needed to ensure replacement of air. Solvent free paints should preferably be used in confined spaces for safety reasons.

4) Temperature of application

   Temperature limits should be respected in order to ensure satisfactory application and drying. This applies especially to chemical curing paints, as epoxy.

5) Recoating time

These are the minimum and maximum times between which a second coat of paint may be applied, to retain maximum adherence between the two coats.

6) Drying time

This is an important factor, particularly in case of repairs for which the available time is often short.

7) Colour

In order to check that one coat will cover the coat below, colour of paints can be alternated.

8) Maximum dry film thickness

When the paint film is thin, several coats can be needed to ensure the required protection. This implies a significant increase in the application cost.

9) Covering properties

Certain very hard paints, or paints which have a very smooth, high gloss finish, present poor ahesion qualities. It is advisable to use such paints only for the top coat.

10) Elongation

This property is to be taken into account when the paint is applied to a zone subject to stresses and/or to fatigue.

11) Resistance to water and chemicals (acids, solvents, etc)

This parameter is to be considered in relation to the environment in contact with the painted surface. The word "permeability" can also be used as equivalent to "waterproof".

12) Resistance to abrasion, impacts, heat and UV

These properties should be examined in relation to the surrounding environment.

13) Toxicity

For health and safety reasons, the painter must be informed of any dangers he may incur.

3.2.4. Surface preparation

1) Importance of surface preparation

The only way of ensuring the durability of a coat of paint is to ensure that it adheres properly to the underlying material.

Such adherence is possible only on a well cleaned surface.

The following substances are to be removed, according to relevant standards :

- metal oxides,
- scales,
- water soluble salts,
- old coatings,
- dust,
- grease and oil,
- foreign matters,
- humidity.

Moreover, the cutting sharp edges and angularites on welds are to be treated, in order to avoid local cracks in the paint film.

In order to ensure the good adherence of the coating, the so prepared surface is to present the specified roughness, adapted to the type and thickness of the coating.

2) Types of surface preparation

Degres of rust and surface preparation are defined by reference to standard ISO 8501.1. Other standards may be used for reference, if they are recognised as equivalent to the ISO standard.

Surface roughness is defined by reference to standard ISO 8503.

Table 3.I below shows, in a general scope, the characteristics of the two main modes of cleaning: blastcleaning ("Sa" according to ISO 8501.1) and mechanical or manual cleaning ("St" according to ISO 8501.1).

Table 3.I

METHOD	CARACTERISTICS
Blastcleaning (Sa)	- Excellent to remove metal oxides, scales and substances adhering to the surface, - Excellent to ensure surface roughness, - May be insufficient to remove grease, oil and water-soluble salts, - Work time much shorter than for other methods.
Mechanical or manual cleaning (St) : - Scraper, - Buffer, - Brush.	- Insufficient to ensure surface roughness : risk of polishing the surface, - Insufficient to remove grease, oil and water-soluble salts, - Costly methods.

Blast-cleaning usually provides an excellent result.

Mechanical means may be used in areas where blastcleaning is difficult to carry out.

Compared to blast-cleaning and mechanical cleaning, manual methods give less results and should consequently be avoided, if possible.

As a general rule, all steel structural components to be painted are blast-cleaned, in order to obtain at least grade Sa 2 1/2, according to ISO 8501.1.

3) Preparation of edges and welds

In general, surface defects, such as splashes of welding material, weld defects and irregular weld profiles, need to be removed before actual surface preparation takes place:

- sharp and acute cutting ridges must be chamfered or rounded,
- welds and burns must be blastcleaned,
- plate defects must be removed by grinding, brushing or blastcleaning.

Users are advised to consult the document "STEELPLATING PREPARATION STANDARDS PRIOR TO PAINT WORK", published by the French Shipbuilding Research Institute, under reference IRCN 3.3.06/85.

3.2.5. Application procedures

1) Ambiant conditions

To prevent problems of adhesion and paint defects caused by condensation, the ambiant conditions given by the paint manufacturer are to be followed and checked.

Except for particular case, the following conditions should, in general, be observed:

- relative humidity of air less than 85 per cent,
- surface temperature at least 3°C above dewpoint,
- minimum and maximum temperatures of the surface are to be in accordance with the recommendation of the paint manufacturer.

2) Methods of application

There are many methods for applying paints. For application to steel constructions, only applications by brush, roller or airless spraygun are recommended. Table 3.II shows characteristic features of these three methods.

Table 3.II

METHOD	CHARACTERISTICS
- Brush	- Very good paint penetration, even with high relative humidity, - Thickness of paint film two or three times less than with airless spraygun application, - Slow speed of application (10 to 20 m^2 per hour), - Easy to apply in areas of difficult access.
- Roller	- Very poor penetration of paint in first coat, - Inclusion of air in wet paint film, - Approximately same thickness of paint film as for bursh application, - Medium speed of application (50 m^2 per hour), - Not easy application for some types of paints.
- Airless spraygun	- Very good paint penetration, - Thick film, - Absence of air in paint film, - High speed of application (250 m^2 per hour), - Training needed for painter.

In general, it is recommended to apply, after the surface preparation, stripe coats by brush on edges, welds, and areas difficult to reach with an airless spraygun.

3.2.6. Defects: causes, prevention and repairs

The following Table 3.III gives a list of common defects during application of paint on steel constructions, their cause, preventive methods, and appropriate repair procedures.

Table 3.III

Defects	Causes	Prevention - Repairs
Runs and sags	- Too much paint per coat, - Gun too close to the surface, - Too much thinner, - Too high paint temperature (in case of two-components paint), - Exceeded pot life.	- Hold the gun at the correct distance from the surface, - Avoid excess thinning, --- - Use a small brush to cancel runs and sags while the paint is still wet.
Orange skin	- Low air pressure implying bad atomisation, - Gun too close to the surface, - Solvent evaporation too rapid, - Overthickness.	- Correct air pressure, - Hold the gun at the correct distance from the surface, - Use proper thinner, --- - Sand down to smooth surface and repaint.
Peeling/ Delamination	- Unsatisfactory surface preparation, - Incompatibility with undercoat, - Contamination of intercoat, - Excessive curing time between coats.	- Peel off and recoat.

Table 3.III (Continued)

Defects	Causes	Prevention - Repairs
Dry spray	- Gun too far from the surface, - Application angle too much open, - Solvent evaporation too rapid - Too high temperature	- Hold the gun at the correct distance from the surface, --- - For zinc primers : reblasting and recoat, - For oxydative curing paints : remove loose dust and apply a new coat.
Bleeding	- Diffusion of a coloured substance through the coat, - In general, associated to epoxy coat covering a coal tar epoxy coat.	- Avoid such a paint system.
Lifting	- Paint with strong solvents applied over incompatible paint, - Excessive softening of base coat by top coat, - Temperature too high or too low.	- Choose the right paint system, - Adjust temperature, --- - Sand down to smooth surface and recoat.
Pinholes/ Holidays	- Porosity in the undercoat or in the metal surface, - Coating over hot steel surface, - Incorrect spray viscosity.	- Adjust temperature, - Use the correct gun technic, --- - Sand down to smooth surface and recoat.

Table 3.III (Continued)

Defects	Causes	Prevention - Repairs
Blistering	- Solvent retention, - Improper coating application, - Soluble salt contamination (non sufficient washing of the surface) under the paint film.	- Use proper thinner, - Use correct application technic, - Efficient washing of the surface, ——— - Reblasting and washing of the affected area and recoating.
Fish eyes	- Application over oil, moisture, dirt, other contamination or incompatible coating.	- Efficient washing of the surface, - Choose a compatible system of coats, ——— - Sand down to smooth surface and recoat.

3.2.7. Advantages and disadvantages

The following Table 3.IV shows the main advantages and disadvantages of different types of paint.

Table 3.IV

TYPE OF PAINT	ADVANTAGES	DISADVANTAGES
PURE EPOXY	- Good chemical resistance, - Good adhesiveness, - Very low permeability, - High mechanical strength.	- Application temperature, - Two components, - Excellent surface prepatation, - Curing time, - Behaviour to UV, - Difficulty of covering.
EPOXY TAR.	- Flexible, - Very low permeability.	- Dark colour, - Temperature for application, - Two components, in case of bad mixing. - Difficulty of covering.

Table 3.IV (Continued)

TYPE OF PAINT	ADVANTAGES	DISADVANTAGES
MASTIC EPOXY	- Curing temperature lower than for pure epoxy, - Very low permeability, - Good chemical resistance, - High percentage of solids.	- UV behavior, - Temperature for application, - Two components.
ZINC EPOXY	- Very short drying time, - 85 per cent of zinc (in dry film), - Good adhesion, - High mechanical strength, - Galvanic protection.	- Temperature for application, - Two components, - Low maximum film thickness (10 to 30 μm), - Poor acid resistance, - Low cohesion.
ZINC SILICATE	- Good solvent resistance, - Good resistance to heat, - Good mechanical strength, - Ease of application.	- Excellent surface preparation, - Curing with humidity, - Temperature for application, - Two components, - Low maximum film thickness (risk of mudcracking above 100 μm).
ALKYDS	- Ease of application, - One component, - Good weatherproof quality.	- Medium acid resistance, - Medium water resistance, - Low solvent resistance, - Difficulty of covering with another type of paint.
CHLORINATED RUBBER	- Application unaffected by temperature, - Good water resistance, - Ease of covering.	- Poor solvent resistance, - Low solid content, - Thermoplastic coating. - Low maximum film thickness (75 μm to 100 μm).
POLYURETHANE	- Good chemical resistance, - Excellent weatherproof quality, - Good solvent resistance, - Possible application at low temperature.	- Two components, - Difficulty of covering, - Contact with skin to be avoided.

TYPE OF PAINT	ADVANTAGES	DISADVANTAGES
VINYL	- Good chemical resistance, - Good weatherproof quality, - Good water resistance, - Flexible.	- Low solid content (35 to 40 %), - Poor resistance to strong solvents, - Low maximum thickness of film.
VINYL TAR	- Good water resistance, - Fast drying.	- Difficulty of covering with finishing paints other than antifouling paints, - Dark colour.
ACRYLIC	- Application unaffected by temperature, - Ease of covering, - Good resistance to weather and UV	- Low resistance to solvents, - Low solid content, - Low maximum film thickness

3.3. Soft coats

3.3.1. Definition

At the opposite of the hard coatings (see 3.2), these remain soft after being applied on the surface to protect.

3.3.2. Soft coats types

The main soft coat types are the following :

1) Petroleum and wool grease based soft coats

They normally are applied by spraying. However they can be applied by floating. In such a case, some particular precautions are to be taken against the pollution of water.

2) Rubber or PVC (or equivalent) tapes

These are applied either by pressing the tape to the surface, or by heating the surface after application (heat shrinkable tape).

3.3.3. Surface preparation

The surface preparation before application of the soft coat should be :

- Removing grease, dirt, dust, and loose rust,
- cleaning of the surface using an high pressure water jet.

As a rule, the soft coats are to be applied on a surface as dry as possible.

3.3.4. Advantages and disadvantages

The following Table 3.V lists the main advantages and disadvantages of soft coats.

Table 3.V

ADVANTAGES	DISADVANTAGES
- Easy surface preparation - Quick to apply	- Short life of the coat, - Risks in survey due to soft and slippery coats, - Dark colour coat, - Frequent surveys with necessary recoating every one or two years, - Fire and explosive risks in case of welding work (specially with wool grease based soft coat), - Risk of water pollution when applied with floating method, - Difficulty or elimination before application of a hard coating.

Due to the preceding advantages and disadvantages, the soft coats can be used for temporarily coating, in case of repairs onboard ships in service. In such a case, the same system of coating is to be continued, due to difficulties for eliminate soft coats.

3.4. Cathodic protection

3.4.1. Principles

The cathodic protection is based on the principles of the galvanic corrosion, as detailed in Appendix 3: when two different metals joined by an external conductor are immersed in an electrolyte (water), electrons are going from the anode (less noble metal) to the cathode (more noble metal) through the electric conductor. Consequently, the anode is corroded and the cathode is protected.

For protecting of a steel structure by using this principle, the steel structure is considered as the cathode, and another metal is used as the anode.

This can be carried out in two ways :

1) Cathodic protection with sacrificial anodes :

A sacrificial anode is a block of very pure metal, connected by welding to the structure. It is to be noted a connection between the two metals is to be achieved. The protection of such anode is very efficient in areas close to the anodes. Consequently, many anodes have to be fitted.

2) Impressed current system

In such a system, the structure to be protected is connected to the negative pole of a Direct Current electrical supply. The anodes are connected to the positive pole. The current is then impressed in order to keep the potential difference as low as possible.

3.4.2. Advantages and disadvantages

The following Table 3.VI lists the main advantages and disadvantages of the cathodic protection.

Table 3.VI

ADVANTAGES	DISADVANTAGES
- Efficient system for corrosion protection, - Complementary protection in case of installation on painted structures.	- Electrolyte (salt water) needed, In case of sacrificial anodes : - Necessary installation of many anodes, well connected to the structure, - Frequent replace of anodes. In case of impressed current : - Hydrogen (explosive gas) development, i.e. risks of explosion in closed structures, without ventilation, - Development of alkalinity on the steeel surface : risks of damage for some types of paints.

By reading the preceding table, it is to be noted that the impressed current system cannot be installed in closed spaces.

3.4.3. Sacrificial anodes

Sacrificial anodes are made in zinc or aluminium, in very pure metal.

The composition of the anode alloy is very important for the proper working of the anode, in order to avoid the creation of an isolated coat on the anode surface.

The metallic connection of the anode with the surface to be protected is to be well ensured in order to have an electrical continuity. For such a purpose, welding is recommended.

The amount of anodes necessary to protect a structure (excluding some particular local protection) can be obtained by the following formula :

$$P = \frac{IAH}{1000K}$$

where :

- P = Total mass of anodes, in kg,
- A = Area, in m^2,to be protected,
- I = Necessary current, in mA/m^2, for cathodic protection of submerged steel, equal to :
  - 1 mA/m^2 for painted steel, in case of no paint defects,
  - 2-10 mA/m^2 for painted water ballast tank,
  - 10-20 mA/m^2 for underwater painted external hull,
  - 50-70 mA/m^2 for uncoated ballast tanks.
- H = Effective life of the anodes, in hours,
- K = Current capacity of anodes, in Ah/kg, equal to :
  - 760 for Zinc anodes,
  - 2400 for Aluminium anodes.

The anodes are to be distributed in order to ensure an efficient protection of all areas of the structure.

In cargo tanks of tankers, only aluminium anodes are permitted. In this case, the maximum height of the anode is to be determined in accordance with IACS Unified Requirement F1.

CHAPTER 4 - NEW SHIPS

4.1. General

The protection systems indicated in this chapter are to be considered as examples of usually applied systems acting satisfactorily. However, some other recognized systems can be considered, as well as new systems.

4.2. Choice of protection systems

The choice can be done between the following protection systems :

- Hard coatings,
- Soft coats,
- Cathodic protection.

4.2.1. Hard coatings

This type of system is very well adapted for the protection of holds in bulk carrier and of Water Ballast Tanks (WBT).

The attention is drawn to the fact that the paint is to be compatible with the cargo or with the water, sometimes strongly polluted in WBT.

The epoxy based paints are a good choice for holds of bulk carriers, due to their particular hardness.

4.2.2. Soft coats

This system does not give a sufficient lifetime protection of the structure. Consequently, the soft coats are not recommended in case of new buildings.

4.2.3. Cathodic protection

This type of protection can only work on structures immerged in an electrolyte, i.e. sea water. Moreover, the impressed current system implies a development of hydrogen and shall not be fitted in closed structures without ventilation. Consequently, only the sacrificial anodes system can be fitted in water ballast tanks, and in general, together with a protection by coating.

Finally, only the following protection system could be recommended :

- For water ballast tanks : hard coatings with or without sacrificial anodes,
- For hold of bulk carrier : hard coatings.

4.3. Water ballast tanks

4.3.1. Hard coatings

1) Paint specification

The paint specification, established jointly by the yard, the owner and the paint manufacturer, defines the paint system.

Appendix 4 gives information of the content of a paint specification.

2) Surface preparation

a) Primary surface preparation

Referring to chapter 3, the minimum primary surface preparation consists in removing mill scale, oxidation and foreign matters by abrasive blast-cleaning treatment to grade Sa 2 1/2, according to the ISO 8501.1 standard. A possible application of a shop primer can follow this surface preparation.

b) Secondary surface preparation

It consists in removing oxidation and foreign matters after fabrication work and weather exposures, prior to application of the paint system. Regarding secondary surface preparation grades, users are advised to consult the document "STANDARD OF SECONDARY SURFACE PREPARATION", published by the French Shipbuilding Research Institute, under reference IRCN 3.3.1984.

3) Thickness

For an expected life of approximatively 12 years, minimum thicknesses (Dry Film Thicknesses) as indicated in the Table 4.I, are recommended.

As a rule, at least two layers of paints are to be applied, in order to obtain an homogeneous final coating with few local defects.

4) Paint colour

It is recommended to select paints of light colour.

5) Compatibility

In the case of Water Ballast Tanks, the paints used are to resist sea water, often polluted, and should also be compatible with the shop primer, if the case may be.

6) Choice of paint

Considering the preceding recommendation, the following paint systems can be considered :

- TAR EPOXY,
- PURE EPOXY,
- MODIFIED EPOXY,
- POLYURETHANE,
- ZINC SILICATE.

It is to be noted that :

- TAR EPOXY based system will be forbidden in the near future.
- POLYURETHANE is to be selected for application at low temperature (down to -5°C).
- ZINC SILICATE paints are recommended for local application on warm bulkheads adjacent to heat compartments.

The following Table 4.I gives the characteristics of such paint systems.

Table 4.I

WATER BALLAST TANKS		
Paint	Total Dry Film Thickness (μm)	Number of coats
TAR EPOXY	350	2
PURE EPOXY	350	2
MODIFIED EPOXY	350	2
POLYURETHANE	350	2
ZINC SILICATE (1)	100(2)	1
Notes (1) : Only on local application on warm bulkheads.		
(2) : It is recommended to apply this paint without over thickness.		

4.3.2. Hard coatings and sacrificial anodes

In the coatings, local defects always exist and are starting points for corrosion. This phenomena occurs particularly on bottom plates of tanks, and pitting corrosion can be developed in these areas.

In order to have a complementary protection, it is recommended to provide a cathodic protection with sacrificial anodes, in addition to the hard coatings. This complementary cathodic protection can be calculated on the basis of half time ballasting and for 4 years.

The dimensions, and distribution of anodes on the structure are to be established jointly between the yard and the anodes supplier.

The protection due to anodes is efficient only on structures submerged in an electrolyte. Consequently, no efficiency is achieved in empty tanks or above the water level.

4.4. Holds in bulkcarriers

The recommendations given in 4.3.1, items 1 to 4 apply to paints for holds in bulkcarriers.

Moreover, the paints are to be compatible with the cargo in holds, in particular, in case of alimentary products.

The selected paints are to be of a high hardness, in order to withstand shocks and abrasion.

Considering these recommendations, the following paint systems can be considered, with comments given in 4.3.1, item 6 :

- TAR EPOXY,
- PURE EPOXY,
- MODIFIED EPOXY,
- POLYURETHANE.

The following Table 4.II gives the characteristics of such paint systems for holds in bulk carriers :

Table 4.II

HOLDS IN BULK CARRIER		
Paint	Total Dry Film Thickness (µm)	Number of coats
TAR EPOXY	350	2
PURE EPOXY	350	2
MODIFIED EPOXY	350	2
POLYRURETHANE	350	2

CHAPTER 5

SHIPS IN SERVICE

MAINTENANCE OF THE CORROSION PROTECTION

5.1. General

A regular and periodical maintenance of the protection against corrosion is recommended in order to increase the life of the protection and consequently to maintain the steel structure in good condition.

For this purpose, it is strongly recommended to repair all defects detected during inspections, and specially localized corrosion on edges of stiffeners and openings.

5.2. Hard coatings

5.2.1. General

As a guidance for repair, the following procedure can be considered : to maintain the coating in GOOD or FAIR condition (as defined in Appendix 2), it is recommended to repair defects as soon as rust extends on more than 5 % of the surface area.

It is to be noted that if the coating is in POOR condition (i.e. rust extends on more than 20 % of the surface area), repairs are necessary, the coating being considered as being no more efficient.

However, and in particular for localized corrosion on edges of stiffeners and openings, it is preferable not to wait and to repair defects as soon as they are detected by inspection.

5.2.2. Types of paints

The paint to be used for repairs is preferably to be of the same paint type as the original. If not possible, the paint should be compatible with the paint system used during the construction of the ship. The compatibility is to be agreed by the paint manufacturer, the yard and the owner.

Considering that the conditions for reparation, and specially the surface preparation and the conditions for application, are not so easy to achieve as in the case of a new building, the paint manufacturers have developed special « tolerant » epoxy paints with the following advantages, compared with « standard » epoxy paints :

- the degree of surface preparation is lower,
- the temperatures application are less compelling,
- the time for recoating is longer.

5.2.3. Surface preparation

As for paint applied on new ships, the surface preparation is of greater importance for the quality and the durability of the coating.

The surface preparation can be achieved by one of the following methods :

- blast-cleaning,
- mechanical cleaning,
- hydroblasting,
- electrolytic descaling.

1) Blast cleaning

This method is the recommended one for having an efficient surface prepartion (refer to 3.2.4. of this document). It shall be applied after washing and degreasing of the surface area.

As a rule, the degree of preparation shall not be less than Sa2 according to ISO 8501-1, and is also to be in accordance with the paint manufacturer requirements.

2) Hand and power tool cleaning

The surface preparation can be achieved by using this method, only for local and limited repairs.

As for blast-cleaning, a washing and degreasing are to be carried out before cleaning.

As a rule, the degree of preparation is to be a minimum St2, according to ISO 8501-1, and preferably St3.

3) Hydroblasting

In maintenance work, hydroblasting is more and more used for the cleaning of the surface to be repaired.

Compared to blast-cleaning, the following advantages and inconvenients can be noted :

- no abrasive is needed,
- no dust is to be removed after cleaning,
- hydroblasting leaves a very low salt content on the surface,
- there is a quick oxydation of the surface area after cleaning,
- no surface roughness is created.

The degree of cleaning depends on the pressure of the water jet. For achieving a complete cleaning, with removal of rust and of all paint layers, a pressure greater than 1700 bar is recommended (Ultra High Pressure hydroblasting).

For the time being, there is no standard dealing with surface preparation by UHP hydroblasting. However, NACE (National Association of Corrosion Engineers - USA) and SSPC (Steel Structures Painting Council - USA) are developing a standard on this subject : « Surface preparation and cleaning of steel and other hard materials by high and ultra high pressure water jetting prior to recoating ».

In case of cleaning on local areas, it is recommended to remove old paints on the border of such areas, these paints being disbonded by hydroblasting.

Then, the new paint to be applied must be well adapted to this type of surface preparation and the « tolerant » epoxy paints, as described in 5.2.2., are particularly suitable.

4) Electrolytic descaling

This method can be used for ballast tanks, before drydocking. It consists on a breakdown of the rust using a very strong electrical current. This current is produced by galvanic effect between steel and a large amount of magnesium anodes fitted for this purpose in the ballast tank, which is completely filled with seawater (electrolyte).

This process requires one to two weeks and is accompanied by heavy hydrogen gas emission, so an appropriate ventilation is to be fitted.

After descaling, an efficient washing of the ballast tank is to be carried out, for removal of rust and of calcareous deposit formed on the tank surfaces.

5.3. Soft coats

5.3.1. General

Soft coats can be considered as a convenient alternative to hard coatings in case of repairs, when the hard coatings are strongly damaged and cannot be quickly repaired by painting.

Due to their short life, soft coats are to be renewed regularly, as a rule annually or biannually.

For this purpose, the yard is to comply with the recoating procedures established by the manufacturer and agreed by the owner within the maintenance specification.

Regarding surface preparation, care shall be taken when removing and applying such coats. Refer to 3.3. of the present document, and particularly to the disadvantages listed in Table 3.V.

5.3.2. Soft coat systems

The systems are, in general, defined by the specification, including thicknesses and number of coats. As a rule, soft coats are to be applied in one coat.

However, a new application is recommended after one year or more (but less than two years) depending on the results of the inspection of the soft coat.

5.4. Sacrificial anodes

In addition to coating and in order to decrease the corrosion rate, it is recommended to fit sacrificial anodes in ballast tanks.

In such a case, an efficient electrical continuity is to be ensured between the anode and the steel structure. The anodes shall be fitted by welding.

The amount of sacrificial anodes is to be defined in accordance with 3.4.3. of this document.

CHAPTER 6 - INSPECTIONS

6.1. General

In order to obtain a long coating life, it is also necessary to carry out inspections during the application.

Scope and relevant standards for such inspections are to be defined within the specification and agreed between the yard, the owner and the coating manufacturer. In particular, the following elements are to be considered :

- methods for inspection,
- criteria of acceptance,
- form of the reports,
- authority of inspector,
- knowledge of inspector.

It is to be noted that all inspections are to be reported by writing.

Some standards that could be used for inspection are given in Appendix 5.

6.2. Working conditions

It is to be checked that, in every step of the coating work, the working conditions (lighting, scaffoldings, ventilation, ..) are satisfactory.

6.3. Coating products

Prior to any surface preparation and application, it is to be ensured that :

- the coating products to be used are in accordance with the specification,
- the storage of the products (coatings, thinner, abrasives) is carried out in accordance with the conditions required by the supplier,
- the batches of products are well identified.

6.4. Surface preparation

Before cleaning the steel surface, it is to be checked that the ambient conditions are satisfactory for this work. It is also to be ensured that the equipment used for the surface preparation is well adapted to this work and is in good conditions.

After the surface has been prepared, the following inspections shall be carried out :

- checking that cutting sharp edges are effectively rounded, and that weld surfaces and other surface irregularities are well smoothed,

- checking that the cleanliness of the surface is in accordance with the specification (Sa 2 ½ or better),
- checking that the surface roughness is in accordance with the manfuacturer's requirements,
- checking that the surface is free from abrasives and dust.

6.5. Coatings

6.5.1. Ambient conditions

Before and during the application, it is to be ensured that the ambient conditions (hygrometry, air and steel temperature) are in accordance with the specified ones, and that the cleanliness of the surface is maintained.

6.5.2. Application equipment

It is to be ensured that the application equipment is well adapted to the product to be applied, and that this equipment is maintained in good condition.

In the same way, the applicator is to be qualified for using this equipment.

6.5.3. Coating application

During and after the coating application, the following points are to be checked, and are to be in accordance with the specification :

1) Number of coats,

2) Wet film thickness : this thickness is to be checked by the applicator for each coat,

3) Dry Film Thickness (DFT) : this thickness is to be checked for each type of coat and for the total coating. For this purpose, a recommended practice is the 90/10 one : a minimum of 90 % of all thickness measurements should be over the specified thickness and none of the remaining 10 % measurements should be lower than 90 % of the specified thickness. However, such a practice would have to be written within the specification.

4) Adhesion : a minimum adhesion value can be specified within the specification. However, it is to be noted that the adhesion tests are destructive ones and consequently, repairs are to be provided in areas where these tests are carried out. Attention is drawn to difficulties of repairs of some paints.

5) Defects : defective areas are to be noted and consequently repaired. For this purpose, an appropriate procedure is to be agreed within the specification. The repaired areas are to be re-checked for acceptance.

6.6. Sacrificial anodes

It is to be checked that the sacrificial anodes are installed in accordance with the drawings and the specification.

In particular, it is to be ensured that the anodes and their fittings are not damaged or coated.

6.7. Coating Inspector

6.7.1. Coating Inspector's duties

Within the specification, the responsibility of inspections is defined between the yard, the owner, the paint manufacturer and eventually a contractually agreed inspection organism.

A qualified Coating Inspector is appointed and is in charge of the following activities :

- tests and inspections as described in 6.2. to 6.6. above : cleanliness, thickness, ambient conditions, installation of anodes, ...

- reporting on the discrepancies between the specified requirements and the quality actually found.

Depending on the quantity of work, more than one Coating Inspector can be appointed, after agreement between the parties.

6.7.2. Inspection equipment

The Coating Inspector should have the minimum following documentation and equipment :

- specifications,
- surface preparation and roughness standards,
- psychrometer or hygrometer,
- steel surface thermometer,
- dew point calculator,
- dry film thickness measuring gauge.

In addition, the following equipment is also recommended :

- adhesion test equipment,
- surface profile comparator, for measuring the roughness,
- measuring device for soluble salts.

CHAPTER 7 - YARD ORGANISATION

7.1. Planning of building

It is recommended to establish a planning of the whole coating work in relation with the other building activities.

Such a planning is to be so detailed and regularly updated in order to permit an efficient following of the coating works by the owner, the coating manufacturer and the Coating Inspector.

7.2. Traceability

It is recommended that the yard draws up and keeps current procedures for applying suitable means to identify consignments of the batches of coating products. Such identification must be enable tracing of the batches back to origin if clients so request, or in the case problems occur during the life of the coating.

7.3. Quality system

To ensure the the coating is in accordance with the specified requirements, it is recommended that the yard establishes and maintains a documented quality system.

The purpose of such a system is to describe the procedures for the following items :

- organisation,
- document control,
- purchasing,
- product identification and traceability,
- process control,
- inspection and testing,
- inspection, measuring and test equipment,
- non-conformities,
- corrective and preventive action,
- internal quality audits,
- training.

APPENDIX 1

GLOSSARY OF TERMS

ABRASION (RESISTANCE)	(Resistance to) frictional rubbing as distinct from (resistance to) knocks and impacts
ABRASIVE	Agent used for blast-cleaning before coating application
ABRASIVE BLASTING	Cleaning of steel with abrasives propelled by compressed air jet preparatory to painting
ADHESION	Bonding strength ; the attraction of a coating to the substrate, or to another film of paint or any other material such as steel
ANODE	Positive terminal of an electrolytic cell at which corrosion occurs
BATCH	The quantity of a paint manufactured at one time in a single vessel and identified by a batch number
BINDER	Non-volatile portion of the vehicle of a paint
BLAST-CLEANING	The same as abrasive blasting
BLISTERING	The formation of blisters in a paint film by localised loss of adhesion and lifting of the film. Blisters may contain liquid, vapour or gas
BUBBLING	A film defect, temporary or permanent, in which bubbles of air or solvent vapour, or both, are present in the applied film
CATHODE	Negative terminal of an electrolytic cell
CATHODIC PROTECTION	Corrosion prevention by sacrificial anodes or impressed current

CHALKING	The formation of a friable, powdery layer on the surface of a paint film caused by disintegration of one or more components of film due to action of the weather and sunlight (ultra-violet radiation)
COAT	The paint applied to a surface in a single application to form a properly distributed film when dry. Each paint layer of a paint system
COATING	Product of various thickness, applied on steel to protect it from corrosion
CORROSION	Degradation of metal by electrochemical processes
CORROSION RATE	Rate at which the corrosion proceeds. This rate is the thickness of metal lost during a year, considering one side of the surface. It is expressed in mm by year
CRACKING	A breakdown in which the cracks penetrate at least one coat and which may be expected to result ultimately in complete failure
CURING	The hardening of a liquid paint by a chemical reaction or by admixing a cross-linking agent or hardener
CURING TIME	Minimum time during which the paint achieve its properties and mechanical characteristics
DEW POINT	The temperature below which water vapour in the air will condense
DECOHESION	Breaking within the thickness of a paint film
DISCSANDING	Mechanical surface preparation by using a sand disc
DRY FILM THICKNESS (DFT)	Thickness of the paint film, after drying or curing
FILM	Continuous coating due to application of one or more coats on the surface. A « wet film » is one that has just been applied, before solvent evaporates. After drying process, the film is called « dry film »

FLAKING	Lifting of the paint from the underlying surface in the form of flakes or scales
FLASH POINT	The lowest temperature at which a liquid gives off sufficient vapour to form a mixture with the air near its surface which, if ignited, will make a small flash, but not catch fire
GENERAL CORROSION	Evenly distributed corrosion on the surface
HARD COATING	Coating which becomes hard after drying. In general, it is of paint type
HARDENER	In two-components materials, the component which produces the chemical reaction linking the molecular chains of the binder together in a more rigid structure
HARDNESS	The ability of the paint dry film to resist mechanical actions as scratching or penetration by a hard object (chocks)
HOLIDAYS	Defect due to the lack of the whole film or of one film layer
IMPRESSED CURRENT	Direct current supplied by a device employing a power from an external source to the electrode system of a cathodic protection installation
LIGHT COLOUR	The light colour of the coating, specially of the top coat, allows to see any rust traces
LOCALISED CORROSION	More or less localised corrosion attacks such as pitting corrosion, crevice corrosion, corrosion on welds and on edges
MECHANICAL WIRE BRUSHING	Mechanical surface preparation by a wire brush
PAINT SYSTEM	The complete number and type of coats comprising by the paint job. In a broader view, surface preparation, pre-treatments, dry film thicknesses, and method of application are included in the specification of a paint system
PINHOLES	Tiny holes through the entire paint film down to the substrate formed during application and drying

POT LIFE during	The period after mixing the components of a two-components paint which the paint remains usable
PRIMER COAT	First coat applied to a surface. Formulated to have good bonding and wetting characteristics and may or may not contain rust-inhibitive pigments
SACRIFICIAL ANODE	Anode made of less noble metal than steel in the galvanic series (zinc or aluminium). This anode corrodes when submitted to galvanic current and so protects the immersed steel structure
SHOPPRIMER	Temporary corrosion protection applied immediately after cleaning in general in low thickness (15 to 25 μm) and before welding and other fabrication
SOFT COATING	Coating which does not dry or which partially dries. It remains soft during its life time
SOLIDS	The non-volatile matter in a paint composition, i.e. the ingredients which after drying are left behind and constitute the paint film
SOLVENT	Liquids, usually volatile, which are used in the manufacture of paint to dissolve or disperse the binder-forming constituents, and which evaporate during drying and therefore do not become a part of the dried film.
SOLVENT-FREE COATING	A solvent free coating is a 100 % solid coating. For practical purposes this may be extended to cover materials containing a small amount of volatile constituent of the binder (solventless)
STRIPE COAT	Coat used locally, before the first coat or between the first and the second coat, in locations where it is not easy to obtain the final thickness of paint by a simple application with gun
THINNER	Volatile liquids added to paints to facilitate application and to aid penetration by lowering the viscosity

APPENDIX 2

BUREAU VERITAS RULES

For information, extracts of BUREAU VERITAS Rules are given hereafter in this Appendix. It is to be noted that BUREAU VERITAS Rules are regularly updated, so it is also recommended to refer to the latest edition of these Rules.

A2.1. Protection coating of seawater ballast tanks

- For ships of less than 65 m in length, the following requirements are given in Article 6.027 (Amendments of August 1991) :

6.027 HULL PROTECTION

1. General

11. Unless otherwise specified, the corrosion protection of hull and superstructures is not covered by classification and remains under both the yard and the Owner's responsibility.

2. Protection of salt water ballast spaces of oil-tankers, bulk carriers and ore carriers

21. All salt water ballast spaces of oil-tankers, bulk carriers and ore carriers having boundaries formed by the hull envelope should have a corrosion protection coating applied in accordance with the manufacturer's requirements.

22. The building yard is to supply the Society with a document mentioning the measures taken during construction for the protection of materials against corrosion, with maintenance provisions to be taken in service to repair and to maintain efficiently this protection.

- For ships of more than 65 m in length, the following requirements are given in Section 6.6. (Amendments of April 1992) :

Section 6-6 | HULL PROTECTION

6-61 General

11 - Unless otherwise specified, the corrosion protection of hull and superstructures is not covered by classification and remains under both the yard and the Owner's responsibility.

6-62 Protection of salt water ballast spaces of steel ships

21 - All salt water ballast spaces having boundaries formed by the hull envelope should have a corrosion protection coating applied in accordance with the manufacturer's requirements.

22 - It is the responsibility of the shipbuilder and Shipowner to make the choice of coating and to have it applied in accordance with manufacturer's requirements.

A2.2. Surveys of holds in bulk carriers and of ballast tanks

These requirements are given in Chapter 2 : « Maintenance of Class » of the BUREAU VERITAS Rules.

- In 2.017 - General provisions concerning surveys - Definitions and procedures related to scope of surveys :

2 - Coating

21 - A corrosion prevention system is normally considered to be a full hard coating. Other coating systems (e.g. soft coating) may be considered acceptable as alternative, provided that they are applied and maintained in compliance with the manufacturers specification.

Coating condition is 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.

- In Section 2.03 :

Section 2-03 | INTERMEDIATE SURVEY (ALL SHIPS)

2-031 Scope of survey

11 - The intermediate survey of all ships consists of an internal examination of one or several cargo holds, ballast tanks or other compartments, as deemed necessary by the Surveyor.

12 - For ships of 5 years age and over, and less than 10 years, and in addition to the requirements of 11, an internal examination of representative salt water ballast tanks is to be carried out.

a) When such examination reveals no visible structural defects, the examination may be limited to the verification that the protective coating remains efficient.

b) Where poor coating condition, corrosion or other defects are found in salt water ballast spaces or where a protective coating was not applied from the time of construction, the examination is to be extended to other ballast spaces of the same type.

c) For salt water ballast spaces other than double bottom tanks, where a protective coating is found in poor condition and it is not renewed, or where a protective coating was not applied from the time of construction, these tanks should be reexamined at annual intervals.

When such defects are found in salt water ballast double bottom tanks, these tanks may be subject to internal reexamination at annual intervals.

When extensive corrosion is found, gaugings may be required at this time.

13 - For ships of 10 years and over, and in addition to the requirements of 11, an internal examination of all salt water ballast spaces is to be carried out.

a) Where such examination reveals no visible structural defects, the examination may be limited to a verification that the protective coatings remain efficient.

b) For salt water ballast spaces other than double bottom tanks, where a protective coating is found in poor condition and it is not renewed, or where a protective coating was not applied from the time of construction, these tanks should be reexamined at annual intervals.

When such defects are found in salt water ballast double bottom tanks, these tanks may be subject to internal reexamination at annual intervals.

When extensive corrosion is found, gaugings may be required at this time.

14 - Double bottom ballast spaces in way of cargo holds have to be tested, for ships 10 years old and more.

15 - The scope of intermediate survey of cargo area and relevant equipment of ships with service notation **oil tanker**, **bulk carrier**, **bulk-ore carrier**, **ore carrier**, **chemical** or **product tanker**, **liquefied gas carrier** is detailed in relevant sections 2-09 to 2-12.

- In 2.052 - Special survey (all ships) - Special survey of hull and hull equipment :

5 - Tank survey

51 - Internal survey of the tanks is to be carried out according to the following table.

TANK SURVEY					
Type and use of tank	Age of the ship (years)				
	age ≤ 5	5 < age ≤ 10	10 < age ≤ 15	15 < age ≤ 20	age > 20
Sea water	all	all	all	all	all
Fresh water incorporated	none	none	all	all	all
Fuel diesel oil incorporated	none	none	none	half (*)	half (*)
Lubricating oil	none	none	none	none	half (*)
Fresh water, lubricating oil - diesel oil (independent)	none	none	none	half (*)	half (*)

(*) Half each 5 years (the tanks not internally examined may be examined externally from accessible boundaries).

52 - For salt water ballast tanks, excluding double bottom tanks, where a protective coating is found in poor condition and it is not renewed, or where a protective coating was not applied from the time of construction, these tanks should be reexamined at annual intervals.

When such defects are found in salt water double bottom tanks, those tanks may be subject to reexamination at annual intervals.

- The preceding Intermediate and Special Survey are also detailed in the following Articles :

  - 2.093 and 2.095 for surveys related to oil tanker cargo area,
  - 2.103 and 2.105 for surveys related to bulk and ore carrier cargo area,
  - 2.113 and 2.115 for surveys related to chemical tanker or product tanker area,
  - 2.123 and 2.125 for surveys related to liquefied gas carrier cargo area.

A2.3. Holds in bulk and ore carriers

The requirements concerning coatings are given in Section 8.3 « Notation Bulk Carrier, Ore Carrier, Bulk-Ore Carrier », of Rules for ships of more than 65 m in length :

3 - Material protection

31 - Double-bottoms, hopper and topside tanks intended for the carriage of salt water are to have a corrosion protection coating applied in accordance with the manufacturer's requirements.

Moreover, the side shell plating and associated framing system including end brackets and transverse watertight bulkheads are to have a corrosion protection coating.

The coating of the side shell is to be extended to the plating of sloped longitudinal bulkheads of topside and hopper tanks for a distance of 300 mm inboard of end brackets, as shown in Figure 8-3.I.

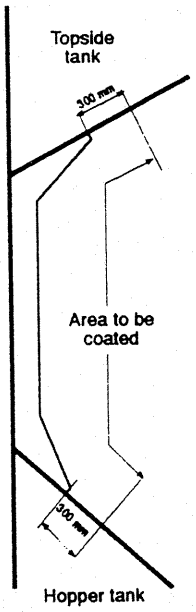

Fig. 8-3.I

Transverse bulkheads are to be coated from their upper part, as shown in Figure 8-3.II, down to 300 mm below the top of the bottom stool. Where there is no bottom stool, the coating is to be applied over the full depth of the transverse bulkhead.

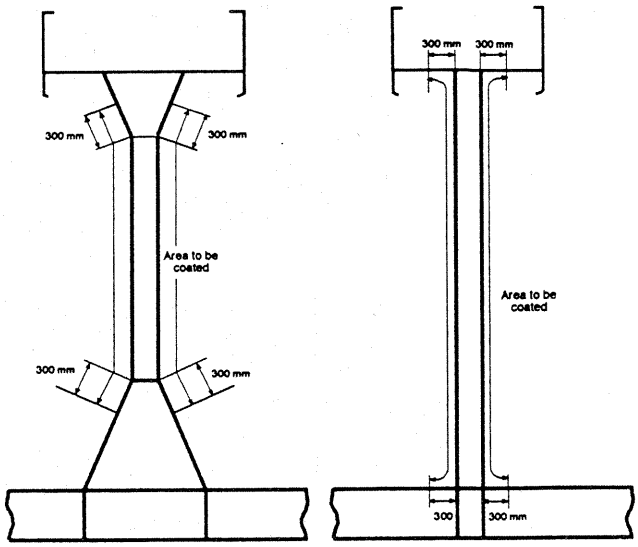

Fig. 8-3.II

The corrosion protection coating is to be of a type epoxy paint or equivalent.

It is the responsibility of the shipbuilder and Shipowner to make the choice of coating suitable for intended cargoes, in particular for the compatibility and to have it applied in accordance with the manufacturer's requirements.

APPENDIX 3

THE GALVANIC CORROSION

A3.1. Standard electrode potentials

When putting a metal M into an electrolyte as seawater, the metal corrodes and the following reaction occurs :

$$M \rightarrow M^{n+} + ne^-$$

The metal release electron e^- which remains on the metal bar, and ions M^+ are dissolved in the electrolyte.
This process occurs until an equilibrium will arise. At this stage, the difference of potential between the metal and the electrolyte can be measured and is called the Standard Electrode Potential of the metal for the electrolyte used.

This potential can be measured for each type of metals and then, potentials can be classed from the most negative one to the most positive one, as given in Table A3.I, not for seawater, the reference potential being equal to zero for hydrogen :

Table A3.I

Element		Potential Eo (Volt)
Potassium	(K)	- 2.92
Magnesium	(Mg)	- 2.36
Aluminium	(Al)	- 1.67
Zinc	(Zn)	- 0.77
Chrome	(Cr)	- 0.74
Iron	(Fe)	- 0.44
Hydrogen	(H)	0
Copper	(Cu)	+ 0.34
Silver	(Ag)	+ 0.80
Platinum	(Pt)	+ 1.20
Gold	(Au)	+ 1.69

The more negative potential means that the metal has a greater tendency to release electrons and so to be corroded.

A3.2. Galvanic serie for seawater

For information, the Table A3.II gives the galvanic serie in sea water, i.e. the table where metals and alloys are listed according to their corrosion protection abilities in seawater.

The top of the table corresponds to the anodic end of the serie and the bottom to the cathodic end.

Table A3.II

Magnesium Zinc
Aluminium alloys
Cadnium
Mild steel
Lead Tin Copper
Stainless steel
Graphite Platinum Gold

A3.3. Electrochemical nature of corrosion

The corrosion process can be illustrated by a simple electrolytic cell : two different electrodes, immersed in an electrolyte and joined by an external conductor.

If a measuring device is fitted on this conductor, a current will be detected.
For example, Zinc (Zn) and Iron (Fe) electrodes can be chosen and immersed in seawater. In such a case, the following reactions occur :

$$Zn \rightarrow Zn^{++} + 2e^{-}$$

$$Fe^{++} + 2e^{-} \rightarrow Fe$$

The zinc electrode being more negative than the iron one, the electrons are going from zinc to iron through the external conductor, and so create an electric current.

The following reactions occur at that time :

a) New zinc atoms are dissolved and leave electrons on the zinc electrode, in order to maintain the potential between the zinc and the electrolyte.
Consequently, the zinc electrode is corroded.

b) The iron electrode takes up the iron ions which will be neutralised by consumption of electrons. Consequently, there is a precipitation of metallic iron, and so the iron will not be corroded.

This phenomena is called galvanic corrosion : the less noble metal (the anode) is corroded, the more noble metal (the cathode) does not corrode. Due to electrons supplied from the anode to the cathode through the electrical conductor, the cathode will be more negative which also prevent the cathode giving its own electrons.

APPENDIX 4

SPECIFICATIONS

A4.1. Purpose of a specification

A specification is a reference and contractual document, agreed by the yard, the owner and the coating manufacturer.

This document covers all information and technical aspects of the entire coating work.

A4.2. Content of a specification

The specification should, at least, contain the following items :

A4.2.1. Paint systems

The exact references of the paints, including shopprimer, are to be given with data sheets from manufacturers.

A4.2.2. Surface preparation

The requirements for surface preparation, roughness, preparation of edges, ... are to be detailed under this item.

A4.2.3. Conditions of application

The following aspects for the application work are to be specified :

- the qualification of applicator,
- the equipment to be used,
- the needed ambient conditions (hygrometry, air and steel temperature, dew point),
- the minimum and maximum limits for the application of the over coat,
- the drying time,
- the necessity of stripe coats,
- the demand in ventilation, lighting and scaffoldings,
- the requirements for health and safety.

A4.2.4. Coating

For each paint system, the following elements are to be indicated :

- number of layers, and reference of the paints,
- wet and dry thickness of each layer,
- total dry film thickness.

Great attention is to be paid to the definition of the thickness : minimum values or average values.

A4.2.5. Procedures for repairs

A repair procedure is to be developed for each type of defect.

A4.2.6. Sacrificial anodes

The requirements for the quality of anodes and the procedure for the installation are to be indicated.

A.2.7. Inspections

For the inspection work, the following points are to be developed :

- extent of inspection,
- methods of inspection, including the criteria for acceptance,
- treatment of non-conformity,
- content of reports,
- qualification of the paint inspector.

A4.2.8. Planning

All the steps of paint and coating works are to be described in details.

APPENDIX 5

STANDARDS FOR COATINGS

A5.1. Standards applicable to surface preparation

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 localized removal of previous coatings.

ISO 8502 : Preparation of steel substrates before application of paints and related products. Tests for the assessment of surface cleanliness.

- Part 1 : Field test for soluble iron corrosion products,
- Part 2 : Laboratory determination of chloride on cleaned surface,
- Part 3 : Assessment of dust on steel surfaces prepared for painting (pressure- sensitive tape method).
- Part 4 : Guidance on the estimation of the probability of condensation prior to paint application.

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 grading of surface profile of abrasive blast-cleaned steel - Comparator 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.

A5.2. Standards for testing of the dry film

ISO 2808	:	Paints and varnishes - Determination of film thickness
ISO 2409	:	Paints and varnishes - Cross cut test
ISO 4624	:	Paints and varnishes - Pull-off test for adhesion
NACE RP 0188	:	Low and high voltage holiday detection
ISO 4628-1 to 6	:	Paints and varnishes - Evaluation of degradation of paint coatings - Designation of intensity, quantity and size of common types of defects.

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 methods.