

Corrosion Protection for Coal-Fired Power Generating Plant Structures and Equipment

By: Philip G. Rahrig, Executive Director
American Galvanizers Association

Introduction

One of the fundamental questions confronting power generation plant maintenance engineers and managers is not what corrosion protection system to specify but how much upfront investment to make in order to minimize or eliminate recurring maintenance. Possible answers include 1) do nothing, 2) paint or 3) hot-dip galvanize. Analyzing all three alternatives should involve not only a performance evaluation, but initial and life-cycle cost analyses. Although not a new solution to corrosion protection, hot-dip galvanizing has proven its metal with astounding performance results.

Zinc metal has been used to hot-dip galvanize steel for 250 years, delivering protection from corrosion in harsh, corrosive environments for 50–75 years or more. The empirical data collected from the field performance of hot-dip galvanized steel from 1940–2005, in industrial and manufacturing settings, indicates that zinc prevents corrosion of the base steel far beyond other surface treatments. This feature means that Powder River Basin (PRB) or eastern coal-fired plants benefit from galvanized steel used for conveyors, vibratory feeders, coal hoppers, chutes, columns, girders, trusses, steps, stringers, handrail, grating, and expanded metal because there are no maintenance costs.

Coal-Fired Power Plant Environment

Since 1920 the American Society of Testing Materials (ASTM) and the American Galvanizers Association have collected data measuring the corrosiveness of various atmospheres and micro-environments. Hot-dip galvanized coatings perform without maintenance for 50 years or more in industrial environments such as a coal-fired power plant. See the hot-dip galvanized coating service-life chart.

How Does Hot-Dip Galvanized Steel Deliver Maintenance-Free Performance?

Hot-dip galvanized steel provides three-way protection from corrosion:

Cathodic – Zinc is more anodic than steel. Thus, when there is a corrosion cell formed, i.e. when the zinc and steel have both an electrolyte and return current path present, the zinc readily gives up electrons to protect the steel from corrosion. Zinc will protect the base steel until all of the galvanized coating is consumed.

Barrier – Zinc metal is impermeable and does not allow moisture (electrolytes) to penetrate the galvanized coating. Thus, the base steel is protected by the impervious barrier.

Patina – When exposed to the atmosphere immediately after the galvanizing process is complete, zinc metal reacts with oxygen in the air to form a very thin zinc-oxide powder on the galvanized coating surface. After a few days, the zinc-oxide reacts with water molecules in the air to form zinc-hydroxide. Over a period of months as the zinc-hydroxide is exposed to carbon dioxide in the air, a thin film of zinc-carbonate forms. Zinc-carbonate is a passive patina film tightly bound to the galvanized coating and is what gives a hot-dip galvanized coating its incredible durability.

Also significant in a power plant application is the abrasion applied to the conveyor and chute steel that comes in contact with coal. Damaging the coating is difficult to do because hot-dip galvanized steel's zinc-iron alloy layers are actually harder than the substrate steel.

Cost Analysis

Although the initial cost of a corrosion protection system is critical in the selection process, a final decision should be augmented by an analysis of the long-term costs associated with maintenance. Quantifying the life-cycle costs for hot-dip galvanizing is quite simple, but for most barrier protection systems, it can be a daunting task, especially when the time-value of money is calculated. Let's first examine the initial costs for a hypothetical power plant for hot-dip galvanizing and a three-coat paint system that is often used as an alternate.

Initial Cost

Example – “X” Powder River Basin Coal-Fired Power Plant

Assumptions:

1. 6,000 tons of structural steel, including conveyors, chutes, hoppers, walkways, handrail, platforms, columns, girders, etc.
2. 250 ft² of steel per ton (typical mix)
3. Projected facility service life of 45 years

4. Low-sulfur coal micro-environment (C5-I industrial environment of high humidity and aggressive atmosphere, according to ISO 12944-2 “Classification of Environments”)

System	Initial Cost (\$/ton)	Initial Cost (\$/ft ²)
Hot-dip galvanizing	240 – 440	0.96 – 1.76 ¹
Inorganic zinc/Epoxy/Polyurethane	650	2.60 ²

Life-cycle Cost

A less expensive and less durable paint system can be selected that may be initially less expensive than hot-dip galvanizing, but when the life-cycle cost is calculated, i.e. maintenance costs are imputed over the 45 year projected life of coal-fired power generating facility, the selection of hot-dip galvanizing clearly becomes apparent as superior. The table below shows the initial cost of hot-dip galvanizing is the final or life-cycle cost, since hot-dip galvanizing has been documented to last approximately 75 years in an industrial environment,. And, per the recommended maintenance practice for the three-coat paint system, it has touchup, maintenance, and full repaint requirements included in its life-cycle cost. The comparison is stark, with the paint system having long-term costs five to 10 times greater than hot-dip galvanizing.

System	Life-cycle cost (\$/ton) *	Life-cycle Cost (\$/ft ² /year)
Hot-dip galvanizing	240 – 440	0.021 – 0.039
Inorganic zinc/Epoxy/Polyurethane	2330	0.207 ²

* Cost in 2006 dollars

Real-World Performance

The AES Power Plant in San Juan, Puerto Rico, with two-coal-fired boilers, was built in 2002 with 10,000 tons of hot-dip galvanized steel. Timely, weather-independent delivery of steel staged for just-in-time delivery was a key decision variable, but it was the impressive 84% lower life-cycle

cost than a two-coat paint system that clinched the deal for galvanizing. Performance of the galvanized steel has been flawless and maintenance-free service is expected for decades.

The McDuffie Coal Terminal in Mobile, Ala. was constructed in 1995 and used 2,000 tons of hot-dip galvanized steel for conveyor, structural steel, frames, walkways, and handrail. Hot-dip galvanized steel was selected because of the abrasion resistance and durability that virtually eliminates maintenance to the conveyor. The hot-dip galvanized steel was inspected in 2006 and after 10 years of service, looks like new, and is predicted to remain in service for 40 or more years.

Summary

PRB coal-fired power plant maintenance engineers can have the best of both worlds if they elect to utilize hot-dip galvanized steel for plant construction. That is, they can have an economical corrosion protection system on an initial cost basis and one durable enough to deliver maintenance-free performance for the life of the facility. Additionally, the corrosion kinetics of cathodic, barrier and patina protection that hot-dip galvanized steel provides makes it particularly suitable for the corrosive atmosphere of a PRB plant.

¹ American Galvanizers Association, 2006 Survey of Galvanizers

² *Expected Service Life and Cost Considerations for Maintenance and New Construction Protective Coating Work*, KTA Tator, 2006

Author

Philip G. Rahrig is the executive director of the American Galvanizers Association (AGA), 6881 S. Holly Circle, Suite 108, Centennial, Colorado 80112. The AGA objective is to deliver zinc, corrosion theory, and galvanizing information to the architectural and engineering community. Mr. Rahrig has a degree in business from Xavier University in Cincinnati, studied physics at Thomas More College in Ft. Mitchell, Kentucky, and has 10 years of experience in the steel industry with USX.