Introduction

"Duplex Coating" is a term first introduced by Jan van Eijnsbergen of the Dutch Hot Dip Galvanizing Institute in the early fifties and was specifically developed for corrosion protection of steel structures used in the highly corrosive environments such as that found in the tulip growing hot houses. The term Duplex coatings describe the protection of steel by hot dip galvanizing plus additional "barrier protection" by coating with a suitable organic paint system. The purpose is to provide additional corrosion protection in highly corrosive environments, with other benefits of visibility, camouflage, or when an aesthetic appearance is required, including various colour combinations.

The Synergy of Duplex Systems

Duplex systems provide synergistic effect by virtue of the fact that the durability of the combined hot dip galvanized substrate and top organic coating system is greater than the sum of the separate durabilities of the hot dip galvanized and organic coating layer applied separately onto the steel substrate. The synergistic effect can be estimated mathematically as follows:

Duplex Life = factor x (zinc life + paint life)

The synergy factors vary from 1.4 in the extreme corrosive environments to 2.7 in less-aggressive environments. In a highly aggressive environment **(Exterior: industrial with high humidity or high salinity coastal, ISO 9223 C5 environment)** where hot dip galvanizing on its own would last approximately 15 years and paint on its own 10 years, the duplex system would give a service life of 35 years and not 25 years, i.e.

1.4 x (15 years + 10 years) = 35 years

The reasons for this synergistic effect are as follows:

Paint systems are all, to a greater or lesser degree, permeable allowing moisture, oxygen and pollutants to diffuse through a paint coating and attack the steel. Red rust forms at the steel surface i.e. at the interface between the steel surface and top paint system. Since rust (a mixture of various hydrated iron oxides with varying compositions) has a volume which is approximately twice the volume of the steel from which it has been formed, the paint coating will lose contact with the substrate and, depending upon its adhesion and cohesion, will start to crack and/or flake off.

In addition corrosion creep under the paint will occur and result in "blistering" and further flaking of the adjoining protection paint and thus exposing more steel to further corrosion. When steel is hot dip galvanized, a metallurgical bond between the impervious metal zinc coating and the steel is formed. This guarantees sound adhesion and a firm base for the paint system. The penetration of moisture, oxygen and pollutants to the hot dip galvanized/paint interface causes the zinc or the more corrosion resistant zinc/iron alloy layers to corrode slowly. However, these zinc corrosion products (mainly zinc oxide and zinc hydroxide) have a volume, which is only 15-20% more than the volume of zinc from which they have been formed.

These zinc corrosion products will seal off small pores, craters or cracks in the top paint coating, thus re-establishing the "barrier protection" properties of the system. It is by this process that hot dip galvanizing and a suitable paint coating complement each other and provide the synergistic properties of the overall coating. For all coating systems, preparation of the surfaces to be protected is of paramount importance for successful corrosion control.

The adhesion of hot dip galvanizing to steel is provided by metallurgical laws, whereas adequate preparation of the hot dip galvanized surface onto which the paint be applied is of paramount importance to ensure long-term adhesion.

Hot Dip Galvanizing as a Protective Base Coating

Hot dip galvanized coatings provide "barrier protection" as well as "cathodic protection". Zinc will react with a corrosive environment forming three basic products of corrosion, firstly, zinc oxide, secondly, zinc hydroxide (both of which are unstable and easily removed) and thirdly a zinc carbonate layer, which is stable, i.e. difficult to remove, and that provides barrier protection of the carbon steel.

Cathodic protection is only activated should the hot dip galvanized coatings become damaged or small isolated uncoated area occur. Zinc being electro-negative to carbon steel, the zinc will act as the anode and "sacrifice itself" to protect the cathode, i.e. exposed carbon steel. The steel, being the cathode, will be protected as long as zinc is present. The Service life of a hot dip galvanized coating is therefore approximately proportional to the coating thickness, i.e. the thicker the coating the longer the service life.

The comparative photographs 1 and 2 illustrate the benefit of a hot dip galvanized substrate under an organic coating system.

Photograph No. 1: Hot dip galvanized + epoxy primer + polyurethane acrylic enamel, after 4000 hours of salt spray.

After 4000 salt spray hours the barrier protection is fully intact. Where the coating has been cross scribed, the underlying hot dip galvanized coating is reacting through cathodic protection and thereby providing corrosion protection to the steel. No red rust is apparent on the damaged crosshatched surfaces. No corrosion creep has developed.

Photograph No. 2: Abrasive blast + inorganic zinc + epoxy primer + polyurethane

After 4000 salt spray hours the barrier protection provided by the 3 layers of paint is providing good corrosion protection to the steel, but is also exhibiting signs of "cracking" together with porosity. The inorganic zinc is providing no significant cathodic protection. Red rust is apparent within the damaged crosshatched surfaces. Little or no apparent development of corrosion creep is in evidence.

Both examples illustrated above are excellent corrosion protective coatings. Photograph 1 is a duplex system, while photograph 2 is a zinc rich primer with similar intermediate and top paint systems. The two photographs illustrate their relative performances and highlight the synergistic benefits of duplex coatings.

One of the most common protective coating systems in current use in marine environments is an inorganic zinc primer followed by a micaceous iron oxide epoxy intermediate coat and a polyurethane acrylic finishing coat. By simply replacing the inorganic zinc primer with hot dip galvanizing, a significant extension of service life of the carbon steel is achieved. This extended service life of a duplex system is approximately 3 to 4 time that of the painted system using inorganic zinc.

Hot Dip Galvanizing Vs Zinc Rich Paint

It must be remembered that it is the zinc metal that provides protection to steel and the extent of such protection is directly proportional to the mass of zinc present. Zinc phosphate and zinc chromate containing paints do not provide cathodic protection as they are inhibitive rather than sacrificial pigments and only provide barrier protection.

When considering zinc rich paints, only those that contain sufficient quantities of metallic zinc dust will provide limited and short-term cathodic protection. There must obviously be sufficient zinc particles present to ensure that they are in electrical contact with each other as well as in contact with the carbon in order to provide a common anode. Individual isolated zinc particles dispersed in the paint binder will not provide protection, as they would essentially be insulated from the substrate and each other. On the other hand, if too much zinc dust is added to the paint there may not be sufficient binder available to “glue” these particles together, giving an unbound coating with poor adhesion and cohesion. In accordance with ISO 12944, all zinc rich paints should contain a minimum of 80% zinc in the dry film in order to function as sacrificial primers.

From the point of view of zinc content, hot dip galvanizing is the ultimate “zinc rich primer”, as it contains 100% zinc and zinc/iron alloys. In order to facilitate hot dip galvanizing and ultimately a duplex system, one needs to apply simple design procedures and follow normal quality fabricating processes. A number of articles comparing the relative costs of galvanizing versus painting have been published.

The essential difference that must be appreciated is that hot dip galvanizing prices are based on the weight of steel after galvanizing, whilst painting costs are based on surface area to be painted. However, in both instances the coatings are area based and pricing follows the general rule of thumb listed below.

Light steel	30 to 40 m^2/ ton
Medium steel	20 to 30 m^2/ ton
Heavy steel	up to 20 m^2/ ton

Recent price comparisons, which are based on the initial coatings costs, indicate that hot dip galvanizing on its own is competitive across the full range of gauges. A quality duplex coating is competitive in the light and medium steel ranges and currently more expensive for heavy steel.

Hot dip galvanized coatings are described as “honest coatings” in that if the steel is not adequately cleaned prior to immersion into molten zinc, it will not galvanize. The quality of the hot dip galvanized coating is guaranteed by what you see; no uncoated areas indicate “quality control” has been effective.

A consequence of this fact is to facilitate and ensure an adequate quality inspection process before the product is painted (duplex) or dispatched to the erection site. Hot dip galvanized coating thicknesses range from 55 microns to as much as 150 to 200 microns, depending on the parent steel thickness and it chemical composition. A quality duplex system will comprise a top paint system in a range of between 90 to 300 microns, depending on the specific specification employed. Combined coating thicknesses of duplex systems can therefore range from 150 microns through to 400 or even 500 microns of barrier protection. The specific duplex system selected should relate to the corrosive environment encountered and not be under or over specified.

Clearly hot dip galvanized coatings and paint coatings complement each other in the corrosion protection industry. The apparent perception in the market place that the hot dip galvanizers and paint manufacturers are in competition with each other is misleading. The actual position is that we both “fight a common enemy”,

CORROSION!

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