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Use of Galvanized Steel in the Pulp and Paper Industry

J.A. Colwell and T.J. Kinstler

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USE OF GALVANIZED STEEL IN THE PULP AND PAPER INDUSTRY

Jeffery A. Colwell
Associate Professor
Institute of Paper Science
and Technology
500 10th Street, N.W.
Atlanta, GA 30318

and

Thomas J. Kinstler
Technical Manager
Metalplate Galvanizing, Inc.
P.O. Box 966
Birmingham, AL 35201

Introduction

Hot dip galvanizing has been practiced for over 100 years, and in many industries, hot dip galvanized steel has been almost universally accepted as the standard structural material. This acceptance is based on both the technical viability and the economic merit of galvanized steel as a long-lived, virtually zero maintenance cost material in atmospheric service. Decades of field experience and corrosion testing have shown that hot dip galvanized steel performs well in moist environment cycles, seacoast salt exposures, and moderate chemical environments with peak performance in the alkaline pH range, which is perhaps a perfect description of a modern pulp mill. Consequently, there should be many opportunities to solve difficult corrosion problems with galvanized structural steel.

Paper Consumption is Expected to Rise

Paper products are central to life today, and projections are that demand will continue to increase into the next century as is shown in Figure 1. The reasons for this are varied, but there are a few generalizations which may shed some light on these predictions. First, paper will be a growing part of the information age as our work evolves to compile, disseminate, and analyze information. Originally, it was thought by some that the "electronic office" would eliminate paper products, but the opposite has been found to be true, and demand for some office grades is expected to remain strong. Education will also continue to play a pivotal role in society, and the ability to convey thoughts and information will rely on paper.

As environmental compatibility issues drive packaging materials selection, paper and paperboard will remain important to product distribution. Because of the globalization of many industries, the desirability of paperboard products as a lightweight but strong way to protect cargo over long distances will climb. In addition, the recyclability of paper will increasingly become key as solid waste is minimized to avoid the impact on landfills which are already nearing capacity in some locations. Today, recovered paper is providing the U.S. industry with over 40 % of its fiber needs.

Because of this, the outlook for the pulp and paper industry remains strong, and the potential uses of zinc should also increase as demand grows. However, the environmental conditions at specific locations within each mill will dictate where zinc can be utilized successfully.

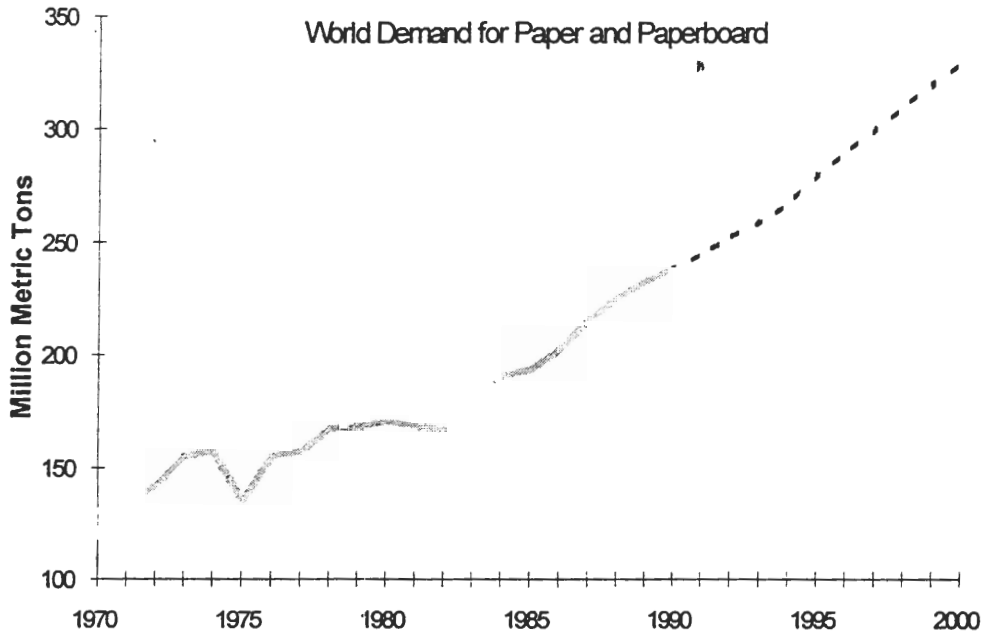


Figure 1. World Demand for Paper Products in Millions of Metric Tons (from American Forest and Paper Association).

Kraft Process Most Widely Used

By far, most of the paper and paperboard products are a result of the kraft pulping process. An overview of the pulping process is shown in Figure 2. Kraft pulping consists of reacting wood chips and white liquor (NaOH and Na_2S) in a digester to yield kraft pulp and weak black liquor. The pulp is further separated from the weak black liquor at the washers, which allow at least 98 % recovery of the pulping chemicals. The weak black liquor from the washers normally has a dissolved solids content of 15 to 17 %, and is further concentrated by evaporation to a range of 65 to 75 % solids. After concentration, the black liquor is burned in the recovery boiler, where the organics are burned and the inorganic sulfur and carbonate compounds are reduced into a mixture of molten salts called smelt. The molten smelt is dissolved in water to form green liquor which is later causticized to produce white liquor which is injected back into the digester to begin the pulping process on new chips. With continuous digesters, the process continues uninterrupted.

The washed pulp can be brightened by bleaching or left as it comes from the washer, depending on the grade being produced. The pulp is mixed with water before entering the headbox on the paper machine until the consistency is about 1 %, although it does vary depending upon the actual mill. At the wet end of the paper machine, additives are used to increase wet strength, or produce other desirable properties. The paper's strength is developed in the press section where complete drying is accomplished by running the sheet through several heated roll nips.

Mill Closure will Decrease Corrosivity of Ambient Environment

There has been, and will continue to be, a great emphasis placed on minimizing air and water discharges from pulp and paper mills. These mill closure efforts have obviously made the process side more corrosive toward equipment because of the concentration of a number of detrimental species, such as chloride. Moreover, other possibly detrimental compounds have also been identified, and process changes have been implemented to minimize these effects, particularly in bleach plants. In short, the emphasis will be on making the process more self-contained to minimize losses to air and water near the mill.

This mill close-up initiative on the process side has a benefit on the nonprocess side. The lack of chemical discharges will make the ambient environment less corrosive, just as has occurred in other industries. Consequently, there is an opportunity to use materials which in the past were marginal performers, but will now give good performance under more benign conditions. This is particularly the case with structural components.

Galvanized Steel May be Attractive for a Number of Applications

Technical Benefits

In the hot dip galvanizing process, a durable metallic zinc and zinc-iron alloy surface, metallurgically bonded by reaction with the base steel, is created by immersion of suitably prepared steel in molten zinc. The result is less a coating, but more a composite material with the superb corrosion properties of zinc, and the strength and fabrication properties of structural steel. Compared to conventional multicoat painted steel, the galvanized steel composite has the superior properties shown below:

Characteristic	Galvanizing	Paint
Basic Structure	Metallic Solid	Polymer Film
Bonding Mechanism	Metallurgical	Adhesive
Bond Strength (psi)	thousands	hundreds
Permeability (O ₂ , H ₂ O)	none	variable
Inspection Requirements	low	high

In addition, because paint films are usually applied in the field and galvanizing is applied in controlled shop conditions, a number of variables can negatively influence paint performance. These may include weather conditions during application, surface preparation, formulation, steel configuration, and intercoat contamination.

During the middle and late 1960s, only a few North American pulp and paper mills were known to have used appreciable quantities of hot dip galvanized structural steel. For example, up until the early 1980s, only two mills in the southeastern United States had used large quantities of galvanized structural steel. Both of these mills have not required any maintenance of the galvanized structural steel components over their entire 25 years of service.

In 1979 (1,2), and again in 1989, corrosion test programs were begun with the objective of studying the efficacy of galvanized steel in a number of North American mills with a wide range of process conditions and geographical locations. It has been common practice to grade the corrosivity of sites to zinc as shown below: (3)

Atmosphere	Corrosion rate, $\mu\text{m}/\text{yr}$
Rural	0.2 to 2
Urban and Industrial	2 to 16
Marine	0.5 to 8

The results of these continuing tests have been reported previously (4,5), and indicate clearly that the use of galvanized structural steel is technically viable in all areas of modern mills except those subject to raw concentrated liquid chemical or vapor attack. The maintenance-free life of typical galvanized structural steel in general mill environments such as power boilers, recovery boilers, evaporators, digesters, woodyards, machine buildings, pipe and utility bridges, and modern bleach plants probably exceeds 40 years. Not counting the mill areas where raw chemicals might contact zinc, the ambient environmental conditions around mills today can best be classified as "Rural." If the local environment pH remains above about 3.5, then corrosion of zinc would be considered manageable. This is generally the case in most environments, as the pH is beginning to climb because of the controls implemented after the Clean Air Act and its amendments.

These early positive experiences with zinc in the pulp and paper industry have led to wider adoption. Current estimates are that approximately 80 % of the mills in the southeastern United States utilize galvanized structural steel, including three of the four latest "greenfield" mills. This is summarized in Figure 3. The largest of components can be easily galvanized, and include sections up to 70 feet long, and weights up to 20,000 pounds.

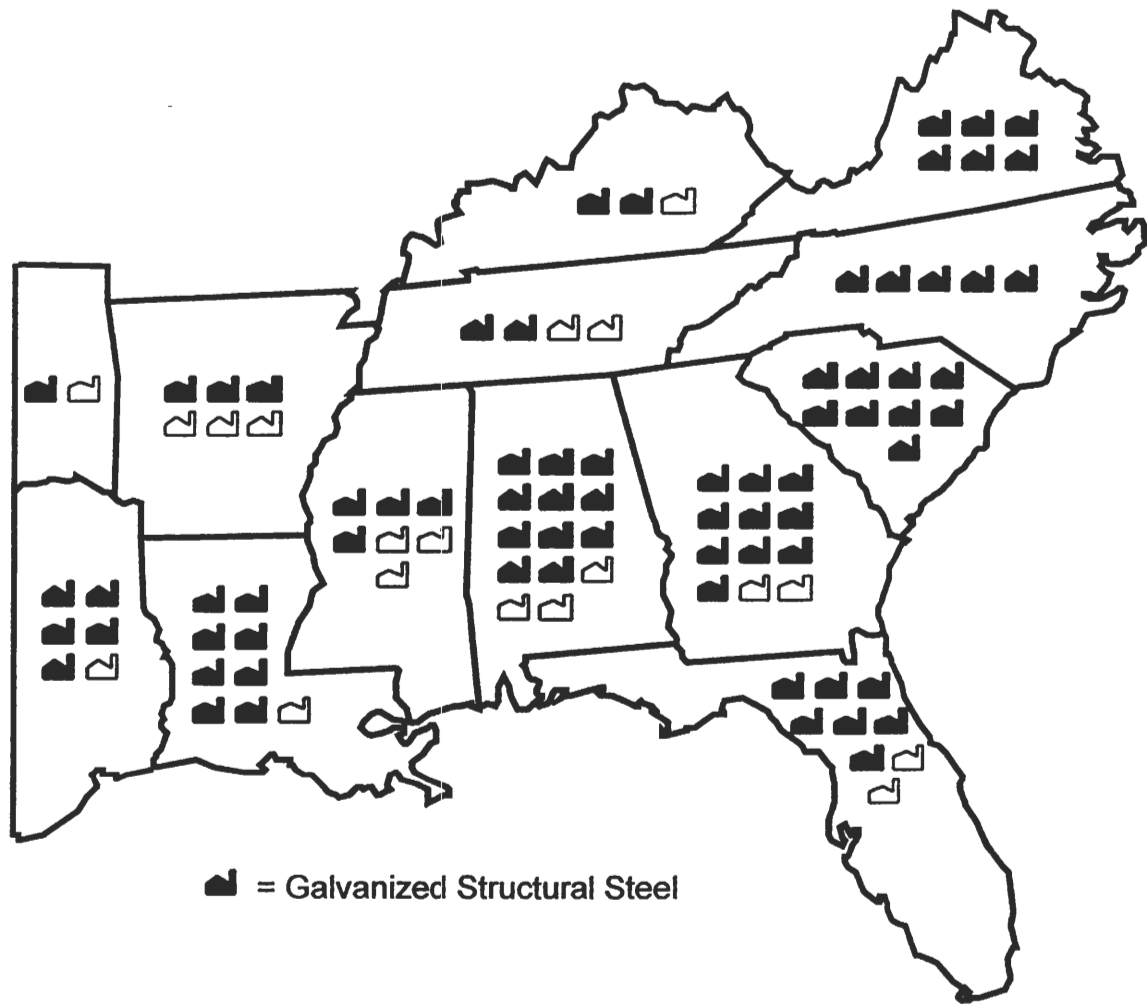


Figure 3. Mill Sites Using Galvanized Structural Steel Through 1991.

Economic Benefits

Current costs for galvanizing typical mill structural steel sections in project quantities are about \$200 per U.S. ton, which is equivalent to the cost in 1979. This cost is nearly independent of surface to weight ratio, and at 250 ft²/U.S. ton (~ 25 m²/tonne), galvanizing costs about \$0.80 per ft².

Painting, by comparison, varies considerably in cost, and almost directly with surface to weight ratio. Recent cost comparisons have shown that hot dip galvanizing is approximately equal to or lower than two-coat paint systems, and equal to or higher than that of three-coat systems.

The economic analysis of the galvanizing vs. painting decision has been reported in the literature (6,7). The life-cycle cash flow schematic diagram of the decision is shown in Figure 4, where the

cost to galvanize is considered as a one-time cash outflow, and the cost for painting is given as a series of escalating outflows which necessarily increase because of the increase in the cost of maintenance painting in the mill environment. It is assumed for this example that the initial cost for painting is lower than that for galvanizing. Because either painting or galvanizing will be chosen, the economic analysis can be restricted to the "difference" cash flow diagram on the right of Figure 4, which resulted from the subtraction of the lower initial cost life-cycle diagram from the higher initial cost diagram.

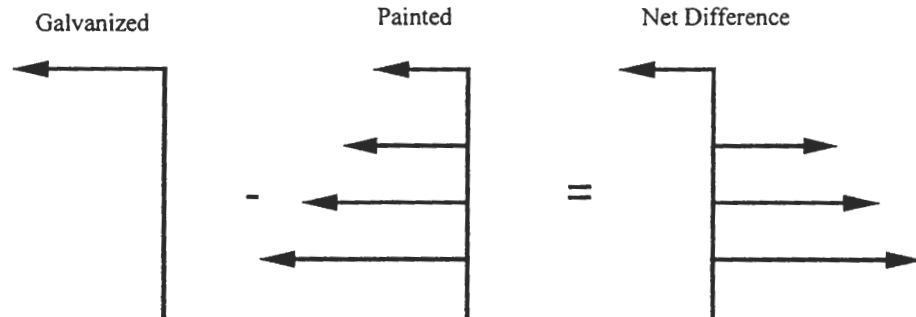


Figure 4. Life-Cycle Cash Flow Diagram - Galvanizing vs. Painting.

To make an informed judgment on the real costs of each method, a consideration of many different tax and accounting factors is required (8). The Net Present Value (NPV) can be used to relate all future cash flows (F_n), discounted at some interest rate $(1+i)^{-n}$, and the net initial cost cash flow (ΔC_0) to some residual calculated value, which if positive, makes the extra cost justified, or if negative, not justified at that interest rate. The expression for NPV is:

$$NPV = \sum \frac{F_n}{(1+i)^n} - \Delta C_0$$

The NPV will be zero at the rate of return for the investment in question. Therefore, if the interest rate is set equal to the minimum attractive rate of return for the organization (MARR), and NPV set equal to zero, the ΔC_0 which can be justified under the conditions of the calculation can be determined. If the calculations are normalized based on the lowest initial cost alternative (paint in this example) by setting the initial cost to one, then $1 + \Delta C_0$ would be the justifiable cost ratio (JCR) of galvanizing to painting (8). Figure 5 provides calculations using values characteristic of the pulp and paper industry.

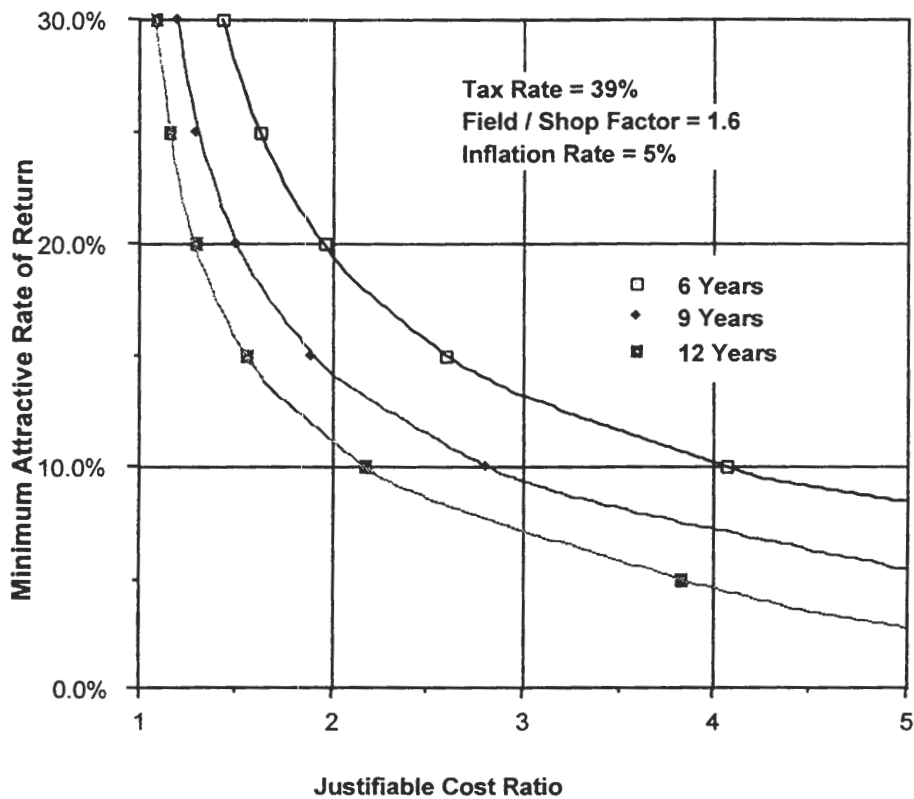


Figure 5. Justifiable Initial Cost Ratio at Minimum Attractive Rate of Return for Various Repainting Cycles.

The curves show that, for example, with a repaint cycle of 9 years and a MARR (after tax) of 15 %, a galvanizing to painting initial cost ratio of 1.9 is justified by the future savings (discounted at MARR) from not having to repaint over the service life.

Economic and operational benefits, even at the occasionally higher initial cost, have allowed rapid growth of hot dip galvanized structural steel as shown previously in Figure 3. The mill areas where galvanized steel has been found to perform well are shown in Figure 2. Some of the areas are aggressive to zinc (indicated by “?”), such as the chemical unloading area, and some locations at the wet end of the paper machine. But, modern bleach plants appear to be relatively safe for zinc. All other areas in the typical kraft mill have been shown to be safe for the use of zinc, and galvanized structural steel should have a lifetime on the order of 40 years.

Summary

It has been shown that galvanized structural steel has many potential applications in the pulp and paper industry. Moreover, because the industry is projected to continue its growth into the next century, this represents a good opportunity for zinc industry growth. Most areas of the mill are not aggressive to zinc, and lifetimes of up to 40 years are expected. And, as pollution control measures are continually implemented, the ambient mill environment is expected to become even less aggressive to zinc. Good experience at two mills in the southeastern United States with hot dip galvanized products over the last 25 years has proven that zinc can play an effective role in corrosion control in the pulp and paper industry.

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