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Analyzing true costs of galvanizing structural steel

KEY CONCEPTS

- Data indicate that zinc prevents corrosion of the base steel far better than other surface treatments.
- Hot-dip galvanized steel is protected from corrosion in three ways.
- Hot-dip galvanized steel offers a durable and economical corrosion protection system.

One of the fundamental questions confronting plant maintenance engineers and managers is how much upfront investment in corrosion protection systems to make in order to minimize or even eliminate recurring maintenance. The possible answers range from do nothing, paint, or hot-dip galvanize, and all three should involve not only a performance evaluation, but also initial and life-cycle cost analyses. Although not a new solution to corrosion protection, hot-dip galvanizing has entered the fray with surprising results.

Zinc metal has been used to hot-dip galvanize steel for 250 years, delivering protection from corrosion in many environments for 50-75 years. The empirical data collected from the field performance of hot-dip galvanized steel from 1940 to 1980 in industrial and manufacturing settings, indicate that zinc prevents corrosion of the base steel far better than other surface treatments. This means that plants benefit from galvanizing steel to be used for columns, girders, trusses, steps, stringers, handrail, grating, and expanded metal because there are no maintenance costs (Fig. 1).

Fig. 1. Industrial plants can justify using hot-dip galvanized steel for external and internal structural elements because there are no maintenance costs.

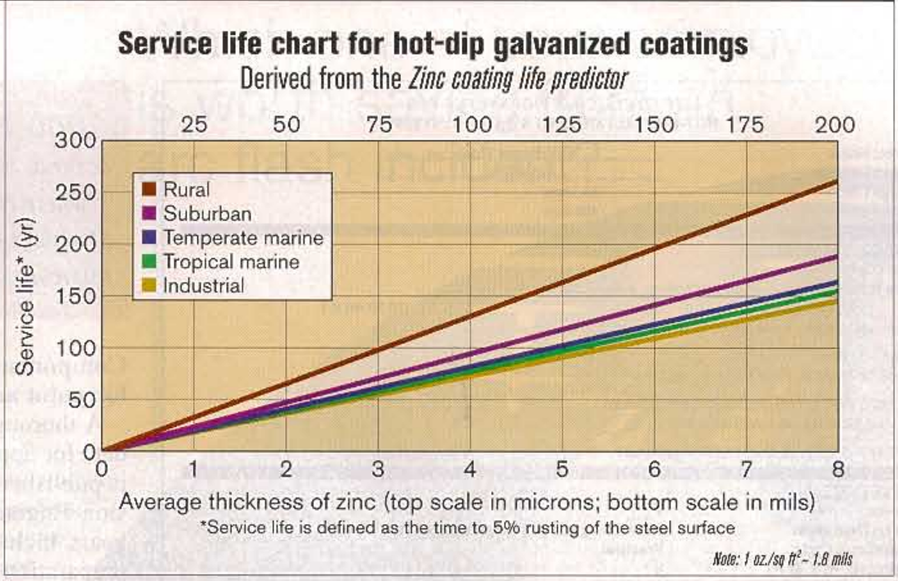
Traditionally, on an initial cost basis hot-dip galvanizing steel was thought to have been a more expensive solution to corrosion protection than other systems. But on a long-term basis (life-cycle cost per year) it is a more economical answer. With the relative stability in zinc metal pricing over the last 12 years and process improvement by galvanizing operations during that period, hot-dip galvanizing is now more than competitive with other methods of corrosion protection — initially and by a wide margin — over the lifetime of a facility.

Plant environments

Macro environments

Due to the urging of some government agencies and the conviction and commitment of industries and individual companies, the overall environment in the United States has become substantially less polluted and safer over the last 20 years Sulfur and chloride emissions from sources such as automobiles, power plants, and industry in general have been reduced. Because both sulfur and chloride compounds increase the corrosion rate of most metals, including zinc, it can reasonably be assumed that galvanized steel will last longer today than in previous decades. This is exactly what was discovered in a 2001 study funded by the International Lead Zinc Research Organization (ILZRO) and conducted by Dr. Gregory Zhang of Teck Cominco.[1]

A software program, the *Zinc Coating Life Predictor*, was developed to estimate the corrosion rate of zinc in various environments. The program performs calculations based on models developed using statistical methods, neural network technology, and an extensive worldwide corrosion database. The environmental data input required to estimate a corrosion rate includes temperature, airborne salinity, sulfur dioxide concentration, relative humidity, rainfall, and sheltering condition (indoor, rain-sheltered, or outdoor). Once these values are known, the software calculates and reports a corrosion rate and also gives the option to either calculate the predicted life given the coating thickness, or the coating thickness required to achieve a specified life. This software was used to calculate the performance of hot-dip galvanized steel in selected North American cities representing the five different types of corrosive climates (see "Corrosive climate regions of North America").


Service life chart for hot-dip galvanized coatings

Derived from the *Zinc coating life predictor*

*Service life is defined as the time to 5% rusting of the steel surface

Note: 1 oz./sq ft^2 - 1.8 mils

Fig. 2. Service life chart for hot-dip galvanized coatings shows how service life increases as the thickness of the zinc coating increases.

These data points were then used to develop a graph of service life of hot-dip galvanized steel as a function of zinc coating thickness for each of the corrosion atmospheres (Fig. 2). The environmental data required to use the *Zinc Coating Life Predictor* can be found on various web sites (including the American Galvanizers Association's site at galvanizeit.org).

Micro Environments

A significant discovery is that the *Zinc Coating Life Predictor* can be used to estimate corrosion rates in microenvironments such as inside, or on the perimeter of a manufacturing plant. The environmental data for the input variables must be collected just as in a macro environment. When these data are entered into the predictor, a corrosion rate/expected lifetime of performance can be predicted. Knowing this information can help plant maintenance personnel predict when and to what extent maintenance of corrosion protection systems will be necessary. In the case of hot-dip galvanized steel, the model often indicates that the structural steel of the buildings and the walkways/railings will need no maintenance over the useful lifetime of the plant.

Protection modes

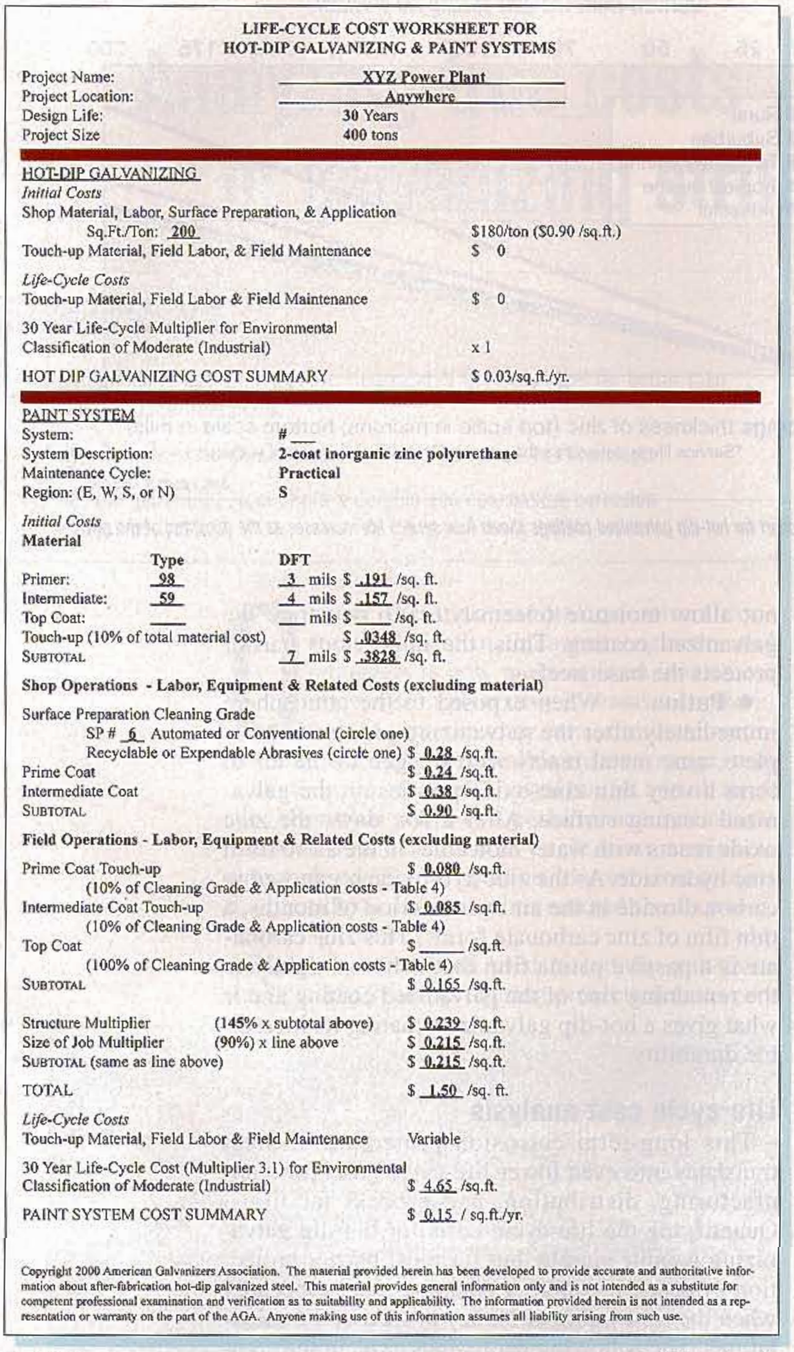
Hot-dip galvanized steel is protected from corrosion in three ways:

- **Cathodic** — Zinc is more anodic than steel. Thus, when there is a corrosion cell formed, (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 very dense and does not allow moisture (electrolytes) to penetrate the galvanized coating. Thus, the impervious barrier protects the base steel.
- **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. As the zinc hydroxide is exposed to carbon dioxide in the air over a period of months, a thin film of zinc carbonate forms. This zinc carbonate is a passive patina film that is bound tightly to the remaining zinc of the galvanized coating and is what gives a hot-dip galvanized coating its incredible durability.

Life-cycle cost analysis

This long-term corrosion protection of steel translates into even lower life-cycle costs for manufacturing, distribution, and process facilities. 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 used in the calculations. The following paragraphs explain the components of the calculations and provide a simplified method of determining life-cycle costs.

Life cycle-costs of a corrosion prevention system are calculated by adding initial costs and the costs associated with the planned maintenance of the coating for the expected lifetime of the project, structure, facility or building. Of course, any anticipated maintenance costs must include the time value of money — interest rate and inflation rate. Generally, life-cycle costs are discussed in terms of cost per year.



LIFE-CYCLE COST WORKSHEET FOR
HOT-DIP GALVANIZING & PAINT SYSTEMS

Project Name: **XYZ Power Plant**
Project Location: **Anywhere**
Design Life: **30 Years**
Project Size **400 tons**

HOT-DIP GALVANIZING

Initial Costs
Shop Material, Labor, Surface Preparation, & Application
Sq.Ft./Ton: 200 — $180/ton ($0.90 /sq.ft.)
Touch-up Material, Field Labor, & Field Maintenance — $ 0

Life-Cycle Costs
Touch-up Material, Field Labor & Field Maintenance — $ 0

30 Year Life-Cycle Multiplier for Environmental Classification of Moderate (Industrial) — x 1

HOT DIP GALVANIZING COST SUMMARY — $ 0.03/sq.ft./yr.

PAINT SYSTEM
System: # ___
System Description: **2-coat inorganic zinc polyurethane**
Maintenance Cycle: **Practical**
Region: (E, W, S, or N) **S**

Initial Costs
Material

	Type	DFT
Primer:	98	3 mils $ .191 /sq. ft.
Intermediate:	59	4 mils $ .157 /sq. ft.
Top Coat:	___	___ mils $ ___ /sq. ft.
Touch-up (10% of total material cost)		$ .0348 /sq. ft.
SUBTOTAL		7 mils $ .3828 /sq. ft.

Shop Operations - Labor, Equipment & Related Costs (excluding material)

Surface Preparation Cleaning Grade
SP # 6 Automated or Conventional (circle one)
Recyclable or Expendable Abrasives (circle one) $ 0.28 /sq.ft.
Prime Coat $ 0.24 /sq.ft.
Intermediate Coat $ 0.38 /sq.ft.
SUBTOTAL $ 0.90 /sq.ft.

Field Operations - Labor, Equipment & Related Costs (excluding material)

Prime Coat Touch-up $ 0.080 /sq.ft.
(10% of Cleaning Grade & Application costs - Table 4)
Intermediate Coat Touch-up $ 0.085 /sq.ft.
(10% of Cleaning Grade & Application costs - Table 4)
Top Coat $ _____ /sq.ft.
(100% of Cleaning Grade & Application costs - Table 4)
SUBTOTAL $ 0.165 /sq.ft.

Structure Multiplier (145% x subtotal above) $ 0.239 /sq.ft.
Size of Job Multiplier (90%) x line above $ 0.215 /sq.ft.
SUBTOTAL (same as line above) $ 0.215 /sq.ft.

TOTAL $ 1.50 /sq. ft.

Life-Cycle Costs
Touch-up Material, Field Labor & Field Maintenance — Variable

30 Year Life-Cycle Cost (Multiplier 3.1) for Environmental Classification of Moderate (Industrial) — $ 4.65 /sq.ft.

PAINT SYSTEM COST SUMMARY — $ 0.15 / sq.ft./yr.

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Fig. 3. If faced with the decision of whether to paint steel or use hot-dip galvanizing, the "Life cycle cost worksheet for hot-dip galvanizing and paint systems" allows you to quickly determine the economic decision factors for the project.

Components of life cycle-cost analysis for hot-dip galvanizing

As was shown in Figure 2, the projected durability of galvanized steel in a variety of environments is easily 75 years.[1] This means that the galvanized coating will require no maintenance over the planned life of most steel structures. In equation form, this means:

> *HDG Life-cycle cost/yr = (HDG Initial cost/no. of yr of useful project life) x NPV*
>
> *where HDG = hot-dip galvanizing and NPV = (1+i)n/(1+I) n; where i = inflation rate, I = interest rate, n = structure life*

Components of life-cycle analysis for paint and other barrier protection systems

A thorough compilation and analysis of the cost data for approximately 100 different paint systems is published by the National Association of Corrosion Engineers International (NACE)[2] every few years. Included are the material costs for the surface preparation and paint, the in-shop application labor and equipment, in-field material and labor application, and touchup. Also provided is the recommended maintenance cycle (ideal or practical), full repaint times and how to calculate the associated costs. Maintenance and full repaint occurring every few years also means future expenditures of budgeted dollars. In equation form, this means:

> *Paint life cycle cost/yr = [(Primer & intermediate material cost + abrasive cleaning cost + shop labor + primer material touchup and labor in field + intermediate coat touchup and labor in field + topcoat material and labor in field) + NPV (surface preparation + paint material + labor for* yr_1*)* + NPV (surface preparation + paint material + labor for yr_2) + NPV (surface preparation + paint material + labor for yr_3)]/no. of yr of useful project life)
>
> *where* yr_1, yr_2 and yr_3 are years from initial painting to maintenance painting

When these cost components are entered into the "Life-cycle cost worksheet for hot-dip galvanizing and paint systems," a project manager or plant engineer can quickly determine the economic decision factors for the project (Fig. 3). The worksheet is a simplified version of the initial and life-cycle cost analyses presented in the NACE International Paper #509. The time-value-of-money calculations (net future value and net present value) used for life-cycle analyses have been summarized into a single mathematical factor to be multiplied by the initial costs of the galvanized and painted systems, respectively.

In the worksheet example, the designers of a new manufacturing plant analyzed the cost of hot-dip galvanizing the steel or painting it with a two-coat paint system (inorganic zinc primer and

Corrosive climate regions of North America

	Rural	Temperate Marine	Tropical Marine	Suburban	Industrial
Northwest	Boise, ID	Seattle, WA	N/A	Portland, OR	Seattle, WA
Southwest	Yuma, AZ	San Diego, CA	Mazatlan, Mexico	Scottsdale, AZ	Los Angeles, CA
North Central	Helena, MT	Duluth, MN	N/A	Twin Cities, MN	Chicago, IL
South Central	Meridian, MS	Corpus Christi, TX	Cancun, Mexico	New Orleans, LA	Dallas, TX
Northeast	Caribou, ME	Atlantic City, NJ	N/A	Philadelphia, PA	Newark, NJ
Southeast	Athens, GA	Charleston, SC	Miami, FL	Orlando, FL	Atlanta, GA

Hot-dip galvanizing vs. painting

	Initial cost	Life-cycle cost
Hot-dip galvanizing	$0.90/sq ft	$0.03/sq ft
IOZ/polyurethane paint system	$1.50/sq ft	$0.15/sq ft

polyurethane topcoat). Based on a projected facility life of 30 years in the current environmental conditions at the project site, not only was galvanizing more economical on an initial cost basis, but over the life of the project, hot-dip galvanizing would cost just $0.03/yr, compared to the paint system cost of $0.15/yr (see "Hot-dip galvanizing vs. painting").

The life-cycle cost comparison provided by the worksheet is based on the galvanizer's actual pricing for the particular project in question and the paint costs for the same project, as provided in the NACE International Paper #509 presented at its annual corrosion conference.

The selected design life of 30 years is a typical project requirement. If a specific project life is longer than that, hot-dip galvanizing may be even more economical, because more costly paint maintenance will be required. It is likely that if the project life is so long that some galvanized steel touchup is required to protect some exposed steel surface area, those costs will be minimal compared to the paint maintenance.

The selected environment of light industrial ("moderate industrial," by the NACE International paper definition) is the most aggressive in terms of accelerating the corrosion rate for coatings. If the particular project would be installed/constructed in a different environment, the relative performance of galvanizing to most paint systems would not be substantially different.

Although the mix of structural steel to be galvanized or painted may be such that painting is initially less expensive than galvanizing, a complete life-cycle cost analysis will usually reveal galvanizing to be the most economical over the useful life of the project. Given the 75-year or more maintenance-free performance of galvanized structural steel in most environments, the quantitative analysis of costs would seem to be a formality. However, if the project justification requires the extra effort of such an analysis, the "Life cycle cost worksheet for hot-dip galvanizing and paint systems" and/or NACE International Paper #509 can be used to accurately provide a corrosion prevention system cost per year. With annual corrosion costs in the U.S. alone estimated to be more than $300 billion[3], the extra effort seems worth it.

Summary

Plant engineers can have the best of both worlds if they elect to use 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 plant. The stability of zinc pricing for the last decade and the fact that the overall environment continues to become less corrosive make hot-dip galvanizing a very attractive option.

References

[1] *For 1/4-in. thick steel with the minimum zinc coating thickness of 3.9 mils (100 microns) in all environments with the exception of tropical marine, as specified by ASTM A123*

[2] *Corrosion 98, Paper #509, National Association of Corrosion Engineers, KTA Tator, Inc., 1998*

[3] *Battelle Memorial Institute, 2001.*

More Info:

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