Zinc Generator Tanks for the Alkaline Cyanide-Free Zinc Plater

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Zinc plating is one of the highest volume processes in the plating industry, and the use of alkaline cyanide-free zinc technology is the fastest growing segment of the zinc plating industry. This shift is being driven by increasing environmental and safety concerns associated with alkaline cyanide-containing baths.

Today's alkaline cyanide-free processes can duplicate the brightness, ductility, and throwing power of cyanide processes without the related hazards. These new processes offer lower operating costs than chloride zinc, as well as more even deposits from high to low current densities.

With the growth of alkaline cyanide-free plating baths comes a change in traditional thinking regarding anode selection and zinc metal replenishment of the plating bath. Alkaline cyanide-free zinc plating solutions require stricter control of dissolved zinc metal levels than cyanide-containing solutions.

The concept of using inert steel anodes and a separate "zinc generator" tank in place of traditional zinc anodes in alkaline zinc plating solutions has been around for many years; however, until recently, the availability of practical designs and field experience was less than adequate. This article addresses the advantages of using a zinc generator tank and provides practical designs and information.

ZINC REPLENISHMENT

Zinc can be replenished in alkaline cyanide-free plating solutions by either dissolution from zinc anodes, as with cyanide zinc plating, or by dissolution of zinc metal in a separate "zinc generator" tank containing a sodium hydroxide solution. This zinc-rich solution is then circulated to the plating tank. Unlike cyanide plating solutions, undissolved zinc salts cannot be added directly to alkaline cyanide-free plating solutions.

The most popular forms of zinc anodes are balls contained in steel wire baskets or large slabs suspended from steel hooks; however, alkaline cyanide-free zinc platers find that using zinc anodes as the only form of zinc replenishment can be inadequate and problematic. The absence of cyanide results in a narrower range for dissolved zinc metal, so tighter controls are necessary to maintain stable zinc levels—especially as productivity increases. For the average plater it is impractical to monitor and control all of the factors that influence zinc levels in the alkaline cyanide-free plating solution on a daily basis: anode surface area, solution drag-out, amount of electrical current, solution temperature, sodium hydroxide levels, cathode surface area, and the volume of the plating work.

Also, when adjustments in the zinc metal level of the plating solution are necessary, the plater must physically remove or add anodes and adjust the level of sodium hydroxide in the plating tank. More monitoring and solution testing are required to determine if further corrections are necessary.

ZINC GENERATOR TANKS

Replenishing metal with a small zinc generator tank containing zinc balls/slabs and sodium hydroxide and using inert steel anodes in the plating tank give the plater much more control than relying on zinc anode dissolution. Additional advantages of this approach include the following:

- The time and labor associated with solution testing is reduced.
- There is separate control of zinc plating and zinc generation.
- An immediate supply of zinc to the plating tank, as well as a reservoir for future needs, is provided.
- A simple way to raise quickly or lower zinc metal to satisfy requirements for different types of parts is provided.
- The use of less expensive zinc slabs instead of zinc balls is allowed.
- The possibility of zinc anodes polarizing, which can contribute to deposit roughness on parts, is removed.

Installing a zinc generator tank will not address all the concerns of the alkaline cyanide-free zinc plater. It will not alleviate the need for meticulous cleaning prior to plating, nor will it ease waste generation and effluent monitoring. It will, however, help simplify the plating operation and stabilize the plating bath to produce bright, uniform work from day to day.

IS A ZINC GENERATOR TANK NECESSARY?

Certain factors of the plating operation determine how beneficial a zinc generator tank will be to the plater. Generator tanks can prove to be extremely beneficial to both barrel and rack platers. Consider these questions before constructing a zinc generator tank:

1. Will the plating line be a high volume line?
2. Are the parts generally considered "high drag-out" parts?
3. Will the parts be plated at relatively high current densities?
4. Will the plating line be used every day?
5. Is there adequate space for a zinc generator tank?

A "yes" answer to any of these questions indicates a probable application for a zinc generator. Here's why.

Zinc is plated and dragged out at various rates based on the parts being plated and the plating cycle. Platers using zinc balls/slabs for anodes will find that with continued high-volume, high-current-density production, it is nearly impossible to keep a stabilized zinc level in the plating line. After just a few hours of intense plating it may be necessary to increase zinc anode area

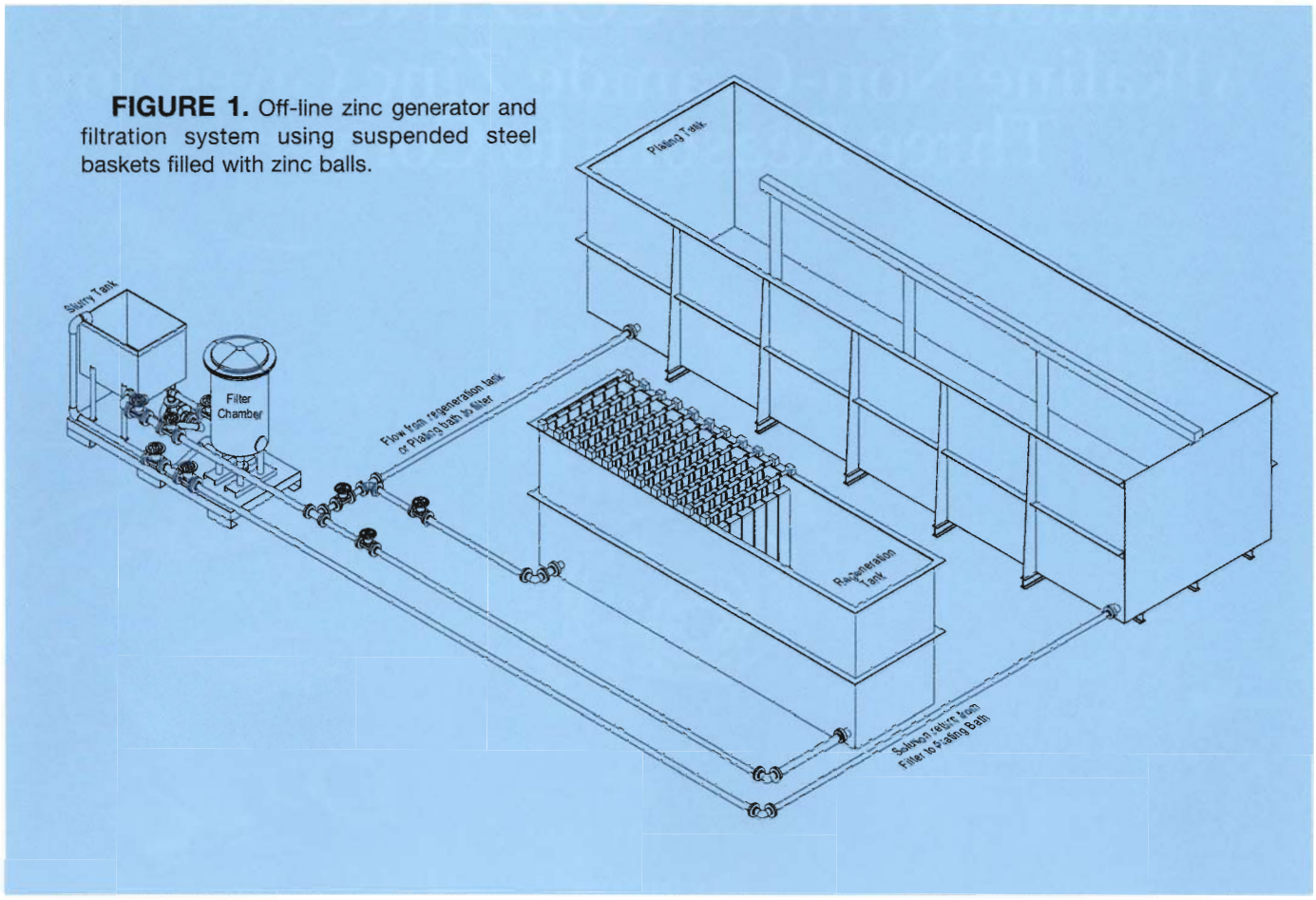

FIGURE 1. Off-line zinc generator and filtration system using suspended steel baskets filled with zinc balls.

and/or sodium hydroxide in order to generate more zinc. During idle periods it may be necessary to decrease anode area because zinc continues to dissolve. Eventually, "downtime" may be required to get the bath chemistry back in total order.

Uniform plating is also a problem. A typical alkaline noncyanide plating line that uses zinc anodes may begin the week with a zinc level of 11 to 12 g/L. After two 8-hr shifts each day of the week the zinc level may drop to 6 to 7 g/L. Often, platers without zinc generator tanks must rely on the weekend shutdown (and unscheduled shutdowns) to replenish the zinc in the plating solution.

On the other hand high-volume, high-drag-out shops with zinc generator tanks are able to operate continuously for very long periods of time without the need to shut down in order to rebuild the zinc level. Shops that have generator tanks also see much more stable and even zinc levels from Monday to Friday, resulting in quality work all week long. Reducing the fluctuation in zinc metal lets proprietary brightener systems work more efficiently and with more predictable results, and platers with generator tanks can easily alter the zinc levels to accommodate different types of parts to be plated.

THE ZINC GENERATOR TANK DESIGN

By designing a small zinc generator tank containing a highly concentrated solution of sodium hydroxide (115-165 g/L) and an ample supply of zinc, the plater will be able to circulate concentrated zincate solution throughout the bath to maintain stable zinc levels easily.

The first mandate is that the zinc in the generator tank must be in constant contact with the steel baskets or dividers. This will form a galvanic cell that enables the zinc to dissolve readily and at an even rate. If the zinc supply is not in contact with steel it will dissolve too slowly to maintain a surplus of zinc in the generator tank.

Next, air agitation, submersible recirculation pumps, or exterior plumbing with a pump must be used to move the zincate solution throughout the generator tank continually. Failure to provide adequate solution movement will cause the zinc balls/slabs to form a hard crust of zinc oxides/zinc hydroxides that will impede dissolution. If allowed to form, this hard crust must be removed or the zinc will not dissolve in the caustic solution.

A well-designed generator provides easy access for replenishing zinc balls/slabs and making additions of sodium hydroxide to the system. Typically, plating lines that operate with a generator tank never have to make "over the side" additions of sodium hydroxide to the plating tank itself. All zinc and electrolytes are provided via the generator tank.

Maintaining an adequate zinc supply means different things to different platers. High-volume shops will require a larger zinc reservoir, whereas specialty/part-time shops may require much less. The average zinc generator tank is approximately 15 to 20% of the volume

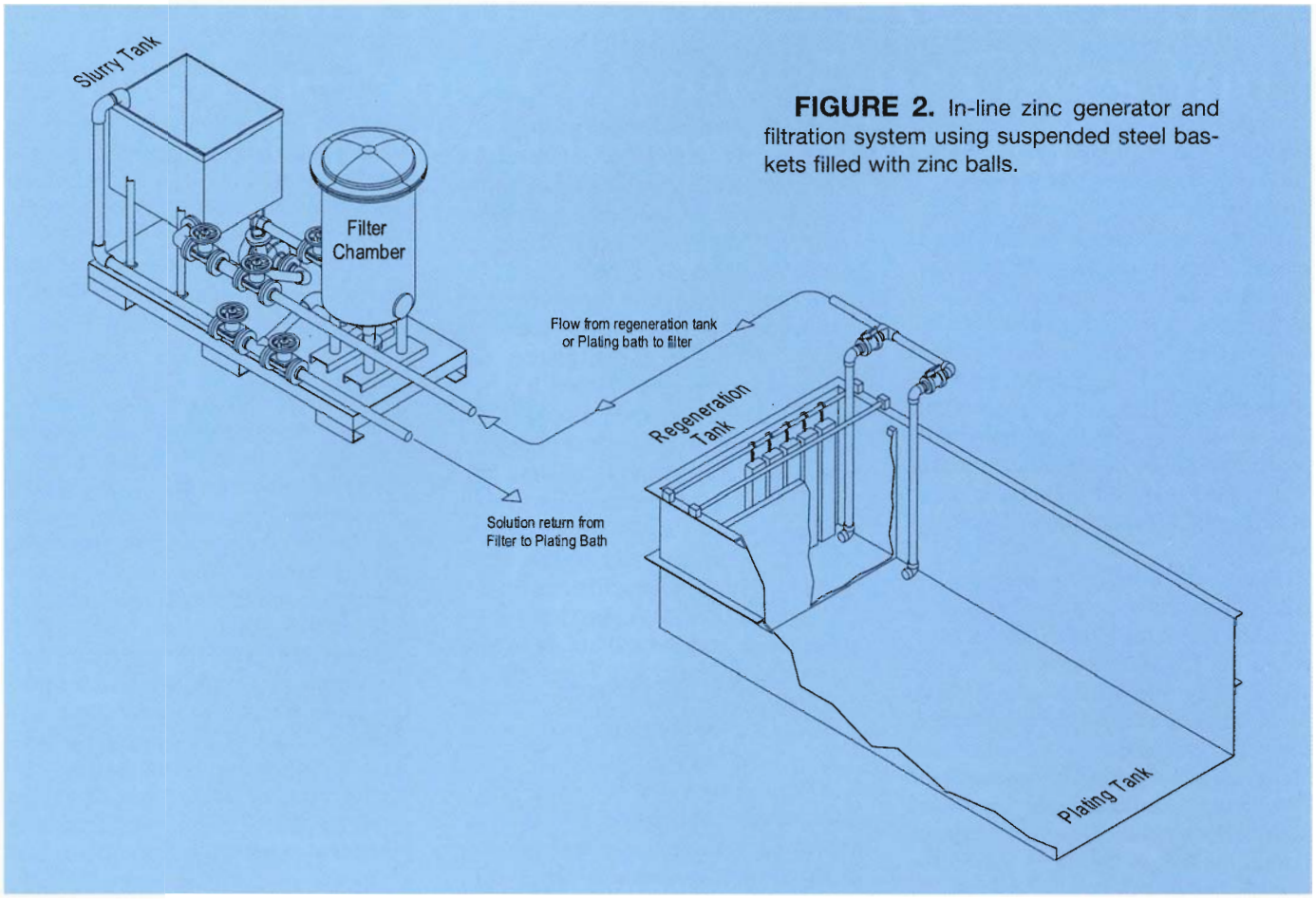

FIGURE 2. In-line zinc generator and filtration system using suspended steel baskets filled with zinc balls.

of the plating tank; some high-volume platers increase the size of the generator tank to around 33% in order to ensure adequate zinc reservoirs.

To determine the size of the generator tank needed, the plater must consider the plating schedule and the space limitations in the shop. To make a generator tank that is 15 to 20% the volume of the plating tank, the plater must make space for the tank itself, the filter, the pumps, an exhaust system for the fumes, and all the plumbing that is used to circulate solution from the plating tank to the generator tank.

The generator tank is generally located near the plating line and connected to the plating tank via a network of plastic plumbing and pumps. Proper positioning of the plumbing for the plating and generator tanks should utilize gravity to help circulate solution, eliminating the need for extra pumps (see Figs. 1 and 2). It is best to filter all the solutions before they enter the plating tank to remove any undissolved zinc particles that may cause roughness in the plating bath.

THE ZINC GENERATOR TANK CONSTRUCTION

Zinc generator tanks are constructed of mild steel. Steel baskets or dividers are then installed to fit inside the tank, providing the holding area for the zinc balls/slabs. The baskets or dividers should be removable to provide space for pumps or other circulation equipment and to allow for easier tank repairs and maintenance.

Steel baskets and dividers are manufactured out of mild steel and should be heated with a torch prior to installation. The resulting blue oxide film acts as a catalyst in the dissolution of the zinc. Dividers can be constructed of floor/bar grating, which is commonly used for "catwalks" around plating lines. Plumbing connecting the plating tank with the generator tank should allow the solution to travel from one tank to the other or to be isolated and filtered separately. Proper placement of pumps and filters will ensure adequate flow and circulation of the zincate solution, as well as the control of zinc levels in the plating tank.

There are several efficient methods of solution movement. Compressed air running through perforated pipes along the floor of the generator tank provides excellent solution movement and allows for good zinc dissolution. Recirculating pumps can also be used but must be resistant to highly alkaline solution and allow for good solution turnover. Exterior plumbing with a circulation pump also keeps the zincate solution moving, but this requires the operation of an additional pump.

The generator tank plumbing system needs to be composed of polypropylene plastic to withstand exposure to the caustic solution. Valves should also be high-quality polypropylene to ensure long life and reliability when routing the solution in and around the generator and plating tank. Pipe size will depend on the size of the plating tank and the volume of work that will be processed.

Specify pumps that will pump viscous, highly alkaline solution without any problems. The number of pumps used will depend on the plumbing configuration, the size of the pump, and the distance that the solution needs to trav-

el. Pumps and filters should generally be sized to allow for two to three "turnovers" of solution per hour. For example, a 2,000-gal plating bath plus a generator tank would require a pump and filter system, which can accommodate 4,000 to 6,000 gal/hr for optimum performance.

Pumps and filters can be supplied as separate pieces or as matched units. Matched units are very efficient and include the pump, filter, plumbing, and a slurry tank. Matching the correct size of pump (e.g., 1, 3, or 5 hp) with the correct size of filter will optimize the flow of solution through the maximum square footage of filter media. A rule of thumb is to move the solution at a rate of 100 gal/hr for every square foot of filter media.

Filters are a must for any alkaline zinc system and should be placed in an area where solutions will pass prior to reentering the plating tank (see Figs. 1 and 2). Filter life can be extended with filter aids such as diatomaceous earth or activated carbon. By using a slurry tank along with the pump/filter system, the filter papers can easily be precoated with the filter aid. This will not only extend the life of the filter papers but will also reduce the micron size of the filter, increasing its ability to remove precipitated impurities from the bath.

ZINC GENERATOR: INITIAL SOLUTION MAKEUP, OPERATION, AND MAINTENANCE

After the design and construction of the zinc plating line has been established and the generator tank, pumps, filters, and plumbing have all been installed, it is time to supply the empty tank with zinc balls/slabs and sodium hydroxide solution.

Varying the surface area of the zinc and varying the concentration of sodium hydroxide will dissolve zinc at different rates. Initial operation of the generator tank should be with the baskets 1/2 to 3/4 full of zinc and the sodium hydroxide solution approximately 120 to 140 g/L. If this produces too much dissolved zinc simply cut back on the amount of zinc in the generator tank. If too little zinc is produced increase zinc surface area (add more zinc balls/slabs to the generator) and/or increase the sodium hydroxide to approximately 160 g/L.

The generator tank cannot only generate zinc for maintaining zinc levels of a working bath, but it can dissolve zinc to make up a brand new plating bath. By dissolving zinc through multiple batches in the generator tank and then pumping this solution over to the plating tank, it is possible to generate thousands of gallons of fresh alkaline cyanide-free zinc solution. Just add proprietary brightening agents and begin plating.

Formulas for the generation of dissolved zinc are good in theory, but in a production line they do not take into account solution drag-out, plating volume, and various other factors. It is best for each plater to experiment with his generator tank over the first couple of weeks of operation and to observe how much zinc must be generated to maintain steady zinc levels in the plating tank. In general, maintain the zinc metal in the generator tank approximately 2 to 6 g/L higher than the desired level in the plating tank and the sodium hydroxide approximately 6 to 20g/L higher than in the plating tank. This should allow most platers to generate sufficient zinc to replenish the plating solution.

Maintenance of the generator tank is quite simple. Keeping zinc in the baskets/dividers and the sodium hydroxide at an acceptable level and maintaining good solution movement throughout the generator tank will minimize problems.

DESIGN OF INERT STEEL ANODES

Inert anodes are constructed of mild steel. Floor/bar grating, which is typically used for catwalks around the plating line, is commonly used. Anode area should be maximized to allow for proper plate distribution.

There are basically two ways to connect the steel anodes to the copper bussing. The traditional method utilizes a copper or steel anode rail, positioned above the plating solution. The steel anodes hang from the anode rail. The contacts between the anode rail and the steel anodes must be cleaned periodically to remove built-up oxides that impede the current flow. Care must be taken to avoid any introduction of copper into the plating solution during contact cleaning. A preferred method utilizes a steel anode rail that is submersed in the plating solution. The steel anodes can either hang freely or be bolted onto the submersed anode rail. This method ensures proper contact between the steel anodes and the anode rail by eliminating any oxide buildup or resistance at the connecting sites.

Because the applied current will typically exit from the bottom of the anodes it is beneficial to stagger the height (depth) of these anodes throughout the plating tank. By varying the distance that the anodes extend into the plating tank from 1/2 to 3/4 of the distance to the bottom, the current will flow to different areas of the work, thus "averaging" the current.

CONCLUSION

As alkaline noncyanide zinc plating continues to increase in popularity it would be prudent for any zinc plater contemplating an alkaline noncyanide system to consider a zinc generator tank. Traditional zinc anodes require constant monitoring and physical labor that is difficult and impractical. Although it is possible to operate effectively with zinc as the anode in the plating tank, a zinc generator tank will eliminate many of the problems associated with alkaline cyanide-free zinc plating. Use of a zinc generator tank gives the plater more control, reduces labor, and maintains more uniform bath chemistry over a long period of time. When the bath chemistry is under control, proprietary brightener systems will operate more predictably and will produce consistent, high-quality work from the plating line. A well-designed zinc generator tank will prove to be a very reliable ally to the alkaline cyanide-free zinc plater.

Acknowledgment

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