SURFACE PREPARATION

Surface preparation is the most important step in the application of any coating. In most instances, where a coating fails before the end of its expected service life, it is due to incorrect or inadequate surface preparation.

With galvanizing, the surface preparation process contains its own built-in means of quality assurance and quality control in that zinc will simply not react with a steel surface that is not perfectly clean. Any failures or inadequacies in surface preparation will be immediately apparent when the steel is withdrawn from the molten zinc and uncoated areas remain, and immediate corrective action is taken.

Conversely, a barrier coating applied by brush or spray to an inadequately prepared surface can pass initial inspection but fail on the job weeks, months or even years later, before the end of the expected service life of the coating.

Hot dip galvanizing is a factory-applied coating, and as such, primary responsibility for surface preparation as well as coating application falls with the galvanizer.

Surface preparation for galvanizing typically consists of three steps:
Caustic Cleaning — A hot alkali solution is often used to remove organic contaminants like dirt, paint markings, grease, and oil from the metal surface. Epoxies, vinyls, asphalt, or welding slag must be removed by grit blasting, sand blasting, or other mechanical means, before galvanizing. Removal of these materials is usually the responsibility of the fabricator.

Pickling — Scale and rust are normally removed from the steel surface by pickling in an ambient temperature hydrochloric acid.

Fluxing — Fluxing is the final surface preparation step in the galvanizing process. Fluxing removes oxides and prevents further oxides from forming on the surface of the metal prior to galvanizing and promotes bonding of the zinc to the steel or iron surface. In the dry galvanizing process, the steel or iron materials are dipped or "prefluxed" in an aqueous solution of zinc ammonium chloride. The material is then dried prior to immersion in molten zinc.

GALVANIZING

In this step, the material is completely immersed in a bath consisting of a minimum 98 percent pure molten zinc. The bath chemistry is specified by the American Society of Testing and Materials in Standard A 123. The bath temperature is maintained at approximately 830 degrees Fahrenheit.

Fabricated items are immersed in the bath long enough to reach bath temperature. The articles are slowly withdrawn from the galvanizing bath, and the excess zinc is removed by draining. The chemical reactions that result in the formation and structure of the galvanized coating continue after the articles are withdrawn from the bath as long as these articles are near bath temperatures. The articles are air cooled after withdrawal from the bath.

COATING THICKNESS

ASTM and CSA specifications and inspection standards for galvanizing recognized that variations inherently occur in both coating thickness and compositions. Thickness specifications are stated in both average terms and as a minimum for any individual articles tested. Further, coating thickness measures must be taken at several points on each inspected article to comply with ASTM A 123.

ASTM specifications establish minimum standards for thickness of galvanized coatings on various categories of items. By the nature of the galvanizing process, the minimum standards specified by ASTM are routinely exceeded.
by galvanizers. Factors influencing the thickness and appearance of the galvanized coating include:

- Chemical composition of the steel
- Steel surface condition
- Cold working of steel prior to galvanizing
- Bath immersion time
- Bath withdrawal rate
- Steel cooling rate

The chemical composition of the steel being galvanized is very important. The amount of silicon and phosphorus present in the steel strongly influences the thickness and appearance of the galvanized coating. A silicon level of 0.04 percent or greater or a phosphorous level of 0.05 percent or greater in the steel will generally result in thick coatings consisting primarily of zinc-iron alloys. The carbon, sulfur, and manganese content of the steel also may have a minor effect on the galvanized coating thickness.

Certain steel compositions tend to accelerate the growth of zinc-iron layers. This may result in a finished galvanized coating consisting entirely of zinc-iron alloy. Instead of the shiny spangled appearance, the galvanized coating will have a dark gray, matte finish. This dark gray, matte galvanized coating will provide as much corrosion protection as a galvanized coating having the common spangled appearance.

As the galvanizing reaction is a diffusion process, higher zinc bath temperatures and longer immersion times will generally produce somewhat heavier alloy layers. Like all diffusion processes, however, the reaction proceeds rapidly at first and then slows as layers grow and become thicker.

Continued immersion beyond a certain time will have little incremental effect. In galvanizing of silicon bearing steels containing more than 0.04 percent silicon, the diffusion process significantly changes.

The thickness of the outer pure zinc layer is largely dependent upon the rate of withdrawal from the zinc bath. A rapid rate of withdrawal causes an article to carry out more zinc and generally results in a thicker coating.

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THE METALLURGICAL BOND

Galvanizing forms a metallurgical bond between the coating and underlying steel or iron. Galvanizing creates a barrier that is a part or extension of the metal itself. During galvanizing, the molten zinc reacts with the surface of the steel or iron article undergoing galvanizing to form a series of zinc/iron alloys. A typical galvanized coating consists of three alloy layers and a layer of metallic zinc. Moving from the underlying metal surface outward, these are:

- The thin Gamma layer composed of an alloy that is 75 percent zinc and 25 percent iron
- The Delta layer composed of an alloy that is 90 percent zinc and 10 percent iron
- The Zeta layer composed of an alloy that is 94 percent zinc and 6 percent iron
- The outer Eta layer that is composed of zinc

Each layer is characterized by a measure of hardness called the Diamond Pyramid Number (DPN). The DPN is a progressive measure of hardness (i.e., the higher the number the greater the hardness). Typically, the Gamma, Zeta, and Delta layers are harder than the underlying steel. The hardness of these inner layers provides exceptional protection against coating damage through abrasion. The Eta layer of the galvanized coating is quite ductile, providing the galvanized coating with good resistance to damage by abrasion.

The galvanized coating is adherent to the underlying steel on the order of several thousand pounds per square (psi) inch. Other coatings typically offer adhesion rated at several hundred psi at best.

These three factors, hardness, ductility, and adherence combine to provide the galvanized coating with unmatched protection against
damage by rough handling during transportation to and/or at the job site as well as on the job. The toughness of the galvanized coating is extremely important since barrier protection from corrosion is dependent upon the integrity of the coating. Other coatings damage easily during shipment or through rough handling on the job site. Experts will argue that all organic forms of barrier protection (such as paint) must be permeable to some degree. Correctly applied galvanized coatings are impermeable.

If the coating is physically damaged, the galvanizing will continue to provide cathodic protection to the exposed steel. If individual areas of underlying steel or iron of length and/or width of as much as 1/4" become exposed, the surrounding zinc will provide these areas with cathodic protection for as long as the coating lasts.

The galvanizing process naturally produces coatings that are at least as thick on the corners and edges as the coating on the rest of the article. As coating damage is most likely to occur at the edges, this is where added protection is needed most. Brush- or spray-applied coatings have a natural tendency to thin at the corners and edges.

Because the galvanizing process involves total immersion of the material, it is a complete process; all surfaces are coated. Galvanizing provides both outside and inside protection for hollow structures. Conversely, hollow structures that are painted have no corrosion protection on the inside.

The inspection process for galvanized items is simple, fast and requires minimal labor. This is important because the inspection process required to assure the quality of many brush- and spray-applied coatings is highly labor intensive and uses expensive skilled labor.

The Galvanizing process can be done under any weather or humidity conditions. Most brush- and spray-painted coatings are dependent upon proper weather and humidity conditions for correct application. The dependence of most brush- or spray-applied corrosion systems upon proper weather and humidity conditions often translate into costly construction delays at the job site.

The galvanizer's ability to work in any type of weather allows a higher degree of assurance of on-time delivery. Working under these circumstances, galvanizing can be completed with short lead and turnaround times. A turnaround time of two or three days for galvanizing is common, and a week is standard.
INSPECTION

The most important method of inspection for galvanized articles is visual. A variety of simple physical and laboratory tests may be performed for:

- Thickness
- Uniformity of the coating
- Adherence of the coating
- Appearance

Products are galvanized according to the long established, well accepted, and approved standards of the American Society for Testing and Materials (ASTM). Additional relevant standards are provided by the Canadian Standards Association (CSA) and the American Association of State Highway and Transportation Officials (AASHTO). ASTM standards cover everything from the minimum required coating thicknesses for various categories of galvanized items to the composition of the zinc metal used in the process.

CHARACTERISTICS OF GALVANIZED SURFACES

Three factors — hardness, ductility, and adherence — combine to give galvanized coatings unmatched resistance to damage by corrosion or rough handling.

- **Hardness.** Each layer of the galvanized surface is characterized by a measure of hardness called the Diamond Pyramid Number (DPN). The higher the DPN, the greater the hardness. Typically, the Gamma, Zeta, and Delta layers are harder than the underlying steel. This provides excellent resistance to damage from abrasion.
- **Ductility.** The Eta layer of the galvanized coating is quite ductile, or pliable, adding to the coating’s abrasion resistance.
- **Adherence.** A galvanized coating is adherent to the underlying steel at several thousand pounds per square inch (psi). Other coatings typically offer adhesion rated at several hundred psi at best.