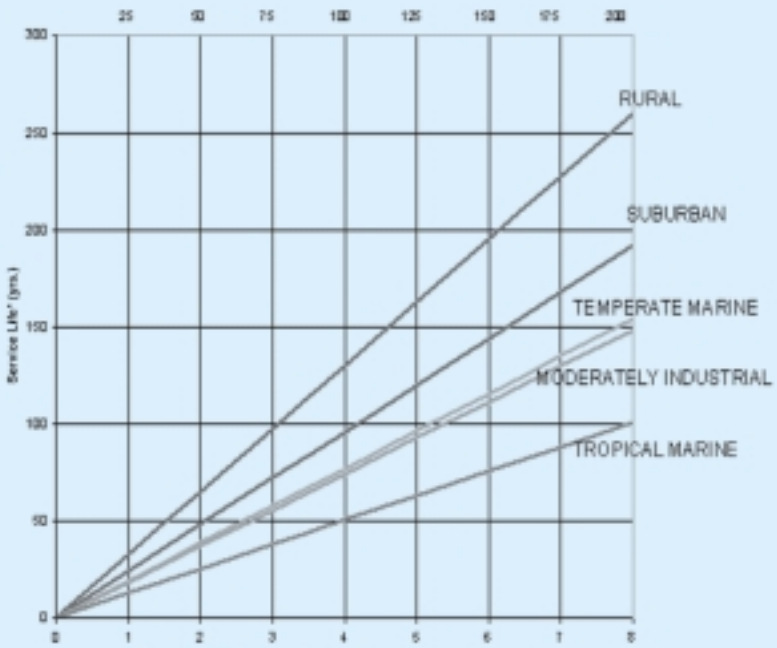
Zinc Coatings on Handrail Tubing: A Comparative Analysis

When applying zinc metal to steel handrail tubing for corrosion protection, batch hot-dip galvanizing and in-line, continuous galvanizing are the two most common methods.

Figure 1: Service Life Chart for Hot Dip Galvanized Coatings



Batch hot-dip galvanizing handrail tubing involves loading a rack or overhead lifting fixture with 50 or more cut-lengths (usually 20′ or 40′) of tubing, thoroughly cleaning the steel and then immersing the entire load into a molten zinc bath. This process coats all exterior and interior surfaces. Once the newly galvanized tubing cools, it is ready for shipment to the job site or transport to a paint contractor for paint application.

In-line, continuous galvanizing involves feeding the tubing through a bath of molten zinc and then applying a conversion coating to prevent the formation of naturally occurring zinc oxide and hydroxide. Usually, a topcoat of a clear, inorganic, polymeric paint is applied over the conversion coating. It is important to note that only the outside of the tubing goes through this process. The tubing's inside surface receives only a coating of zinc-rich paint.

Fundamentally, zinc metal will provide some level of corrosion protection to steel used in a myriad of applications. However, understanding the metallurgy, bond strength, corrosion mechanisms and testing of these two galvanizing methods may lead to better design decisions for particular applications.

Comparison

Zinc-coating thickness—For standard 0.25″ wall tubing, the batch hot-dip galvanizing process applies a minimum of 3.0 mils (1.7 oz/ft²) of protective zinc. The

in-line process applies about 0.9 mils (0.5 oz/ft²). As the Service Life chart (Figure 1) indicates, the batch-process-produced zinc coating will perform in use without maintenance approximately three times longer than the in-line-produced zinc coating.

Taking into consideration the organic clear-coat applied to the handrail galvanized in the continuous process, it is important to note that applying a barrier protection system over a galvanized coating (no matter what process is used) results in a service 1.5 times the sum of the service life of the two systems. While applying a barrier coating to the in-line galvanized handrail will enhance the service-life, it still does not match that of the unpainted batch-process galvanized handrail. In addition, since the interior of a continuous-process handrail is not provided a metallurgically bonded zinc coating, it is difficult to accurately compare service-life expectancies.

Bond strength—The batch hot-dip galvanizing process generates a metallurgical reaction between the molten zinc and the iron in the steel tubing. This reaction results in the formation of three zinc-iron alloy layers metallurgically bonded to the base metal, topped by an impact-resistant pure zinc outer layer. The metallurgical bond between the zinc-iron alloy layers and the steel is measured at approximately 3,600 psi. This bond strength is especially important for the interior surface of batch-galvanized tubing where the coating resists corrosion caused by trapped water and moisture. By comparison, the zinc-rich paint applied to the inside of tubing galvanized via the in-line, continuous process has a mechanical bond in the range of 300–500 psi. Because of this lesser bond strength, it is possible for trapped moisture to make its way between the zinc-rich paint and the steel tubing, causing rust formation and eventual flaking and failure of the paint system.

Corrosion protection throughout—Batch hot-dip galvanizing metallurgically bonds zinc to all surfaces of the tubing. In fact, batch galvanized tubing and pipe often is used in fabrications with hot-dip galvanized vessels and tanks to store a wide range of liquids. The zinc-rich paint applied to the inside of

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tubing galvanized via continuous in-line processes provides some corrosion protection, but performs less effectively when exposed to liquids. In such cases, moisture makes its way to the base steel of the tubing through cracks, damaged areas or porosity in the zinc-rich paint. This allows corrosion to begin where it is not apparent and is not easily remedied.

Inspection and testing—Salt-spray or salt-fog tests often are used to compare the corrosion protection provided by various coatings. Simply put, galvanized coatings, in use, require wet and dry cycles in order to develop a naturally occurring, protective zinc-carbonate patina that increases the coating's long-lasting corrosion protection. Laboratory salt tests are not reflective of real-world situations. So, it is unrealistic and ill-advised to use salt spray tests to develop a realistic comparison between batch hot-dip galvanized tubing (without an additional barrier protection system) to in-line galvanized tubing (that is additionally conversion coated and top-coated with inorganic polymeric paint).

Durability—The three-plus mils of zinc in the zinc-iron alloy layers applied via the batch hot-dip galvanizing process are actually harder (250 DPN) than the base steel (159 DPN). It is extremely difficult to damage the thick zinc coating to the extent that corrosion protection would be affected. In comparison, the inorganic polymeric paint covering the thin layer of zinc applied in the in-line process damages as easily as any other paint, and is particularly susceptible to deterioration caused by the sun's ultraviolet rays. Any damage to the paint covering exposes the thin layer of zinc, resulting in a protection system that lasts only as long as the zinc thickness will allow, or about a third as long as the batch-galvanized tubing. Additionally, surface contaminants and normal wear and tear are particularly threatening to topcoat paints.

Touchup and repair—Batch hot-dip galvanizing is done after the tubing is cut to length and protects all surface areas. Touchup is rarely required after transport and field construction because the thick zinc coating is hard and bound tightly to the steel surface. In-line continuous galvanized tubing is cut to lengths after galvanizing. These unprotected ends are susceptible to corrosion if not touched up with zinc solder, metalizing spray or zinc-rich paint. They also are potential sites of structural failure.

Clearly, an architect's or engineer's decision to use batch hot-dip galvanized tubing or in-line continuously galvanized tubing depends on the design life desired for a handrail project and the funds available for future maintenance. Additional factors to consider include exposure to ultra-violet rays, moisture and durability.

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