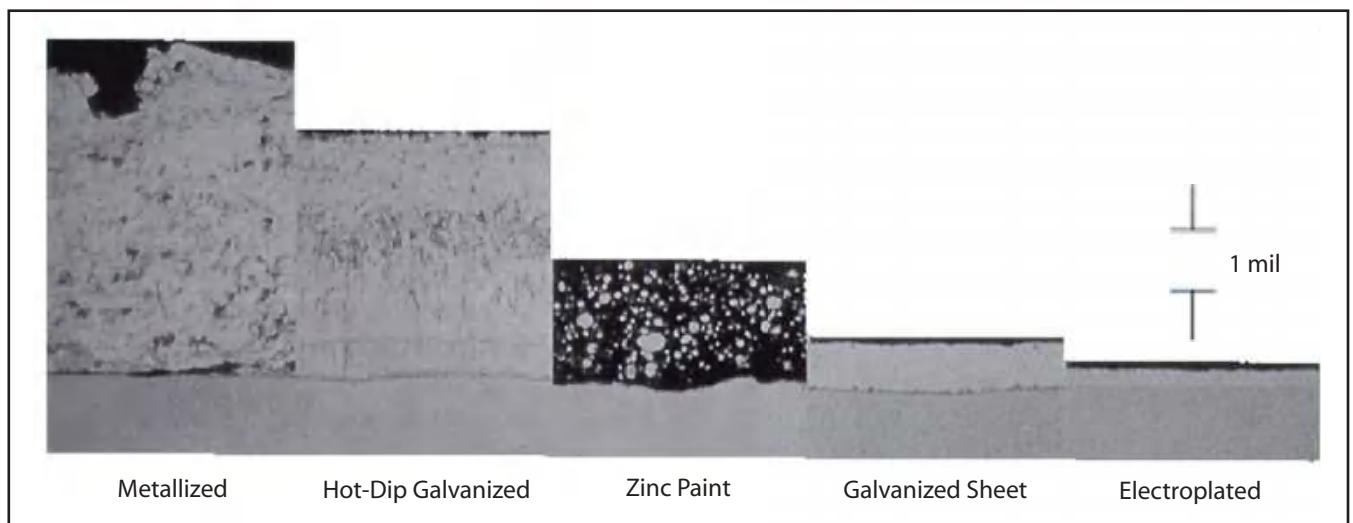


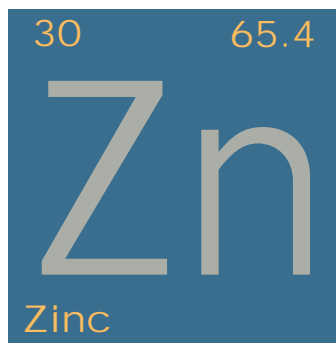
Zinc Coatings



Microstructures of Various Zinc Coatings

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Copyright © 2006 American Galvanizers Association. The material provided herein has been developed to provide accurate and authoritative information about after-fabrication hot-dip galvanized steel. This material provides general information only and is not intended as a substitute for competent professional examination and verification as to suitability and applicability. The information provided herein is not intended as a representation or warranty on the part of the AGA. Anyone making use of this information assumes all liability arising from such use.

Introduction

Zinc has a number of characteristics that make it a well-suited corrosion protective coating for iron and steel products in most environments. The excellent field performance of zinc coatings results from its ability to form dense, adherent corrosion product films and a rate of corrosion considerably below that of ferrous materials (some 10 to 100 times slower depending upon the environment). While a fresh zinc surface is quite reactive when exposed to the atmosphere, a thin film of corrosion products develops rapidly, greatly reducing the rate of further corrosion.

In addition to creating a barrier between steel and the environment, zinc also has the ability to cathodically protect the base metal. Zinc, which is anodic to iron and steel, will preferentially corrode and protect the iron or steel against rusting when the coating is damaged (see *Figure 1*, below).

Many different types of zinc coatings are commercially available,

and each has unique characteristics. These characteristics not only affect applicability but also the relative economics and expected service life. The method of processing, adhesion to the base metal, protection afforded at corners, edges, and threads, hardness, coating density, and thickness can vary greatly among the different coatings.

This practical aid discusses each of the major types of zinc coatings, applied by batch hot-dip galvanizing, continuous sheet galvanizing, electrogalvanizing, zinc plating, mechanical plating, zinc spraying, and zinc painting, to help specialists assess and select zinc coatings for corrosion protection.

Production Processes for Zinc Coatings

Batch Hot-Dip Galvanizing. The batch hot-dip galvanizing process, also known as general galvanizing, produces a zinc coating on iron and steel products by immersion of the material in a bath of liquid zinc. Before the coating is applied, the steel is cleaned to remove

all oils, greases, soils, mill scale, and rust. The cleaning cycle usually consists of a degreasing step, followed by acid pickling to remove scale and rust, and fluxing, which inhibits oxidation of the steel before dipping in the molten zinc.

There are two different fluxing methods, dry and wet. The dry process is accomplished by pre-fluxing in a zinc ammonium chloride



Removal from Batch Galvanizing Bath

solution. The wet process uses a molten flux blanket on the zinc bath surface (see *Figure 2*, next page).

Hot-dip galvanized coatings are used on a multitude of materials ranging in size from small parts such as nuts, bolts, and nails to very large structural shapes. The size of available zinc baths and material handling restricts the size of steel that can be galvanized. Molten zinc baths 60 feet long and eight feet deep are common in North America. However, the maximum size that can be accommodated in the zinc bath is increased substantially, to near double bath length or depth by progressive dipping (immersing one portion of the product and then the other).

Because the material is immersed in molten zinc, the zinc flows into recesses and other areas difficult to access, coating all areas of complex shapes thoroughly for corrosion protection.

Continuous Sheet Galvanizing. The continuous hot-dip coating process is a widely used method originally developed over fifty years ago for galvanizing of products such as steel sheet, strip, and wire. The molten coating is applied onto the surface of the steel in a continuous process. The

Figure 1: Cathodic Protection from Zinc

| Arrangement of Metals in Galvanic Series | |
|--|---|
| CORRODED END | Cathodic protections can occur when two metals are electrically connected. Any one of these metals and alloys will theoretically corrode while offering protection to any other which is lower in the series, so long as both are electrically connected. |
| Anodic or less noble (ELECTRONEGATIVE) | |
| Magnesium | |
| Zinc | |
| Aluminum | |
| Steel | |
| Lead | |
| Tin | |
| Nickel | |
| Brass | |
| Bronzes | |
| Copper | |
| Stainless Steel (passive) | |
| Silver | |
| Gold | |
| Platinum | |
| PROTECTED END | However, in actual practice, zinc is by far the most effective in this respect. |
| Cathodic or more noble (ELECTROPOSITIVE) | |

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steel is passed as a continuous ribbon through a bath of molten zinc at speeds up to 600 feet per minute. The size of the steel sheet can range from 0.010 to 1.70 inches (0.25mm to 4.30mm) thick, and up to 72 inches (1830mm) wide.

This continuous hot-dip coating process begins by cleaning the steel in a process unit that typically uses an alkaline liquid combined with brushing, rinsing, and drying. Then, the steel passes into the heating or annealing furnace to soften it and impart the desired strength and formability. In this annealing furnace, the steel is maintained under a reducing gas atmosphere, composed of hydrogen and nitrogen, to remove any oxide that may be on the steel surface. The exit end of the furnace is connected with a vacuum chamber, known as a “snout,” to the molten coating bath to prevent any air from re-oxidizing the heated steel product. In the bath, the steel product is sent around a submerged roll and reacts with the molten metal to create the bonded coating, and then removed in a vertical direction. Once the product is removed from the bath, high-pressure air is used to remove any excess molten zinc to create a closely controlled coating thickness. Then the steel is cooled

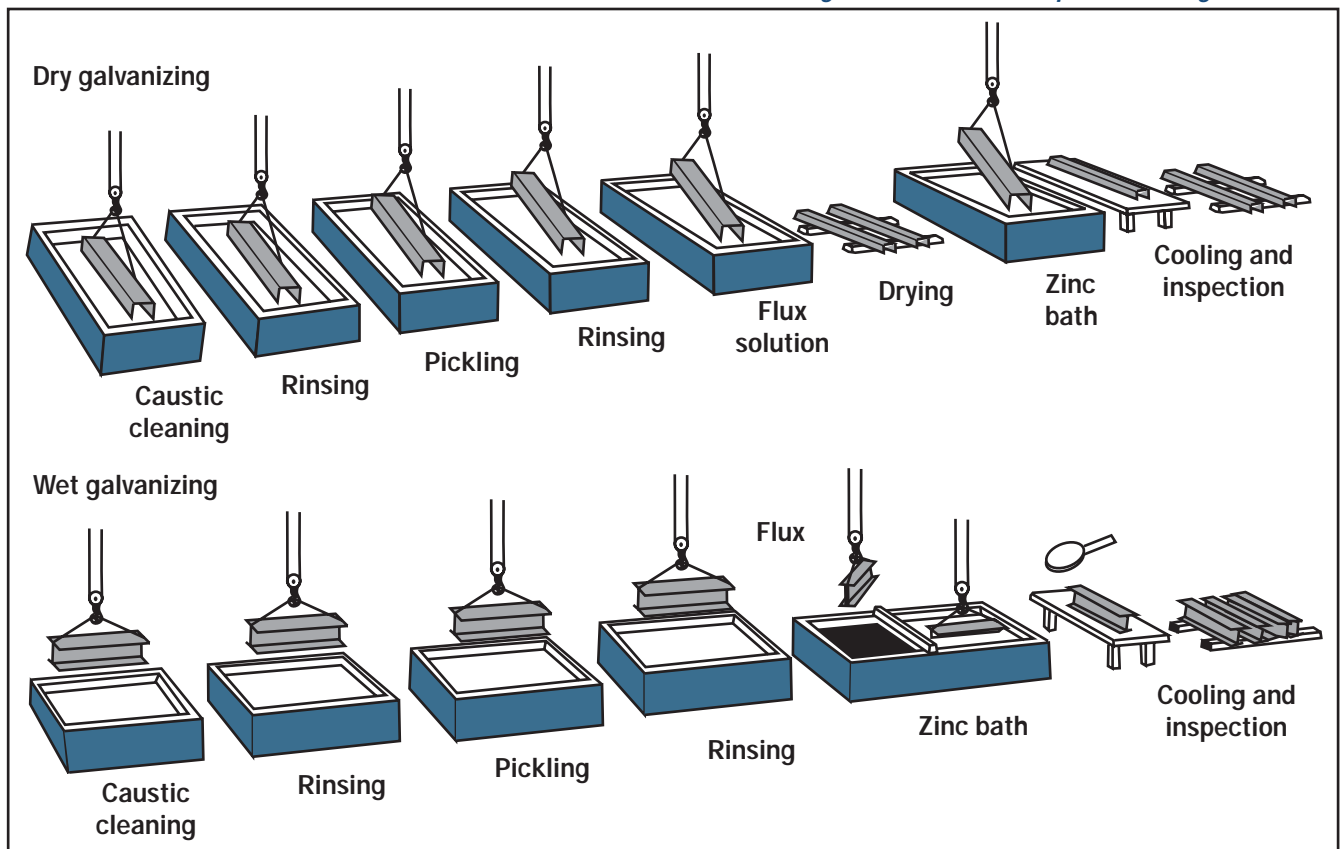
to allow the metal to solidify onto the steel surface, which is done before the steel contacts another roll to avoid transferring or damaging the coating.

The hot-dip process for sheet product is used today to make seven different types of hot-dip coated products, including galvanized (zinc), galvanized (90-92% zinc / 8-10% iron alloy), two alloys of zinc and aluminum (55% aluminum / 45% zinc alloy & 95% zinc / 5% aluminum alloy), two aluminum based alloys (100% aluminum, 89-95% aluminum / 5-11% silicon alloy), and the terne coating (85-97% lead / 3-15% tin alloy). In 2004, there were approximately 85 hot-dip lines in North America, each of which could apply at least one of the seven coatings listed above.

Electrogalvanizing. Electrogalvanized coatings are applied to steel sheet and strip by electrodeposition. Electrogalvanizing is a continuous operation where the steel sheet or strip is fed through suitable entry equipment, followed by a series of washes and rinses, and finally into the zinc plating bath.

The most common zinc electrolyte-anode arrangement uses lead-silver, or other insoluble anodes and electrolytes of zinc sulfates. Soluble anodes of pure

Figure 2: Batch Hot-Dip Galvanizing Processes



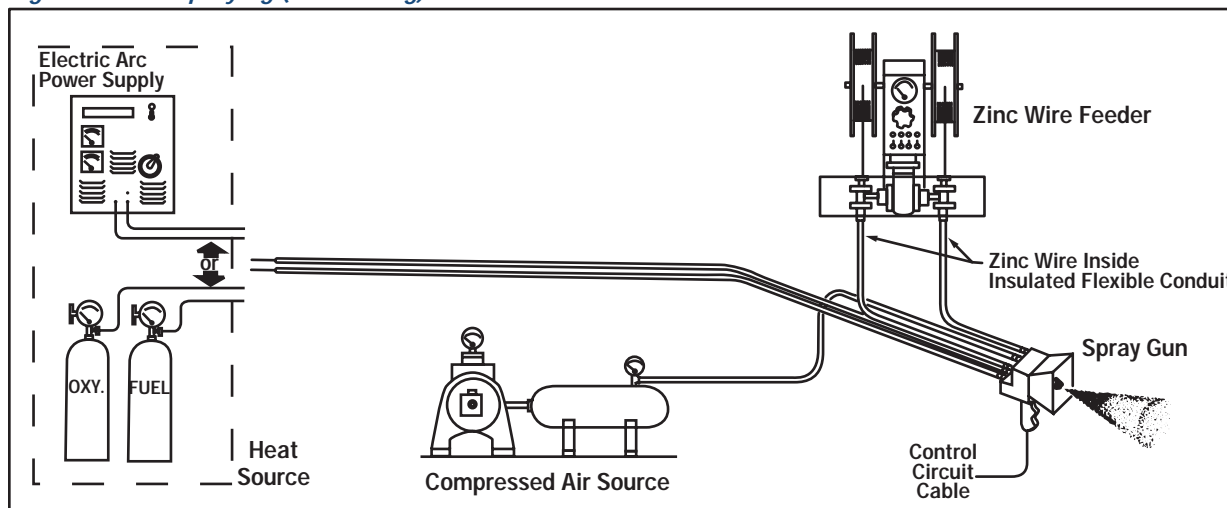
zinc are also used. In this process, the steel sheet is the cathode. The coating develops as zinc ions in the solution are electrically reduced to zinc metal and deposited on the cathode. Grain refiners may be added to help produce a smooth, tight-knit zinc coating on the steel.

Zinc Plating. Zinc plating is identical to electrogalvanizing in principle because both are electrodeposition processes. Zinc plating is used for coatings deposited on small parts such as fasteners, crank handles, springs and other hardware items.

The zinc is supplied as an expendable electrode in a cyanide, alkaline non-cyanide, or acid chloride salt solution. Cyanide baths are the most operationally efficient but can potentially create pollution and are hazardous.

After alkaline or electrolytic cleaning, pickling to remove surface oxides, and rinsing, the parts are loaded into a barrel, rack, or drum and immersed in the plating solution. Various brightening agents may be added to the solution to add luster, but careful control is needed to ensure a quality product. Post-plating treatments may be used to passivate the zinc surface as well as impart various translucent colors or to extend the life of the coating.

Figure 4: Zinc Spraying (Metallizing)



Mechanical Plating.

Small iron and steel parts may be coated by drum tumbling with a mixture of proprietary promoter chemicals, zinc powder, and glass beads. After cleaning the parts – usually limited in size to about 8-9 inches (200-300mm) and weighing less than one pound (0.5 kg) – they are flash copper coated and loaded into a plating barrel. Then the barrel is filled with chemicals, glass beads, and zinc powder and tumbled (see *Figure 3*, above). The tumbling action causes the beads topeen the zinc powder onto the part. Thickness is regulated by the amount of zinc charged to the plating barrel and the duration of tumbling time. After coating, the parts are dried and packaged, or post-treated with a passivation film, then dried and packaged.

Materials mechanically plated must be simple in design. Complex designs with recesses or blind holes may not be thoroughly coated because of inaccessibility to the peening action of the glass beads. It is also important that the compaction agents (glass beads) are large enough to avoid being lodged in

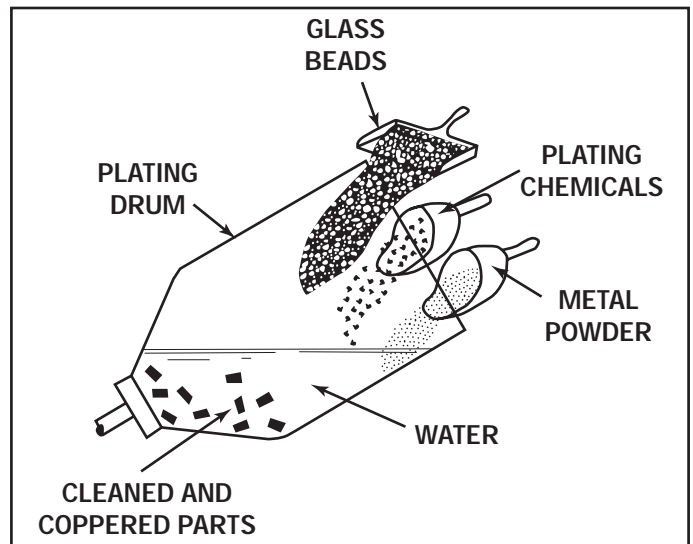


Figure 3: Mechanical Plating

any cavities, recesses, or small threads in the parts.

Zinc Spraying (Metallizing). Zinc spraying, or metallizing, is accomplished by feeding zinc in either wire or powder form into a heated gun, where it is melted and sprayed onto the part using combustion gases and/or auxiliary compressed air to provide the necessary velocity (see *Figure 4*, left).

Heat for melting is provided either by combustion of an oxygen-fuel gas flame or by electric arc. Processes have been developed for feeding molten zinc directly into the spray nozzle, primarily for use in shop rather than field applications.

Metallizing can be applied to materials of nearly any size, although there are some limits to the complexity of the structure due to limited access to recesses, hollows, and cavities by the metal spray. Abrasive cleaning of the steel is required before metallizing. The zinc coating is normally sealed with a

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thin coating of a low viscosity polyurethane, epoxy-phenolic, epoxy, or vinyl resin.

Zinc Painting. Zinc-rich paints typically contain 92-95% metallic zinc in the film of the paint after it dries. The paints are applied by brushing or spraying onto steel cleaned by sand-blasting. While white metal blasting (NACE No. 1) is preferred, near white (SSPC-SP 10) or commercial blast cleaning (SSPC-SP 6) are acceptable.

When the zinc dust is supplied as a separate component, it must be mixed with a polymeric-containing vehicle to provide a homogenous mixture prior to application. Application is usually by air spray, although airless spray can also be used. The paint must be constantly agitated and the feed line kept as short as possible to prevent settling of the zinc dust. Uneven film coats may develop if applied by brush or roller, and cracking may occur if the paint coating is applied too thick. Zinc-rich paints are classified as organic or inorganic, depending on the binder, and must be applied over clean steel.

Characteristics of Zinc Coatings

Batch Hot-Dip Galvanizing. The batch hot-dip galvanized coating consists of a series of zinc-iron alloy layers with a surface layer of pure zinc. The unique coating is metallurgically bonded to the steel substrate, with the coating integral to the steel. The strength of

the bond, measured in the range of several thousand psi, results in a very tightly adherent coating.

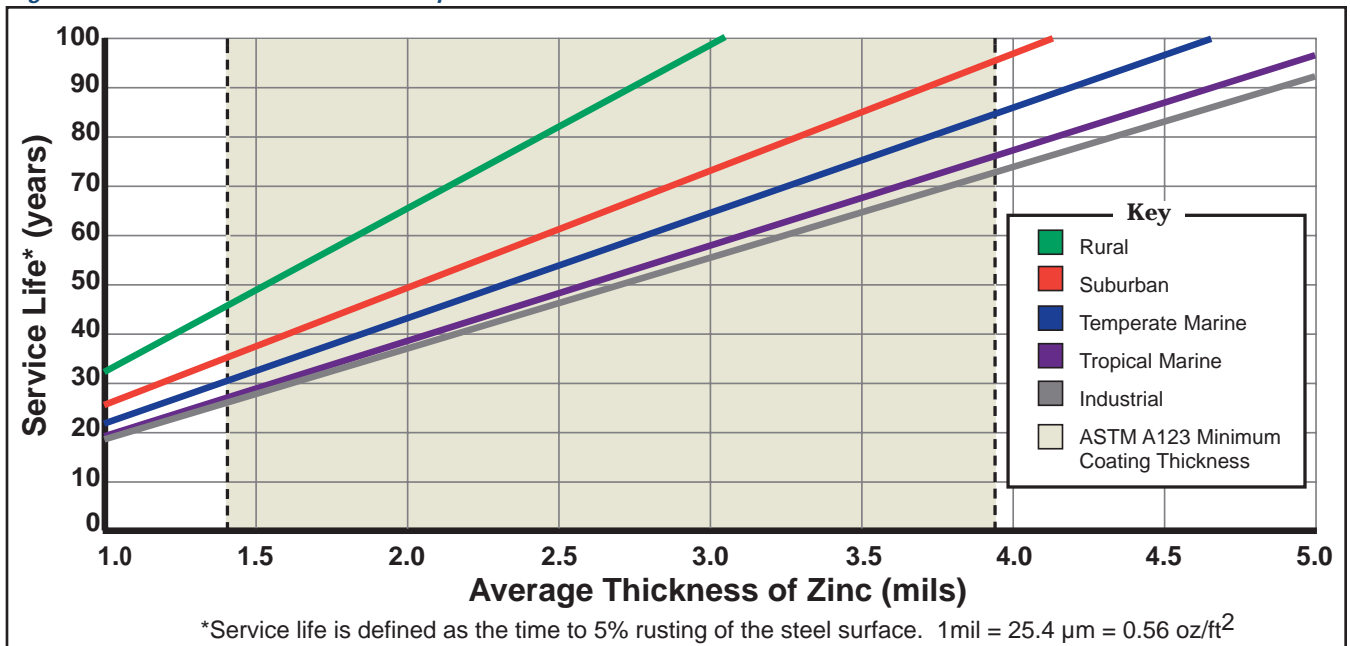
Batch hot-dip galvanizing produces a coating typically thicker than other zinc coating processes. Minimum coating thicknesses for various steel products and steel thickness are established by the ASTM standards A 123, A 153, and A 767, as well as the CSA specification G 164. *Figure 5* shows the relationship between estimated service life and coating thickness. The shaded area represents the minimum thickness requirements found in the most common batch hot-dip galvanizing specification, ASTM A 123.

The zinc-iron alloy of the coating has hardness values that approach or exceed those of the most commonly galvanized structural steels, offering excellent abrasion resistance for applications such as stairs and walkways. The zinc-iron alloy layers are actually harder than the base steel (see *Figure 6*, next page).

The hot-dip galvanized coating is generally uniform on all surfaces. Edges, corners, and threads have coatings at least as thick, or thicker than flat surfaces, providing excellent protection at these critical points.

The pure zinc layer and the zinc-iron alloy layers are anodic to steel, providing sacrificial protection in the event the coating is scratched. This ensures steel exposed as a result of damage to the hot-dip coating will not rust as long as there is sufficient coating on the surface of the steel.

Figure 5: Service Life Chart for Hot-dip Galvanized Steel



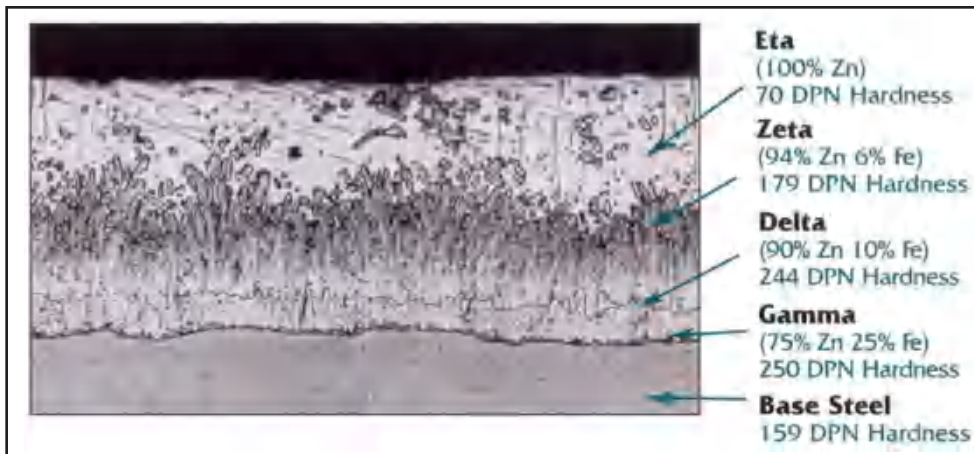


Figure 6: Photomicrograph of Batch Hot-Dip Galvanized Coating

Continuous Sheet Galvanizing. After galvanizing, the continuous zinc coating is physically wiped using air knives to produce a uniform coating across the width of the strip. The uniform coating consists almost entirely of unalloyed zinc and has sufficient ductility to withstand deep drawing or bending without damage. A variety of coating weights and types are available, ranging up to just over 3 mils (76 μm) per side. One of the most common zinc coatings is Class G90, which has 0.9 oz/ft² of sheet

(total both sides) or about 0.80 mils (20 μm) thickness per side. Continuous sheet galvanized coatings often get confused with batch hot-dip galvanized coatings because the term “galvanizing” is used interchangeably. Table 1 compares the available coating grades of continuous and batch hot-dip galvanizing and their corresponding coating thicknesses. Zinc coating thickness is proportional to the service life as evidenced in Figure 5, (previous page).

Continuously galvanized sheet steels are used to make cars, appliances, corrugated roofing and siding, and culvert pipe. The coated product can be suitably treated for painting, which will increase the service life. Because of the thin coating, this product normally is used for interior applications or where exposure to corrosive elements is mild.

Electrogalvanizing. This electro-deposited zinc coating consists of pure zinc tightly adherent to the steel. The coating is highly ductile and the coating remains intact even after severe deformation. The coating is produced on strip and sheet materials to coating weights up to 0.2 oz/ft² (60 g/m²), or thickness up to 0.14 mils (3.6 μm) per side. On wire, coating weights may range up to 3 oz/ft² (915 g/m²). Heat-treated and electrocoated wire can be cold drawn to about 95% reduction in area, depending on the chemical composition of the wire, heat treatment, and diameter.

Table 1: Comparison of Continuous Sheet & Hot-dip Galvanizing

| Continuous Sheet Galvanizing | | | | | Hot-dip Galvanizing | | | |
|---|--------------------|--------------------|------|---------------|---|------|---------------|--------------------|
| Total Both Sides | | One Side | | | One Side | | | |
| Coating Grade | oz/ft ² | oz/ft ² | mils | μm | Coating Grade | mils | μm | oz/ft ² |
| G360 | 3.60 | 1.80 | 3.24 | 82.3 | 100 | 3.94 | 100 | 2.19 |
| G300 | 3.00 | 1.50 | 2.70 | 68.6 | 85 | 3.35 | 85 | 1.86 |
| G235 | 2.35 | 1.18 | 2.12 | 53.7 | 80 | 3.15 | 80 | 1.75 |
| G210 | 2.10 | 1.05 | 1.89 | 48.0 | 75 | 2.95 | 75 | 1.64 |
| G185 | 1.85 | 0.93 | 1.67 | 42.3 | 65 | 2.56 | 65 | 1.42 |
| G165 | 1.65 | 0.83 | 1.49 | 37.7 | 60 | 2.36 | 60 | 1.31 |
| G140 | 1.40 | 0.70 | 1.26 | 32.0 | 55 | 2.17 | 55 | 1.20 |
| G115 | 1.15 | 0.58 | 1.04 | 26.3 | 50 | 1.97 | 50 | 1.10 |
| G90 | 0.90 | 0.45 | 0.81 | 20.6 | 45 | 1.77 | 45 | 0.98 |
| G60 | 0.60 | 0.30 | 0.54 | 13.7 | 35 | 1.38 | 35 | 0.77 |
| G40 | 0.40 | 0.20 | 0.36 | 9.1 | Hot-dip Galvanizing: Coating grades are determined by the steel thickness and type. Coating grades correspond to minimum zinc coating thickness on one side. It is important to remember these are minimum coating thicknesses the galvanizer must achieve; however, thicker coatings are common, assuring conformance to specification. | | | |
| G30 | 0.30 | 0.15 | 0.27 | 6.9 | | | | |
| G01 | no minimum | | | | | | | |
| Continuous Sheet Galvanizing: The number following the “G” coating grade designation correlates to the total thickness of zinc applied to both sides of the steel sheet. | | | | | | | | |

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The electrogalvanized coating can be treated to make it suitable for painting. Due to the extremely thin zinc coating on the sheet, painting or other top coating is recommended to improve the service life. Electrogalvanized sheet product is commonly used in automobile and appliance bodies.

Zinc Plating. Normal zinc-plated coatings are dull gray with a matte finish, although whiter, more lustrous coatings can be produced, depending on the process or agents added to the plating bath or through post-treatments. The coating is thin, ranging up to 1 mil (25 μm), restricting zinc-plated parts to very mild (indoor) exposures. ASTM Specification B 633 lists four classes of zinc-plating: Fe/Zn 5, Fe/Zn 8, Fe/Zn 12 and Fe/Zn 25. The number indicates the coating thickness in microns (μm). Zinc plating is typically used for screws and other light fasteners, light switch plates, and various small parts. Materials for use in moderate or severe environments must be chromate-conversion coated for additional corrosion protection. The coating is pure zinc, which has a hardness about one-third to one-half that of most steels.

Mechanical Plating. Mechanical plating consists of a flash coating of copper followed by the zinc coating. Coating thickness requirements contained in ASTM Specification B 695 range from 0.2 to 4.3 mils (5 to 110 μm). While thicker coatings are possible, the common thickness on commercial fasteners is 2 mils (50 μm). The coating has a density of about 0.45 oz/ft²/mil compared to the hot-dip galvanized coating density of about 0.6 oz/ft²/mil. The hot-dip coating has over 30% more zinc per unit volume than a mechanical coating.

The coating, on a micro cross-section, appears to consist of flattened particles of zinc loosely bonded together. The mechanical bond between zinc and steel, and zinc to zinc in this process is weaker than the metallurgical bond found in hot-dip galvanizing. Edge, corner, and thread coating thicknesses are usually lower due to minimal peening action at these locations.

Zinc Spraying (Metallizing). The sprayed zinc coating is rough and slightly porous, with a specific gravity of 6.4, compared to zinc metal at 7.1. Zinc corrosion products

tend to fill the pores as the zinc corrodes in the atmosphere. The coating adherence mechanism is mostly mechanical, depending on the kinetic energy of the sprayed particles of zinc. No zinc-iron alloy layers are present.

Metallizing covers welds, seams, ends, and rivets well, can be used to produce coatings in excess of 10 mils (254 μm), and can be applied in the shop or field. Coating consistency is dependent on operator experience and coating variation is always a possibility. Coatings may be thinner on corners or edges and the process is not suitable for coating recesses and cavities.

Zinc Painting. Organic or inorganic zinc-rich paints are applied to a dry film thickness of 2.5 to 3.5 mils (64 to 90 μm). Organic zinc paints consist of epoxies, chlorinated hydrocarbons, and other polymers. Inorganic zinc paints are based largely on organic alkyl silicates. The zinc dust must be at a concentration high enough to provide for electrical conductivity in the dry film for cathodic protection to be possible. However, there is some question as to whether cathodic protection is possible at all due to the encapsulation of the zinc particles in the non-conductive binder.

Adhesion bond strengths of zinc-rich paints are a few hundred pounds per square inch (psi), while galvanized coatings measure in the several thousand psi range. Like metallizing, zinc-rich painting can be applied to large articles in either the shop or field.

Zinc-rich Paint Application



Limitations include cost, difficulty in applying, lack of coating uniformity (particularly at corners and edges), and the requirement for a clean steel surface. Zinc-rich paints should be top coated in severe environments.

Inorganic zinc-rich paints, which adhere with the substrate by mild chemical reactivity, have good solvent resistance and can withstand temperatures up to about 375 C (700 F). Inorganics do not chalk, peel, or blister readily, are easy to weld, and cleanup is easier than with organics.

Contents of inorganic zinc-rich paints range up to about 0.35 oz/ft²/mil of zinc, about one-half less zinc per mil than hot-dip galvanized coatings.

The properties of organic zinc-rich paints depend on the solvent system. Multiple coats may be applied within 24 hours without cracking. Zinc-rich paints are often used to touch up galvanized steel that has been damaged by welding or severe mechanical impact.

Limited to 200 to 300 F, organic zinc-rich paints do not have the temperature resistance of inorganic zincs. They are also subject to ultraviolet (sunlight) degradation, and are not as effective as inorganics in corrosion protection.

Zinc dust/zinc oxide paints (MZP) are classified under Federal Specification TT-P-641G as either Type I, Type II or Type III, depending on the vehicle. The vehicles used are linseed, alkyd resin, and phenolic resin, respectively. These paints are widely used as either a primer or topcoat and show good adhesion to galvanized steel, making them the logical choices for painting that substrate. Type I is good for outdoor applications, Type II for heat-resistant applications, and Type III for water immersion or severe moisture conditions. MZPs cannot

provide sacrificial protection to the base steel because of their lower metallic zinc content. When used as a coating over galvanized steel, the service life of the

galvanized coating is extended because of the increased barrier protection of the paint. The service life of the paint is also extended as the galvanized surface is a better substrate than steel. Zinc galvanized) corrosion products are less voluminous than iron (steel) corrosion products minimizing the incidence of lifting and separation of the paint film. MZPs can be top-coated with a variety of paint types if colors other than gray, green or tan (from pigmented additives) are desired.

Selection of Zinc Coatings

After deciding to use a zinc coating for corrosion protection, some factors must be considered to ensure the proper coating is selected for the intended application and service environment. Obviously, zinc coating processes which are limited to small parts, and operations limited to continuous lines in steel mills (i.e. continuous galvanizing and electrogalvanizing) cannot be considered for the protective coating of structural steel members.

Each zinc coating reviewed provides various degrees of corrosion protection. When selecting a coating, it is important to investigate the corrosiveness of the exposure environment to ensure the zinc coating selected will provide adequate service life for the cost.

Coating Thickness vs. Coating Weight. The usual criterion for determining the expected service life of zinc coatings is thickness: the thicker the coating, the longer the service life. This is an

| | |
|---|----------------------|
| Hot-dip galvanizing (batch or continuous), electrogalvanizing, zinc plating | 1.7 mils (43 μm) |
| Zinc spraying (metallizing) | 1.9 mils (48 μm) |
| Mechanical plating | 2.2 mils (55 μm) |
| Zinc-rich Paint | 3-6 mils (75-150 μm) |

Table 2: Coating Densities

acceptable criterion when comparing zinc coatings produced by the same process (see *Figure 5*, page 4).

When comparing zinc coatings produced by different processes, the thickness criterion cannot be used without considering the amount of available zinc per unit volume. It is also important to keep in mind various ASTM or other specifications as they relate to coating weight or thickness, and reduce the coating requirements to a common denominator prior to making a comparison of different zinc coatings.

While the coating densities for some of the different types of zinc coatings are nearly identical, others differ considerably. The coating thickness required to equal 1 oz of zinc/ft² of surface, are displayed in *Table 2*, above.

Each of these thicknesses, representing the same weight per unit area of zinc, would be expected to provide equivalent service life; i.e. 1.7 mils of hot-dip galvanized would give about the same service life as 2.2 mils of mechanical plating or 3 to 6 mils (depending on the paint formulation) of zinc-rich paint.

It is also important to remember that for all continuous galvanized sheet materials, including electrogalvanized, the coating weight is given for the total zinc weight for both sides of the sheet. To obtain the amount of zinc per unit area of surface, the weight given must be divided in two, assuming equal distribution on both sides. For example, an ASTM A 653 Class G90 sheet

contains 0.90 oz zinc/ft² of sheet or about 0.45 oz/ft² per side (see *Table 1*, page 5).

Economic Considerations. Selection from the wide range of coatings available for steel will normally depend on the suitability of the coating for the intended use and the economics of the protective system. Factors that affect the economics for a particular application include:

- Initial cost of the coating;
- Coating life to first maintenance;
- Cost of maintenance;

Hidden costs, such as accessibility of the site, production loss due to maintenance recoating, and rising wages for labor-intensive coatings, such as metal spraying and painting must also be considered.

The choice of the most economical system is not precise, because neither the timing nor the cost of future maintenance can be accurately predicted. In addition, depreciation of capital investment, tax relief for investment and maintenance cost and the time value of money must be considered and can change.

A number of economic models from NACE, SSPC and the American Galvanizers Association are available for comparing the costs of different coatings. A model for predicting coating service life from field and test data is also available, as well as theoretical models of coating corrosion behavior.

Conclusion

All of the zinc coatings reviewed in this document are summarized in *Table 3* (next page) along with representative applications for each. While a coating is not limited to those uses listed, the applications listed represent the most common types of products coated by the process.

Acknowledgements

We acknowledge the assistance of the following who supplied illustrations for use in this booklet:

Cover Photo Courtesy of Teck Cominco Metals, Ltd.

Figure 2 Adapted from drawing courtesy Nordisk Föorzinkningsförening Stockholm, Sweden from “Rust Prevention by Hot Dip Galvanizing.”

Figure 3 Courtesy Lester Coch, Tru-Plate Process, Inc Jericho, New York from the Economics of Mechanical Plating, April 1978.

Figure 4 Courtesy Falconbridge, Ltd., Toronto, Ontario, from Zinc Metal by Thermal Spraying.

Zinc Coatings

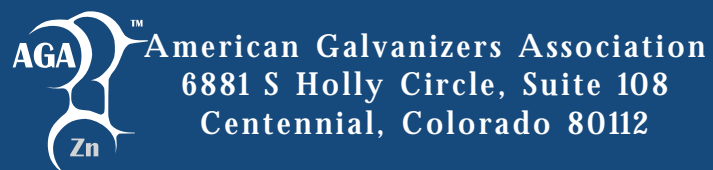
| <i>Method</i> | <i>Process</i> | <i>Specification</i> | <i>Coating Thickness</i> | <i>Application</i> |
|------------------------------|--------------------------|--|---|--|
| Electrogalvanizing | Electrolysis | ASTM A 879 | Up to 0.28 mils ¹ (7.11µm) | Interior. Appliance panels, studs, acoustical ceiling members |
| Zinc Plating | Electrolysis | ASTM B 633 | 0.2 to 1.0 mils ² (5.1 to 25.4µm) | Interior or exterior. Fasteners and hardware items. |
| Mechanical Plating | Peening | ASTM B 695 | 0.2 to 4.3 mils ² (5.08 to 109.2µm) | Interior or exterior. Fasteners and hardware items. |
| Zinc Spraying (Metallizing) | Hot Zinc Spray | AWS C2.2 | 3.3 to 8.3 mils (83.8 to 210.8µm) | Interior or exterior. Items that cannot be galvanized because of size or because on-site coating application is needed. |
| Continuous Sheet Galvanizing | Hot-Dip | ASTM A 653 | Up to 4.0 mils ¹ (101.6µm) | Interior or exterior. Roofing, gutters, culverts, automobile bodies. |
| Batch Hot-Dip Galvanizing | Hot-Dip | ASTM A 123 ASTM A 153 ASTM A 767 CSA G164 | 1.4 to 3.9 mils ³ (35.6 to 99.1µm) | Interior or exterior. Nearly all shapes and sizes ranging from nails, nuts, and bolts to large structural assemblies, including rebar. |
| Zinc Painting | Spray Roller Brush | SSPC-PS Guide 12.00, 22.00 SSPC-PS Paint 20 SSPC-PS 12.01 | 0.6 to 5.0 mils/coat (15.2 to 127µm/coat) | Interior or exterior. Items that cannot be galvanized because of size or because on-site coating application is needed. Large structural assemblies. Aesthetic requirements. |

¹ Total for **both sides** of sheet.

² Range based on **ASTM minimum thicknesses** for all grades, classes, etc., encompassed by the specifications.

³ Range based on **ASTM and CSA minimum thicknesses** for all grades, classes, etc., encompassed by the specifications.

Table 3: Zinc Coatings and Applications



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