Protective Coatings – An Introduction

Introduction

Painting is the application of a liquid coating to a surface to protect it. It is considered the oldest method of corrosion control. It is one of the most recognisable to people outside the corrosion protection field. Painting’s simplicity – the application of a protective film to protect the underlying metal from exposure to the environment – belies the reality of the sophistication behind the technology that is required to do it effectively.

Although protective coatings have been in existence for many years, it was only in the mid-1900’s that the true protective mechanisms of paint coatings were understood. Prior to then, it was thought that paint coatings worked by providing a complete insulation between the protected metal and the environment. In fact, the reality was much more complex and led to improvements in the way paint was used to protect metal, most commonly steel.

It is now known that most paints to a certain extent allow moisture and atmospheric components to travel through them in varying quantities. Rather than being a problem, this property can actually assist in the paint’s corrosion protection of the base metal. Modern protective coatings are highly sophisticated and there are many characteristics depending on the type of protection required. These modern coatings protect in different ways, are made of different materials and have improved surface preparation and application. Specifiers need to be aware of the different properties available in the large range of protective coatings.

Although many different types of metals are painted today, this discussion will focus primarily on steel and structural steel.

How Coatings Work

To Protect the Metal Substrate

There are many different types of protective coatings and these also have different mechanisms by which they protect steel.

Barrier coatings protect the metal substrate by preventing the conditions and factors that cause corrosion from reaching its surface. They can be thought of as insulation for the metal from the surrounding environment. For example, in coastal environments, salt on the surface of steel will increase the conductivity of any moisture present. This will facilitate electron transfer between anodic and cathodic sites, thus setting up a corrosion cell. A correctly specified barrier coating will prevent salt reaching the surface of the steel and therefore inhibit corrosion. Barrier coatings can also work by preventing oxygen from reaching the metal surface. A barrier coating can be thought of as an impermeable filter that excludes the corrosive aspects of the environment from reaching the surface of the metal.

Note that it is practically impossible to produce a paint coating that is impermeable to water. However, by limiting or totally excluding the conductive ions and oxygen, key ingredients in the “corrosion recipe”, then the coating can be considered to have performed its function.

Coatings can also work via cathodic protection. This involves the paint coating being loaded with the dust of a more anodic metal than the substrate material, i.e. it’s protecting. So, in the case of steel, this usually involves zinc dust. These dust particles increase the conductivity of the coating, i.e. the “rich paints.” There has to be sufficient zinc in the paint to make sure that there is high enough conductivity to enable effective cathodic protection.

Another method by which coatings can protect is to promote passivation of the surface of the substrate metal. These coatings are normally classified as inorganic primers. They encourage the formation of a passive film at the interface of the metal and the primer. As the name suggests, they are usually applied directly to the surface of the metal and then provide a stable base for further paint layers.

What are Paints Made of?

There are many different types of protective coatings, but most are made up of the following:

1. Pigments
2. Binders
3. Solvents
4. Additives

Pigments are granular particles added to the paint to give it different properties. Despite their name, pigments are not only used for colouring purposes. The main types of pigments are colour pigments, extending or filler pigments and anti-corrosive pigments.

Colour pigments contribute a number of different properties beyond the cosmetic, they also provide opacity. This is known as the “hiding power” of the protective coating. It describes how well the colour of the substrate below the paint is hidden. The higher the opacity, the less the colour gets through visually, and it means that less paint can be used if this is an important consideration. The selection of certain colour pigments will also improve the UV absorption and protective qualities of the final paint coating.

Extending or filler pigments are also added for a variety of reasons. They add viscosity, contribute to the structure of the paint and can also help to reduce the cost.

Anti-corrosive pigments, as their name implies, improve the corrosion protection and reduce the extent of corrosion. They can perform either as barrier pigments, require oxidation to retard the progression of corrosive elements through the paint, or they can be active pigments, such as zinc, which provide the sacrificial or cathodic protection described above.

The binder is the “body” of the paint. It holds all the other components in place and is generally used as the reference to name the coating type eg acrylic, epoxy, etc. There are many other terms used for the binder and some common ones include medium, vehicle and matrix. The binder is what holds together the protective coating and its components.

Many protective coatings in their liquid state also contain a solvent. The solvent helps to impart flow and enhances the application properties of the paint. In terms of ensuring the adhesion of the paint system to the metal and also in its efficacy as a corrosion protection. It is no coincidence that protective coatings are described as coating “systems” since all of the components of surface preparation, paint selection and system selection combine to make up the overall system.

The Dry Protective Coating

There are two main ways in which a protective coating forms its protective film. There is the non-convertible type of film formation, which most closely follows the term “drying” used by many paint users, and there is the convertible or “curing” type where the protective coating undergoes a chemical change during its formation into a protective film.

In the non-convertible formation, the paint dries from a liquid to a solid as the solvent evaporates. This is shown in the diagram below.

Examples of non-convertible coatings include chlorinated rubber, vinyl and bituminous paints.

Convertible coatings, as their name suggests, undergo a conversion process. The coating becomes solid due to a chemical reaction. The chemical reaction can be initiated via a number of methods: exposure to air (oxygen), by chemical curing agents, exposure to UV light or moisture and by the application of heat to the “wet” coating. Convertible coatings may still contain solvents, but the chemical reaction is the key process. The convertible solvent based coatings are shown in the diagram below.

Common examples of protective coatings that are cured via a conversion process are epoxies, polyurethanes and polyasoxamines.

It will be noted that there are references to WFT and DFT in the figures above. These denote “wet film thickness” and “dry film thickness” and refer to the thickness of the coating at different stages of application. The WFT and DFT terms are used to compare the performance of protective coatings at various stages of application and can be a useful measure of performance.

Coatings that are cured via a conversion process include those that are cured thermally, by UV light, by exposure to air and by exposure to other chemicals.

Surface preparation is such an important process that it will be discussed separately in more detail later, but it is important that designers and specifiers understand and consider the importance of surface preparation processes and levels depending on the type of paint and substrate that are to be protected and the conditions under which it has to perform. As with the development of protective coatings, surface preparation has also been researched in recent years, both
“dry film thickness”. Since protective coatings are applied as a liquid, they are “wet” when they initially sit on the substrate. Ultimately, they either dry or cure and the coating process is completed. Coatings containing a solvent will have a different wet film thickness, or WFT, as opposed to when they are dry. This is because some of the volume of the initial coating is lost as the solvent evaporates.

The WFT and DFT are important parameters for coating specifiers and applicators. They basically determine whether the coating is thick enough for the required application. Not meeting the figures, particularly the DFT, will mean that the coating is not at the manufacturer’s required thickness. Many coatings will underperform if not applied to the recommended thickness and this can result in major problems and financial loss at a later stage. Like preparation, the testing and inspection of coatings is another major component of the process of applying protective coatings to metalwork.

Durability of Protective Coatings

The durability of protective coatings, like all corrosion protection systems, relies heavily on a number of different factors apart from the coating itself. Design of the steelwork, suitability for the substrate, preparation, application technique and environment are all significant factors in the performance of a protective coating.

The standard that provides a guide to many of these issues is AS/NZS 2312:2002. The standard is titled “Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings.” The standard is indeed a guide: it is by no means definitive. However, it does provide a significant amount of information that is useful to designers and specifiers.

Protective coatings have qualities that mean their life in certain environments varies between different coating types and systems. A more expensive coating may not be required if a maintenance schedule is set up that allows a cheaper coating to be effective. Ultimately, it becomes a consideration of life cycle costs for the assets being protected and what type of maintenance schedule is put in place. A more expensive coating may have a higher initial cost, but this could be offset by the significantly decreased maintenance intervals that are required. Also, the importance of the asset should be considered. If the asset is required to have almost one hundred percent availablity and failure or removal from service is not desirable or even not an option, then the extra expense of a more sophisticated protective coating system may be vindicated. There are no hard and fast rules as to the selection of coating systems, but AS/NZS 2312 does provide a guide to coating selection in certain atmospheric corrosivity classifications.

Application of the correct design allows for water or moisture build-up on the steel article. These areas will then hold water for longer, which then leads to potential corrosion hotspots that leave the protective coating vulnerable.

Another common design problem with steelwork is ponding. This is where the design allows for water or moisture build-up on the steel article. These areas will then hold water for longer, which then leads to potential corrosion hotspots that leave the protective coating vulnerable.

Conclusion

Protective coatings are the oldest and most widespread method of protecting steel structures. They are constantly under development and their sophistication and performance belies their simple appearance to the casual observer. Protective coatings are an ideal method of both protecting steelwork and providing an aesthetic finish.

Further discussion will focus on the different options available to the specifier in selecting protective coatings and also in the preparation and design of steelwork to maximise the performance of their selected coating or coating system.

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Figure 3: The application of protective coatings on large infrastructure requires careful thought and planning (courtesy of Jotun)

Figure 4: Petroleum storage tanks are usually located in highly corrosive areas (courtesy of Jotun)

Figure 5: AS/NZS 2312 suggested requirements for edge corrosion protection for paint systems. Note extra engineering design required to prevent reduced DFT (Standards Australia)

Figure 6: Painted bridge rail on Geelong Ring Road, Victoria. Note the detailing of the steel to allow moisture runoff and minimise ponding issues.

Figure 7: Protective coatings have to endure harsh and varied conditions to protect steel (courtesy of Jotun)