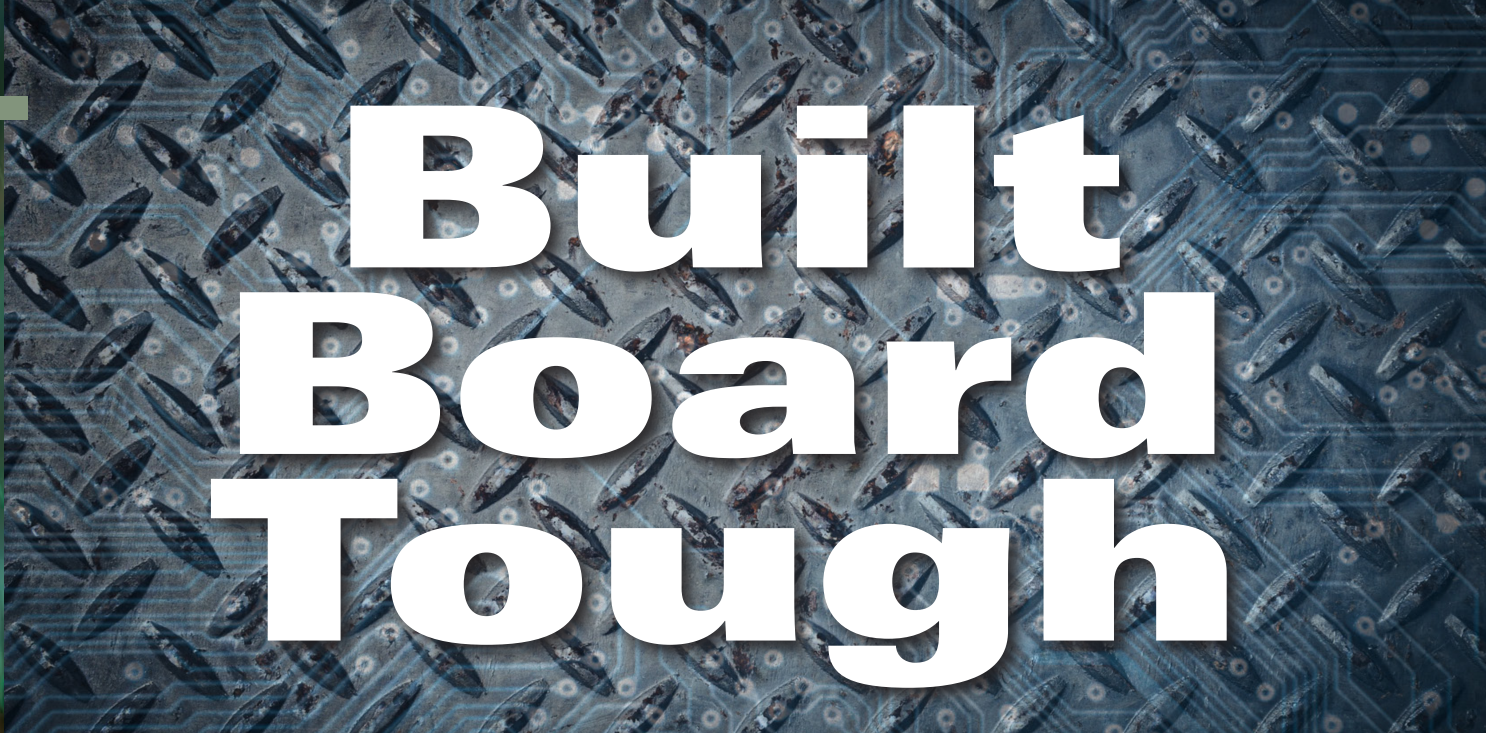

Built Board Tough

Budget DC Copper Plating for High-Reliability and Increased Capabilities

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SUMMARY: Converting your old DC copper plating setup to one that produces high-reliability and higher aspect ratio copper plating for vias isn't difficult; some old jeans and a little resourcefulness can produce world-class plating capabilities in a small hand-plating line.

In last year's reliability issue for PCB Magazine, we touched on three "backbone" processes that are critical in yielding high-reliability PCBs. I'm going to focus on the copper plating portion of that article in this issue.

Remember the conversion kits that made a Fiero look like a Ferrari with new outer skins and decals? While nice on the outside, they still performed like the 4-cylinder roadster they were made to be. Or, for you baseball comedy fans, who can forget Willie Mays Hayes' Rolls Royce Beetle from *Major League?*

Well, we're going to discuss a project with quite the opposite outcome: converting your old DC copper plating setup to a setup that produces high-reliability as well as higher aspect ratio copper plating for vias.

Since I started in this industry, my dad has impressed upon me the importance of a proper copper plating line setup. In fact, back in the good old days he designed his own line to optimize all parameters related to copper plating—and had it built in-house. Our suppliers called it a $1 million R&D project as some of the features were not commonly used in the industry. Thankfully, it worked out and he was still able to pay my tuition and other (bar) bills.

When I acquired Saturn Flex in 2010, I inherited a classic type of plating setup: a basic three-rack line with a single rectifier. Like every teenaged 35-year-old, I didn't listen to what my dad was preaching and left the line as is, to focus on other aspects of turning around this company. Of course, the first higher-technolo-

gy order we received saw us scrapping out more than half of the pieces due to copper plating issues. At that moment, we began a total conversion of our copper plating line to optimize all plating parameters with the goal of building extremely high-reliability and high-technology PCBs, which I will describe in this article.

Rectification

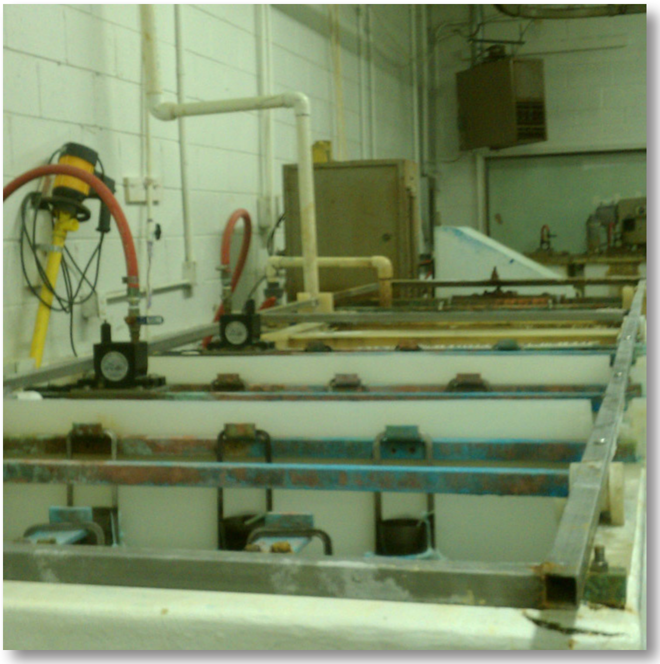
First and foremost is rectification. The most common setup is a single rectifier that provides power for multiple plating racks. While common, it is the least optimal setup. The ideal setup would be for each plating rack to have two rectifiers (one for each side), which allows for optimization of the amps applied to each side of the panels based on specific design characteristics—including aspect ratio and exposed copper area. This, in turn, allows you to hold a set number of amps per square foot (ASF)—no matter the degree of design imbalance of the PCB from one side to the other. This is critical on higher density designs as it will ensure that you meet minimum plating requirements in the hole, while avoiding over-plating the surface copper. Overplating the surface copper can result in plating resist entrapment between fine circuitry, which prevents etching of the underlying copper, thereby causing short circuits in your design that may not be able to be repaired.

Next we have to address the type of rectifier. My preference is going with a newer style rectifier that has solid state controls, less than 0.5% ripple effect, and is rack-mountable for ease of operation. It boggles my mind to see that folks are still using older, variable-frequency manual-control rectifiers due to the cost of newer rectifiers (or that they don't know the benefits of newer rectifiers). In researching rectifiers, I benefited from the fact that unlike most of the other equipment we use to build PCBs, rectifiers are not PCB industry specific and can be found through multiple sources. Coincidentally, I bought mine on eBay, of all places. I chose Sorenson DC8-75 rectifiers, meaning they were capable of outputting 75 amps at eight volts. Lower voltage is required for PCB copper plating as it allows you to plate at a slower rate for a longer period of time. This results in a much lower ripple effect. Ripple effect is AC current mixing in with the DC current output of the rectifier. The more AC that leaks into the DC current, the more chance you have for quality issues that include step-plating and increased additive consumption. Increased additive consumption can result in reduced uniformity and poor grain structure refinement, both of which can lead to long-term reliability issues.

For my three-rack plating line I needed six rectifiers, which I purchased for about $400 each. In addition we spent another $1,000 on 3/0 AWG welding cable to connect the rectifiers to the anode and cathode bars. All in all, not a huge investment and one that most shops can make—and one that is easy to pay off in as little as one higher technology quick-turn order. For the connections to be safe, we found all copper fittings which we then coated with plastisol to prevent oxidation that would inhibit current flow.

Agitation

Simply put, agitation is the movement of the plating racks to which the production panels are mounted in a back and forth motion



so that the copper plating chemistry is forced against the face of the panel. While it seems like a simple concept, it's surprising how many plating lines I have seen at smaller shops that have their plating racks fixed in place. That was also the case at my shop when I bought it.

By not agitating the plating racks, you are relying on only the chemical side of the copper plating process to plate your through-holes. This can result in severe "dog-boning" of the plated through-hole, meaning that the knees of the hole will plate much thicker than the middle of the hole. Not only does this setup require a much longer cycle time to meet minimum plating thickness requirements, but in the case of higher aspect ratio vias it can result in not achieving the minimum required plating thickness in the middle of the hole. Personally, I don't think meeting IPC Class III requirements on aspect ratios of 6:1 or higher is possible in a production environment without adequate agitation of the plating rack.

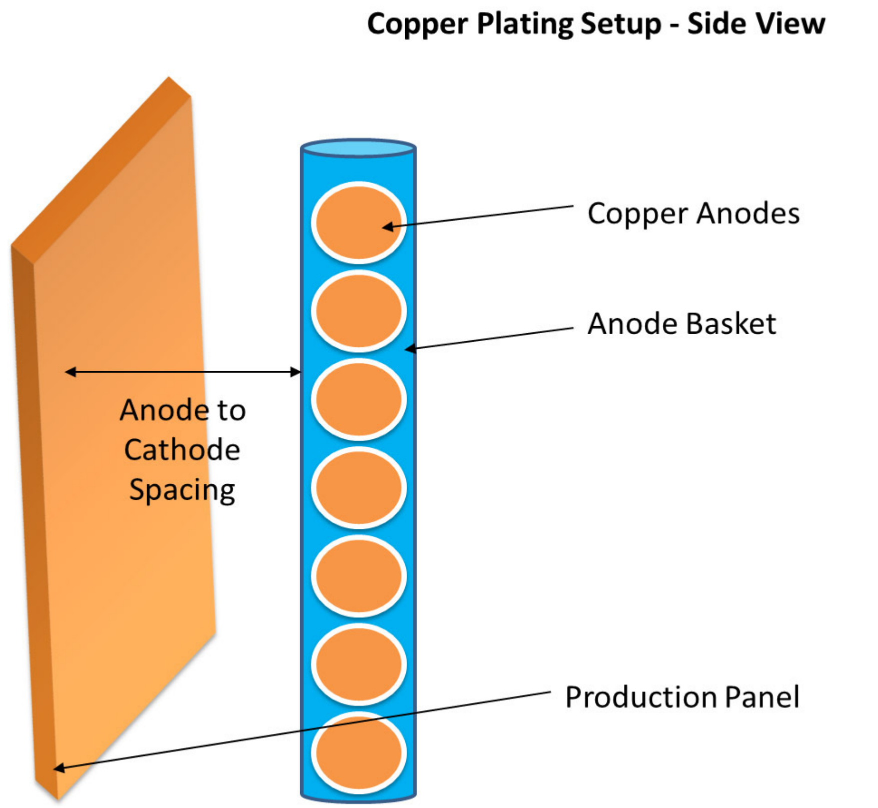
Agitation provides local solution flow through the holes, which not only enhances copper plating by replenishing depleted chemistry, but also removes air from the holes as a byproduct of the process.

A retrofit to an existing plating line is pretty easy. The first step is to bolt or weld on a mount for the agitation motor, which needs to be low RPM with high torque. We chose a ¼ H.P. motor from Marathon Electric (model# 5kh33gn-c140a) for a cost of about $200.

The next step is to build an agitation ladder. Once again, the materials and skills involved are not PCB-industry specific. We purchased a 1.5" square stainless steel rod and then contracted a local welder to put it all together (make sure you qualify that the welder has experience and the equipment necessary to weld stainless steel as it's not the same as normal steel). Another item to be aware of is to make sure that the agitation rack is insulated from the copper flight bars that hold the anodes and plating racks. We learned this the hard way, so you don't have to. The cost for the materials and labor was about $400.

We then purchased nylon wheels that the rack rolls on to reduce friction during movement. This reduces resistance to the agitation motor—increasing its life. You can use PVC saddles that the agitation rack slides along as well (we have this setup here in the Detroit shop),

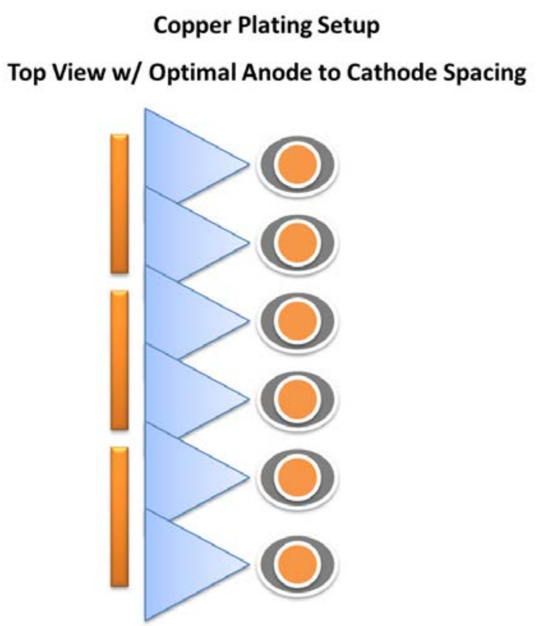
but there will be resistance to the motor. If you're starting from scratch and have the height allowance, I'd recommend going with the wheels.

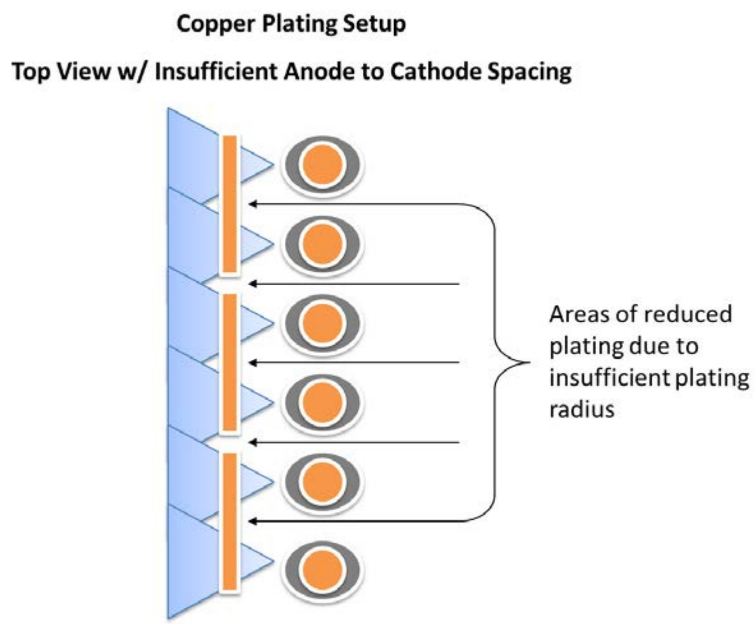


Spacing

The anode-to-cathode (panel) spacing within the plating cell is a very critical characteristic that I'm sure gets addressed when plating lines are initially designed. However, as time goes on and lines get sold, reinstalled, and/or modified, there is a chance that these requirements are superseded for capacity improvements or reductions. This happened to our affiliate in Chicago and after increasing capacity and making room for an education system, their anode-to-cathode spacing was a mere four inches.

The optimum anode-to-cathode distance is 10 inches. The optimal agitation stroke is two inches, meaning that the anode-to-cathode span will be eight to 12 inches, with a mean of 10 inches. The idea is to capture enough plating radius to cover your entire panel surface, while not being too far away such that the plating effect is weakened.

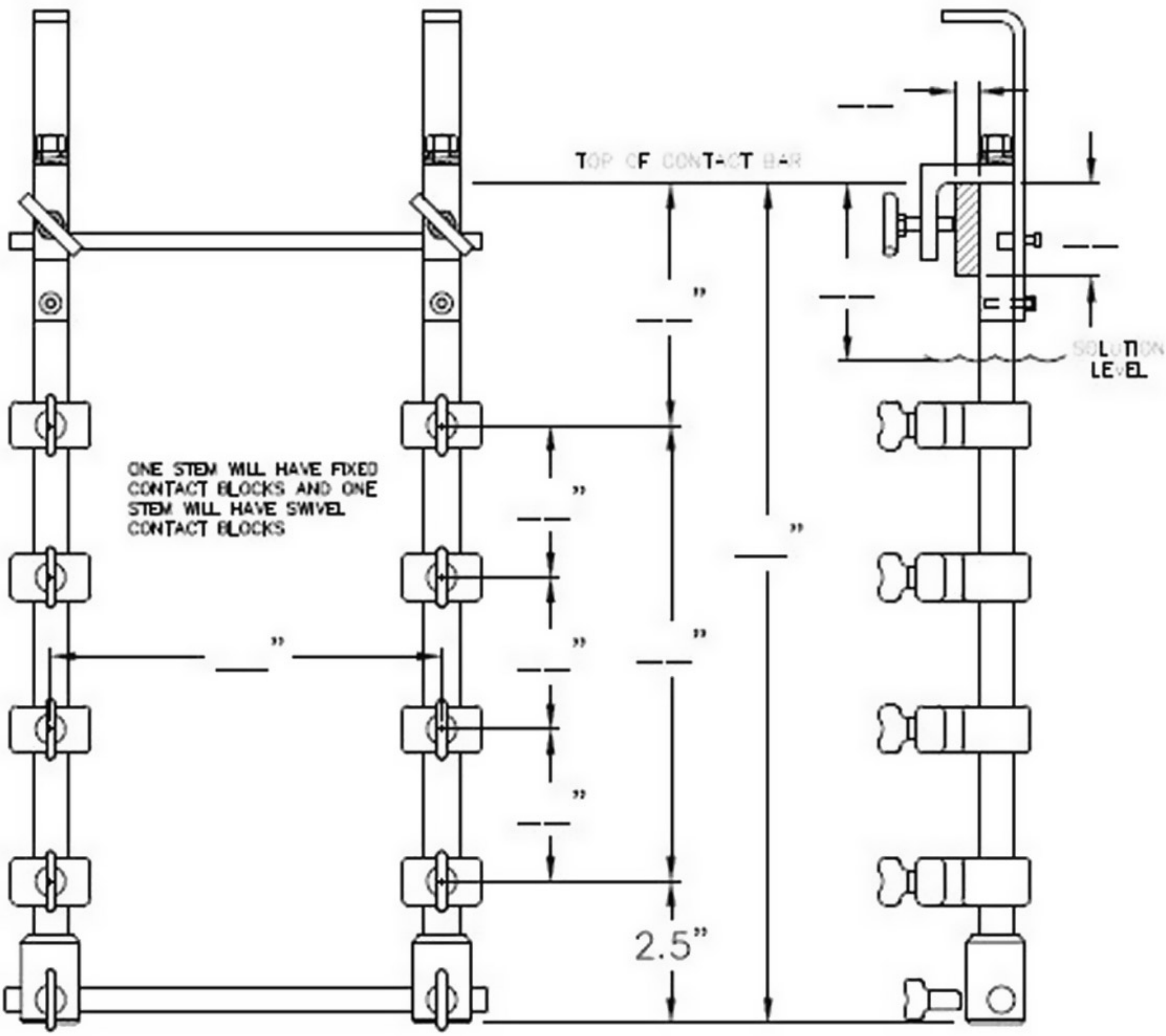




Plating Racks

Plating racks are one of those items in a PCB shop that make an owner really pucker up at the thought of spending money on. The reason is that these are treated as a secondary contributor towards copper plating—"it's only there to hold the panel in place." Not true. Plating racks not only lend mechanical stability to the copper plating process, but also serve as a conduit for electrical conduction.

My primary point of contention is that the panel is only making contact with the rack along one side. This means that the panel will have more current at the point of contact than it does at the other sides, resulting in a higher copper plating thickness variation. High variation increases the likelihood of PCBs with insufficient copper plating thickness in the vias to make it to the customer and into the field. Additionally, from a risk-management standpoint, the more contacts you have, the less impact a single poor



contact will have on the overall quality of the panel.

Our solution to this problem was to make racks that allow for clamping the production panel on both the top and the bottom. If you don't want to custom-design your own rack, M&B Plating has a flexible design that allows for clamping on both sides of the production panel. Regardless of which sides the clamping occurs on, the main benefit is that you now have multiple opposing points of electrical contact for the current you apply during copper plating.

Another benefit to having this type of clamping setup is the added mechanical stability it provides. In a standard manual plating rack the panels will sway back and forth in a bath that has adequate agitation. This reduces the resistance that the panel gives against the copper plating chemistry, thereby reducing the volume of solution flow through the holes on the unsupported sides of the panel. The result will be added plating variation between one end of the panel and the other. Further, higher aspect ratio holes will be afforded much less solution flow on the end of the panel farthest from the clamp point, which translates into reduced copper plating thickness that may violate customer requirements, or result in all out failure at electrical test. These style racks can be purchased new for about \$500-\$800 each, depending upon the size, # and style of clamps, and types of material used.

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Vibration

One common failure mode for open vias is air bubbles entrapped in the hole during copper plating. The air bubble prevents copper plating solution from traveling through the hole. Most air entrapment can be resolved through the use of agitation during copper plating. However, higher aspect ratio and smaller vias may need an extra kick to really make sure they are cleared out in the beginning of the plating cycle. This will ensure that solution is flowing through the holes for sufficient time to achieve the minimum desired plating thickness.

We purchased our vibrators from Cougar, model #ATU-42V1 for about \$200 each, \$600 total for our three-cell system. These are extremely simple to install since they typically run on compressed air. Also, they are mechanically attached to the cathode bars with nuts and bolts, so no welding is necessary. Make sure you fabricate a solid platform that will allow for optimal vibration transfer from the platform to the cathode bar. Before you run out and buy a bunch of vibrators, you need to consult with your chemistry and equipment suppliers to size them properly for your particular plating setup.

Depending upon the method of chemical agitation, you may not even need to run them during the entire plating cycle. You would just run the vibration during the first five to 10 minutes of the plating cycles. The reason for this is that most air is entrapped in vias during the initial movement of dropping the panels into the plating bath. Once the air is out, there is little risk of re-introducing air back into the via unless you have a problem with your air system for chemical agitation…which leads us to our final topic of conversation.

Chemical Agitation

Chemical agitation is most often achieved using an air bubbling system. The air bubbles agitate the chemistry as they move from the bottom of the tank (where they are introduced) to the top. The size of the bubbles typically makes them too large to enter into vias, but there is always a chance that plastic fibers or other errant materials in the lines can cause them to break up into sizes small enough to create an issue.

Chemical eductor systems address this issue. Instead of using air to create chemical agitation, they use fluid pumps. Typically, copper plating chemistry is pumped out of the tank from one end, and reintroduced at a high velocity at the other end across the surface of the panels. Individual chemistry suppliers tend to have their own feelings of what is an optimal setup so it's best to consult with them prior to designing and installing a full chemical eductor system. Between the plumbing, labor, and pumps, you could expect to spend upwards of $1,000 for a small three-cell setup; however, once it's done, it's done. These pumps typically last for a long time, but I would still use a union to hook them up instead of hard plumbing.

Conclusion

While converting a copper plating line isn't as exciting or fun as buying and installing a brand new drilling machine with 225k spindles, linear X, Y, and Z motion, vision, it's still an equally valuable improvement to your process.

Further, this isn't a zero-sum solution in that you need to implement all of the improvements in order to benefit. Every one of these ideas offers an incremental quality and capability improvement so even doing one at a time, over time, will garner benefit. In total, after spending less than $8k and having four pairs of jeans eaten through by chemicals, we now have world-class plating capabilities in a small hand-plating line. Basically it's like a Ford Fiesta with hot rod engine.

There's nothing stopping you from doing the same. Just wear polyester Dickies during your install—you'll save a couple of bucks. **PCB**

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