

The Process of Galvanizing Steel



Whereas the combination of strength and formability, as well as the abundance of iron ore, has made steel one of modern civilization's most important raw materials, its "Achilles' heel" is its tendency to rust. For this reason, most (low-alloy) steel is painted, plated, or otherwise treated so the steel itself is not exposed to air and moisture. Galvanizing is an effective, low-cost way to improve the durability of bare steel, resulting in a surface finish that is more durable than paint alone, yet accepts paint as an additional layer of protection.

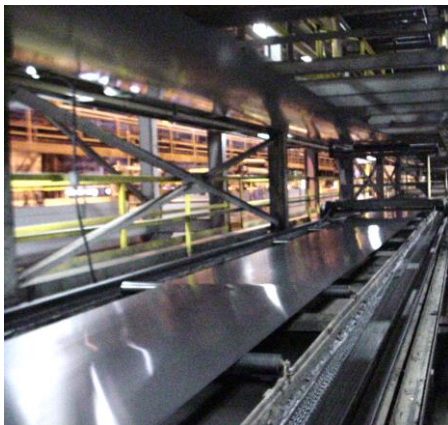


CSI's hot-dipped-zinc coating capabilities are found in two lines: the #1 Continuous Galvanizing Line (CGL) was built in 1966, and the #2 CGL was built in 1998. The primary function of a CGL is to coat the steel in a thin layer of zinc, enhancing the corrosion resistance of the final product.

The two lines, with a few notable exceptions, perform the same operations on the steel using comparable equipment. Incoming substrate is cleaned with an alkaline detergent, annealed, coated with molten zinc, and tension leveled on both lines. Both units are capable of producing Galvanneal product, which is heat-treated a second time after coating to prepare it for painting. Ink printing and Chem-treatment are available in both areas for customers who desire these attributes.

Following a drive upgrade in 1998, the #1 CGL processes flat rolled steel between 0.016" and 0.173", and up to 60" wide. Line speeds up to 400 fpm allow the unit to produce over 450,000 tons of coated material each year for applications such as garage door panels and culvert.

The state-of-the-art #2 CGL was constructed primarily to produce even thinner high-quality coated sheet up to 52" wide. The lightest gauges rolled at the 5-stand, less than one hundredth of an inch thick, are processed here for end-uses such as ventilation ducts and refrigerator panels. Capable of galvanizing at speeds as high as 600 fpm, the 350,000-ton annual capacity is a reflection of the very thin steel produced (no thicker than 0.060").



CONTINUOUS OPERATION

Coils to be processed on either galvanizing line are charged, or loaded, onto one of two Pay-Off Reels. The head of the coil being charged is welded to the tail of the coil being processed by a lap seam welder. Between 1/32" and 1/4" of the two coils are over-lapped onto one another, and a pair of high-voltage copper wheels, one above and one below, roll from one edge to the other, melting the laps and pressing them into one another. The resulting weld is nearly flattened to the gauge of each coil, but with a slight bulge in the center of the seam. The voltage applied between the two dies and the speed at which they roll across the width of the strip are pre-programmed in a computer as various recipes that are called up according to the gauges and grades being processed.

After welding, the strip travels into the 'Entry Loop Car', or accumulator section, where enough material is stored to allow the entry section to shut down for at least a minute and a half while another coil is charged without slowing the process (annealing and zinc pot) section. The Loop Cars for the #1 CGL travel horizontally, while the newer line employs multi-strand, vertical accumulators.

CLEANING & PREHEATING

Before heat treating, the strip is cleaned of rolling oils and iron fines with rotating brushes and diluted sodium hydroxide (caustic soap). The steel is preheated in the process section to a relatively low temperature in order to further clean the strip surface and minimize the time needed for the reducing zones to bring the steel up to its annealing temperature.

Burners in the Preheat section combust natural gas in open air to maintain zone temperatures as high as 2250° Fahrenheit. Under normal operating conditions, the steel is in this section for only a few seconds and never actually reaches this furnace temperature.

Producing 'full hard' galvanized steel requires striking a delicate balance between cleaning the surface adequately for good zinc adherence and not sacrificing the strength desired by the customer by allowing the steel grains to recrystallize. Costly low-carbon steel grades with small additions of titanium are sometimes used because they anneal at relatively high temperatures and can be thoroughly cleaned prior to coating.

HEAT TREATMENT

Because the majority of feed-stock for the galvanizing lines is Full Hard from the 5-Stand, both units incorporate processing steps to remove rolling oils, iron fines and surface oxides from the strip to ensure good zinc adherence, and to anneal the material to achieve the combination of formability and strength sought by the customer.

Immediately after the preheat section, the strip enters the 'reducing zone' where it is annealed to achieve the customer's physical requirements for formability in a heated atmosphere of 1 part hydrogen, 3 parts nitrogen. The atmosphere prevents the growth of scale during heat-treatment, actually 'reducing' light surface oxide back to iron. Heat is supplied by burning natural gas inside sealed tubes above and below the strip, with the heat produced radiating from the walls of the tubes out into the reducing zones. These zones are held at temperatures up to 1650° Fahrenheit, and, under normal operating conditions, the product is annealed for less than a minute. Thin strip at the #2 CGL may spend only 10 seconds in the reducing zones, while heavier gauges at the #1 CGL may take a couple of minutes to reach the necessary temperature. The steel is heated to temperatures typically in the range of 1300° to 1500° Fahrenheit.



Because the furnace is cannot achieve abrupt changes in temperature, specific limits are placed on the scheduling of coils in order to ensure smooth transitions between products with different annealing requirements. Since the annealing process depends on both time and temperature, operators are able to ease the transitions by adjusting the speed of the line.

Immediately after annealing, the strip travels through cooling zones incorporating air jets and recirculating fans before being directed down the 'snout' to the zinc pot. The objective is to cool the steel to a temperature that roughly matches that of the molten zinc; too warm and the coating's adherence will be compromised by an overly thick zinc-iron transition layer; too cool and the aluminum can begin to precipitate (freeze) out of the molten zinc and get picked up by the pot roll, marking the steel.



GALVANIZING

CSI's facilities for coating steel are of the 'hot-dip' type, as opposed to electro-galvanizing, which is a plating process comparable to chroming. After the steel has been thoroughly cleaned, annealed, and cooled to a temperature that roughly matches that of the molten zinc bath, the strip enters the zinc pot and travels around a 'pot roll' which redirects it up through an 'air knife' system.

Coating thickness is controlled by blowing off excess molten zinc; the air pressure applied to a tapered gap in the knife lips, as well as the distance between the knives and the strip, regulate how much zinc is carried out of the pot on the steel's surface.

The height of the air knives above the zinc pot is adjusted according to strip speed. Additional blow-offs called edge baffles serve to prevent the excess zinc coating inherent to the edges from resulting in a condition called 'edge build-up' that causes the coil to flare up at the sides, stretching the material to the point that it will not lay flat during further processing.



The thickness of the zinc applied to the steel is specified by CSI's customers as a coating weight, in the unit of hundredths of ounces per square foot. An order for 'G-60' seeks 0.60 ounces of zinc on every square foot of steel, which, when evenly distributed, equates to a coating thickness of about one-half of one thousandth of an inch (0.0005") per surface.

Since the heavier coating weights add as much as 0.004" (for G-235) to the overall thickness of the coated steel, aim gauges at the rolling mills provide for this so the finished product will meet the customer's gauge requirements. The thickness of the zinc coating is measured with a Gamma-ray and fed back into the computer which in turn makes adjustments to the air knives to optimize the coating weight. Changes in required coating weight, steel thickness, and even line speed are rapidly compensated for automatically.

The 'pot' is replenished periodically with 1-ton ingots of 99.9% pure zinc. Massive induction heaters in the basement maintain the pot at temperatures about 50° above the 800-degree Fahrenheit melt point of the zinc. Small

additions of aluminum improve the adherence of the zinc to the base metal by inhibiting the growth of the brittle zinc-iron transition layer.

The strip travels more than ten stories straight up into the air out of the pot to allow time for the zinc to solidify against the steel. Large fans in the cooling tower air-cool the freshly coated steel before it's sent through a water-quench 'shock roll' tank.

GALVANNEALING

Products designated by an 'A' in their coating weight (for instance A-40) are 'Galvannealed', a process wherein the just-coated steel's surfaces are immediately reheated by open-air burners. The zinc is baked into the steel until the two are alloyed, or metallurgically blended, with one another at the surfaces of the strip. The finished product has a dull gray appearance due to the large proportion of iron that has diffused to the surface.

Galvannealed product corrodes more readily than galvanized steel, and is intended for end-uses that will be painted, such as computer brackets and appliance panels. While hot-dip galvanize must be chemically treated before painting, galvanneal does not. The alloyed layer is relatively brittle and will tend to fracture and flake off ('powdering') if flexed significantly by a paint line or roll-former.

Reheating is accomplished for this operation with a short, vertical, natural-gas furnace that is positioned above each line's zinc pot. Because of the limitations of these furnaces, line speeds are slowed considerably when producing galvannealed steel and available coating weights are normally limited to A-60 or lighter to ensure that 'free zinc' does not remain at the steel's surface.

FLATNESS CORRECTION

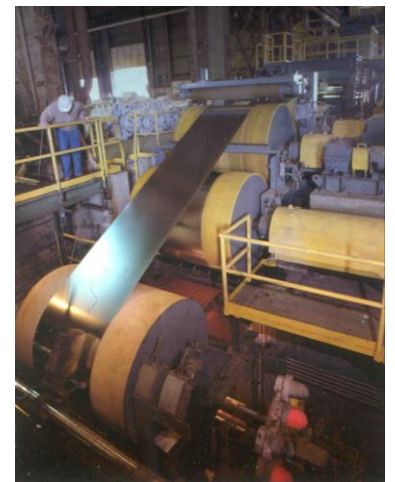
Situated after each pay-off reel is a small uncoiler Leveler that flattens the head-end of the steel by removing its coil-set, or memory of having been coiled up.

After the steel has been through the cooling tower and is roughly room temperature again, it passes through a Tension Leveler much like that at the Pickle Line where the strip is tightly worked up and down by a series of roll cassettes. Shape defects are removed from the strip as its thickness is reduced by around one-half of one percent.

The #2 Galvanizing line includes a 4-hi skin-pass mill stand situated just in front of the tension leveler to reduce strain marks and impart a uniform surface texture on the coated product, subject to the customer's specifications.

FINAL PROCESSING

When required by the customer, a thin coat of rust inhibitor is applied to the strip as it travels through the chem treat section after the tension leveler. A solution is squeegeed onto both surfaces and then air-dried, inhibiting the formation of 'white rust' (water-stained zinc) for six months or longer.





Just before final inspection, the product passes into the stamping area where, when indicated on the schedule, the strip is printed periodically with the product's specifications. The older line uses four 16" diameter ink drums, while the #2 CGL incorporates an ink-jet printer for improved print quality and greater flexibility.

When indicated by the customer, the strip is oiled after inspection. A spreader roll at the #1 CGL squeegees oil evenly across the top surface of the steel shortly before it is recoiled, while the newer line uses an electrostatic oiler. Oil is less expensive than Chem Treat, but it is not as durable and is more difficult for the customer to clean from the strip. Typically, galvanize products that will be painted are

oiled, while end-uses calling for exposed zinc receive Chem Treat.

INSPECTION

Before recoiling, the strip is inspected to ensure it is dimensionally sound, and that any surface or shape defects are acceptable, based on customer- and end-use-specific criteria. Each line has a small laboratory used to monitor the process on an ongoing basis. Rockwell Hardness tests are performed on each parent coil to evaluate the annealing heat treatment and feedback is normally given to the operator in time to make adjustments for the next coil.

Additional tests are performed to evaluate the coating quality; weighing a sample, chemically removing the zinc, then reweighing the coupon confirms the coating weight; creasing a sample with a tight bend tests the adherence of the zinc to the base metal. Periodic checks are performed to monitor the cleaner's detergent levels, the molten zinc bath's aluminum and lead content, and the chem treat solution's make-up. Tensile test coupons to qualify Physical Quality steel are sent to the main lab for evaluation.

The finished strip is recoiled and cut to the weight required by the customer.