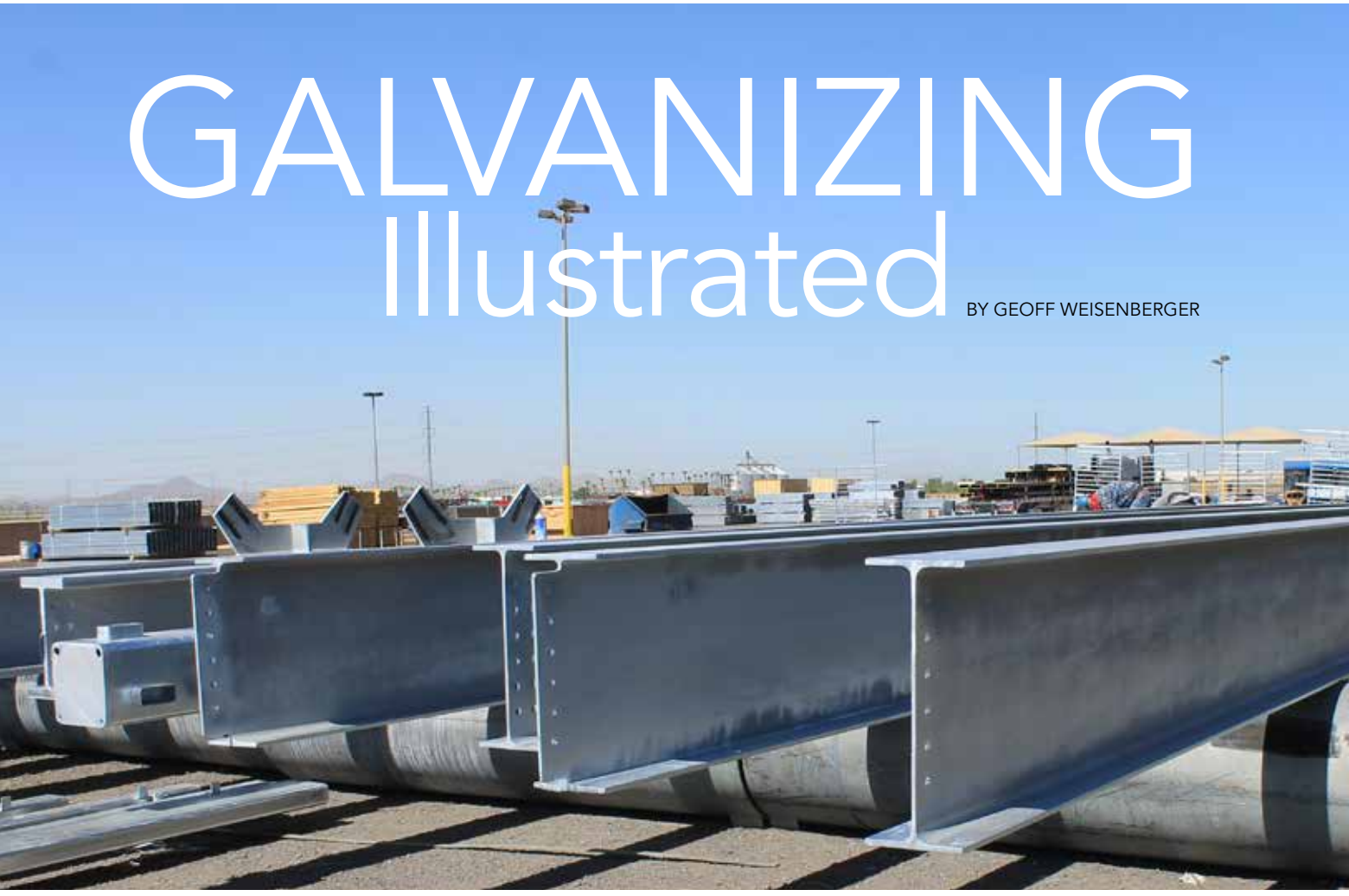
A look at the ins and outs of the hot-dip galvanizing process.

GALVANIZING Illustrated

BY GEOFF WEISENBERGER



HOT-DIP GALVANIZED STEEL, known for its silver-gray hue, sports a protective zinc coating that prevents oxidization. Zinc and iron react to one another through a diffusion process, creating a four-layer zinc iron alloy. This layer of protection is particularly suitable for steel that must withstand harsh, outdoor environments where it is exposed to the elements. And it can be used on myriad types of steel, not just structural.

But how does the hot-dip galvanizing process work? Following is a photo tour of AISC member AZZ Galvanizing's Goodyear, Ariz., plant. By the end, you'll have a better understanding of how steel goes from uncoated to zinc-encased and ready to ship. ■

Geoff Weisenberger (**weisenberger@aisc.org**) is *Modern Steel's* senior editor.

The galvanizing process was discovered in the 1700s and the basics haven't changed much since. The mixture that the steel is dipped in is 99% pure zinc, along with a small amount of aluminum (which gives it a shine) and other proprietary chemicals.

- Steel comes into the facility in various stages of cleanliness; the Goodyear facility has a sandblasting building for steel that needs to be blasted. All steel batches go through a series of tanks or "baths." From the staging area at the beginning end of the plant, the steel takes its first bath in a high-pH (above 13) caustic dip, which removes oil, grease and dirt. Sodium hydroxide is the primary chemical in the dip, which also includes proprietary emulsifiers and surfactants. The metal rests in the caustic bath for 10 minutes to an hour, depending on its condition. After the batch is dipped in the caustic fluid, it must be neutralized, so the second bath it takes is in water.
- Speaking of water, venting is a crucial step for steel elements that will be put through the galvanizing process, particularly with hollow pieces. When moisture trapped inside an element becomes super-heated, it can generate 3,800 psi of pressure and blow a steel piece apart. AZZ makes sure to check steel for proper venting before putting it through the process. And in cases where steel isn't vented properly, they contact the fabricator and either have them add venting holes or perform the work themselves on-site using torching or drilling, charging the fabricator accordingly.
- The third tank is an acid bath, which removes any oxidization. Either sulfuric or hydrochloric acid is used for this "pickling" process; the Goodyear facility uses sulfuric acid. The two acids attack oxide in different ways. Sulfuric finds fissures in the oxide layer, penetrates next to the base metal and removes the oxide layer. Hydrochloric acid is a bit more forgiving on the base metal in that it simply dissolves the oxide layer. The acid bath lasts between 7 and 30 minutes, depending on the metal's rust condition. Metal with heavy oxides might stay in for up to 45 minutes.

- Zinc arrives at the facility in approximately 2,400-lb pieces and is added to the kettles regularly as the levels get low; the operators keep the level 2 in. to 3 in. below the lip of the kettle to prevent spillage when elements are dipped. This facility has three kettles in two different buildings, as well as a decommissioned kettle. The two longest kettles—43.5 ft long and 36 ft long—are both 6 ft wide and 9 ft deep, while the third kettle is 23 ft long, 3 ft wide and 6.5 ft deep.

- From the pickling tank, the batch goes into another water bath to rinse off the acid. The next and final bath before the actual zinc dip is a low-pH zinc ammonium chloride mixture, which acts as a fluxing agent. It also contains a chlorine salt that encapsulates the metal and prevents it from oxidizing again.

- Operators move each batch from kettle to kettle via wired remote control.
- Following the flux, it's time for the zinc. The batch is dipped in a kettle that holds, in the case of the largest kettle at the facility, around 1.1 million lb of molten zinc. A blast shield is lowered for the initial dip to prevent splatter on the operators.

- The zinc in the kettle is kept at 835 °F. Once the base metal reaches the 835 °F mark, which usually takes about 3½ minutes, the reaction is complete.
- The zinc kettle is the most highly skilled position in the shop and operators "finesse" the batches—raising and lowering them into the kettle to make sure the zinc gets into all of the nooks and crannies, tapping them as necessary to remove excess zinc and skimming the top of the tank to make sure that no detritus adheres to the steel as it is brought out of the dip.

- The number of times the batch is raised and lowered into the tank (to completely remove trapped skimmings) depends on its geometry, but each batch eventually emerges with a shimmering silver coat.
- There is no cure time, but each batch is typically dipped in a vat of water for cooling.
- To maximize productivity, the Goodyear plant lines up jobs so that while one batch is in one bath, another batch is in the bath preceding it, and so on. It also bundles its steel orders together to maximize crane capacity. In addition, there are two lifts for the zinc kettle, one at the front and one at the back, so two batches can be hot-dipped simultaneously.

The smaller building employs 7.5-ton cranes while the larger building uses 10-ton cranes to move steel batches down the line. Each batch is tagged for tracking purposes, but the tag is attached high enough so that it is not submerged in any of the tanks or kettles.

Once the steel is galvanized, quality control is essentially built in, as defects or voids in the coating are visible to the naked eye. Deburring is performed outside as necessary.

If there are significant defects in the coating, the steel can be put through the entire process again. The plant also performs various touchup processes as necessary, and there is an outdoor area designated for zinc-rich painting and metallizing (where zinc is sprayed onto the steel) operations.

A third type of touchup work involves the application of additional zinc via a zinc stick. This can be done immediately after the dipping and cooling process when the steel is still warm enough for the zinc to be melted on.

Smaller elements, such as bolts, go through the galvanizing process in special spinner baskets in the 23-ft tank. After the zinc dip, the baskets are spun in a special machine to remove the excess zinc.

Some structural steel elements include portions of the surface that are not to be galvanized. These are covered via a special paint that comes off during the galvanizing process but stays zinc-free when it emerges from the zinc kettle.

Zinc kettles are typically used for about seven years before requiring replacement.

All zinc used at the plant is 100% recyclable. AZZ removes a slag material called "dross" from the kettles about every two weeks. Dross is created from small particles of iron coming off the steel being dipped; the iron particles are encapsulated by zinc, and because they're heavier than zinc, fall to the bottom of the kettle. The dross is compressed into blocks and sold to a company that separates the zinc from the iron, then sells the zinc back to the galvanizer.

In addition, zinc oxide that forms during the galvanizing process is ladled off the top of the kettle and processed in a machine that separates the zinc from the zinc oxide. The zinc is returned to the kettle and the zinc oxide material is sold to the same company that recycles the zinc from the remaining skimmings. From there, the zinc oxide can be used in a number of applications, including health-care products, cosmetics, animal feed and paint.

Once a year the caustic tank solution is pumped over to a rinse tank, and the sludge is removed from the tank, treated and sent to a landfill as a non-hazardous waste. The solution is pumped back over to the caustic tank and rebuilt to operational specifications. The acid is recycled and reused. The Goodyear plant's acid recovery system keeps the tanks free of zinc and iron (contaminants that can contaminate the pickling tank), and the acid tanks are replenished with fresh acid, typically on a daily basis. Water from the caustic rinse and acid rinse tanks is used to build new caustic and acid solutions. The preflux solution and tank go through the same cleaning and recycling process used for the caustic solution and tank.

The turnaround time for a galvanizing job, from the time it arrives from the fabricator to when it is ready to be shipped to a project site or service center, is typically five days.