Paint: a definition and generic organic coating types

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Executive Summary

This report has been prepared as an outcome of discussions within the Institute of Corrosion’s Coatings Working Group where it was agreed to produce a number of technical guidance documents for use by members of the Institute of Corrosion. This document is intended to provide a brief insight into the numerous generic organic coating types that are available, highlighting the types and compositions of organic coatings available. It begins with a brief definition of what comprises a paint system and an outline of why, when and where anticorrosive paint is used. The document then looks at paint formulations in more detail to provide definitions of resins, pigments and extenders, solvents, additives and the paint system as a whole.
1 Introduction

Paint: a definition

A paint coating can be defined as a liquid material which, when spread over a surface as a relatively thin film (e.g. 30 – 300 µm), subsequently dries to form a solid, cohesive, adhesive protective layer.

1.1 What is in a paint system?

The following components form a paint system:

- Resin (or binder) - normally organic based
- Pigments and extenders
- Solvent(s)
- Additives

These components are described in section 2.

1.2 Why do we use anti-corrosive paint and when and where do we use it?

When left unprotected, plain carbon and low alloy steels (and many other metals) will corrode in almost any environment. Organic coatings can protect the metal by providing a barrier, particularly to aggressive ions, although, to a lesser extent, also to oxygen and water. It is important that coatings are specified correctly to provide optimal performance under the exposure conditions that will be encountered during use.

Steel structures such as bridges, tanks, pipelines and, more recently, wind farms are just a few examples of structure types that require protection against corrosion and this is most commonly achieved by applying paint. It should be noted that all paints are permeable to some degree and that their permeability will increase over time. However if they are applied correctly and maintained regularly, they should provide a lifetime to the steel structure, in terms of suppressing potential premature corrosion, of possibly twenty years or more.

2 Details of paint formulations

2.1 Resins

2.1.1 General

Resins are the principal ingredient of paint. They can be liquids or solids. Paints are usually classified depending upon the type of resin used, namely alkyd, epoxy, polyurethane or acrylic. The type of resin used dictates the properties of the paint and hence the choice must be considered carefully when specifying systems for use.

2.1.2 Specific Examples of resin systems

The most common examples are as follows:

- Alkyd: Not as frequently used as other paint systems and generally used in less corrosive environments. Alkyds can be composed of naturally occurring oils, such as linseed oil, which oxidise in air. Whilst they can dry relatively quickly, the oxidation process can take months to reach completion. They are single-pack and therefore easy to use, although their performance is not generally as good as that of two-pack coatings. These coatings should not be applied too thickly (no more than 1.3 times the top of the range recommended by the manufacturer) as this can adversely affect the drying process and adhesion properties.
- **Epoxy:** Probably the most commonly used paints in the protective coatings industry, they are utilised in marine environments, the oil and gas industry, structural steel, flooring and other applications. Two-pack epoxies rely on a chemical reaction occurring between the epoxy resin and a curing agent to form a cross-linked matrix that can be durable and versatile, lending itself to a host of applications. Epoxy resins rely on heat to chemically cure and most will stop curing at temperatures below 5 °C. Epoxies can be water-based, but they are normally solvent-based. Epoxies have a long track record of successful use in many industries and applications.

- **Polyurethane/acylonitrile urethane:** These resins are often used in topcoats due to their good weathering properties, providing excellent gloss and colour retention. They are mainly used for their aesthetic properties and would not normally be applied at more than 50 µm thickness, as they traditionally offer very little corrosion protection. Polyurethanes can be two-pack (requiring an additive to cure) or single-pack (moisture curing), but will usually contain isocyanates, which are undesirable from a health and safety point of view.

- **Vinyl esters:** These are heavy-duty products that are used in onerous environments where good chemical, corrosion, abrasion or temperature resistance may be required. Vinyl esters would in most situations be applied at a high film thickness (1 – 2 mm) and may be reinforced with glass flake barrier coatings. The curing of the resins is catalysed by an organic peroxide, although there can be health and safety issues when dealing with these substances.

- **Chlorinated/acylated rubbers:** These are single-pack paints that do not cure but dry purely by solvent evaporation. These rubbers are very viscous and therefore they need a lot of solvent to make them suitable for use as paints. Consequently, they are only rarely used for corrosion protection, and many coats are usually needed to achieve a satisfactory specification thickness. Furthermore, the process of overcoating these with other products to provide the requisite properties (e.g., UV resistance) can be problematic and unpredictable. Acrylated rubbers are used in ‘thin-film’ intumescent paints for cellulosic fire protection and these coatings are widely used in the construction of high-rise buildings, schools, hospitals, etc.

- **Silicone-based paints:** These coatings are typically used in high temperature situations (>250 °C) as a topcoat over inorganic zinc silicate or thermally applied metal spray systems to seal, or provide an aesthetic quality. Normally these products have high solvent contents and can only be applied as thin films (25 - 40 µm dft), hence they may require multiple coats.

### 2.2 Pigments and extenders

Pigments are finely divided solid particles that are insoluble in the resin. They provide colour, anti-corrosion properties, obliteration (opacity) and mechanical strength. Anti-corrosion pigments can include inhibitors such as zinc phosphate and zinc molybdate, as well as the cathodic protecting zinc dust. Pigments such as micaceous iron oxide and glass flakes enhance the barrier properties. Filler pigments are inorganic solids that are used to control or modify the properties of paint (e.g., viscosity, gloss level). They are generally cheaper than anticorrosive or colour pigments. They contribute little or nothing to the colour or obliterating properties of a paint film but they can be used to optimise the total cost of the raw materials in a paint formulation. The choice of filler pigment can alter the performance level. For example, the selection of lamellar pigment particles may offer better barrier protection than round pigment particles.

### 2.3 Solvents

Solvents are used as a medium to transport the resin and pigments from the container onto the substrate. The choice of solvent can also aid application and help control the curing and drying processes. Generally the solvents are organic compounds including aromatic hydrocarbons, ketones and alcohols. Due to the environmental issues regarding the release and use of Volatile Organic Solvents (VOCs), water is also being increasingly used as a paint solvent. This can help offset the amount of solvent used to ensure that it does not exceed the prescribed limits under the Solvent Emissions Directive (SED). Whilst water-based paints can be effective, it is very important to maintain the correct environmental conditions during drying to ensure that the necessary film properties are achieved. These types of paints are not generally used in onerous environments as their durability is such that they tend not to give the same level of performance as solvent-based paints.
2.4 Additives
These are added to paints in small amounts. They prevent bubbling, skinning and pigment settling, and aid dispersion, surface wetting and application. Some examples of common additives are:

- **Driers**: typically derivatives of heavy metals (cobalt, zirconium, etc), which are used in alkyd paints to accelerate the oxidation of the paint film.
- **Thixotropes**: used in most paints to provide sag resistance and anti-settling properties. The most commonly used thixotropes are bentone, fumed silica and wax, and they are used in almost every type of paint.
- **UV absorbers**: used to reduce the effects of UV light on a coating and to improve gloss and colour stability. These additives are particularly expensive and are used sparingly in a formulation and only in topcoats where weatherability is important.
- **Defoamers**: used to reduce bubbles and air entrapment in the paint. They are especially useful in water-based technologies where ‘foaming’ can be more of an issue than in solvent-based paints.
- **Wetting agent**: used to promote the homogenisation of the resin, solvents and individual pigment particles. Used in all different types of paints to ensure that the pigment particles are efficiently dispersed to maximise the colour properties and also to reduce the time to manufacture the paint.

2.5 Paint Systems

2.5.1 General
Paint systems, sometimes referred to as coating systems, may include the following:

- **A primer**: This provides adhesion to the substrate and anti-corrosion protection. It can vary in dry film thickness from 15 - 50 µm. Paints with higher dry film builds than 50 µm (i.e. up to 200 µm) are often referred to as primer ‘buildcoats’.
- **A stripe coat**: An additional coating applied by brush to welds, edges, rivets and corrosion traps. These types of coating tend to be applied at dry film builds ranging from 75 µm to 250 µm, depending on the nature of the paint, and they are usually applied after the primer coat or first build/intermediate coat. This is carried out to enhance protection of vulnerable potential weak spots that arise as liquid coatings tend to flow away from edges. Some modern paints have been formulated to be more ‘edge retentive’, to further increase the film build on the areas where paint tends to thin out.
- **Intermediate coat or coats**: These provide film build, mechanical strength and barrier protection. Specialist intermediate coats can provide fire protection (see CT06 in this document series) and chemical resistance. Such coatings tend to be high-build products and range from 100 µm up to 2000 µm dry film build thickness.
- **A finish coat**: This provides decoration, colour and gloss retention, and chemical resistance, and can also aid run-off of water/rain. This coat forms the protective envelope of the main coating system and tends to be relatively thin in terms of film build. Dry film thicknesses can vary from 35 µm up to 125 µm.

2.5.2 Overcoating
- Regarding overcoating and compatibility with the underlying coatings, broadly speaking, it is best to use the same generic product types within a given paint specification, as certain products are less compatible than others when used together. There are exceptions to this, for example acrylic urethanes are often used to overcoat epoxies.
- When overcoating any product, the manufacturer’s technical data sheet should be consulted to ascertain whether there is a minimum or maximum overcoating timeframe. If a product is overcoated too soon, the underlying layer may not be dry or cured enough to accept the overcoat and this could result in solvent entrapment or wrinkling. If a product is overcoated
after its maximum overcoat timeframe, the underlying layer could be too cured and cross-linked, which could result in poor adhesion between the two coats and consequently intercoat separation failures could occur. These overcoating timeframes can range from a minimum of hours to products which are indefinitely ‘overcoatable’ (provided they are clean and free from contamination).

- Should an overcoating timeframe be exceeded, then abrasion of the underlying layer may be required to provide a mechanical key for the topcoat. In some cases it may be sufficient to manually abrade the undercoat, but a full sweep blast may be required in other situations, and the manufacturer should be consulted to help advise the best course of action to take.

2.5.3 Typical Full Paint System

A typical three coat paint specification for a Class 4 atmospheric environment for a projected ten year life might be:

- Anti-corrosive epoxy primer (75 µm dft)
- High-build epoxy intermediate (150 µm dft)
- Acrylic urethane gloss topcoat (50 µm dft).

However, there are many other examples of full paint systems. The decision regarding which system to select for a particular application will normally involve the user, the specifier and the paint manufacturer. The choice will depend on the environment and length of service life required before repairs are needed (i.e. the maintenance interval).

3 Glossary

- Lamellar – a structure or microstructure consisting of fine, alternating layers of different plate-like particles.
- Overcoating – an additional coating applied for enhanced protection.
- Obliteration – the degree of paint opacity; the ability of the paint to completely obscure the underlying surface.
- Single-pack coating – a coating supplied in one formulation, not requiring mixing of components immediately prior to application.
- Sweep blasting - low pressure (< 275 kPa) blast cleaning using a fine grade non-metallic abrasive.
- Two-pack coating - a paint which requires two components to be mixed together before application to allow the curing and hardening reaction to begin.
- Weatherability – capacity to withstand the weathering process.

4 References

ISO 12944-5:2007 Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Part 5: Protective paint systems, ed. 2, 2007 – 09. This describes the types of paint and paint system commonly used for corrosion protection of steel structures. It also provides guidance for the selection of paint systems for different environments, different surface preparation grades, and the durability grade to be expected. The durability of paint systems is classified in terms of low, medium and high.

Solvent Emissions Directive (SED):
5 Acknowledgements

Left-hand image on front cover: finish coat on a wind turbine access point by David Horrocks.

Right-hand image on front cover: picture of pigments by Dan Brady, available online at the following sites: http://www.flickr.com/photos/11853009@N07/1382064216/ and https://commons.wikimedia.org/w/index.php?curid=3534510