More of Those Elusive Little Amperes – Part I

by V.E. Guernsey & J. Guernsey

Technical Editor's note: *This is the first of two parts. The second will be published next month (July 2004).*

This paper is an update of an earlier paper submitted and published by AESF. Additional information has been added and clarified for better understanding, some information has been removed and some has been left unchanged. This is a practical article for platers illustrating and defining bipolar current, bipolar problems, live lead systems for bright nickel and chromium, stray current identification, its measurement and various uses of a volt-ohm-milliammeter (VOM) in electroplating. Servicing tips and corrective measures are also included.

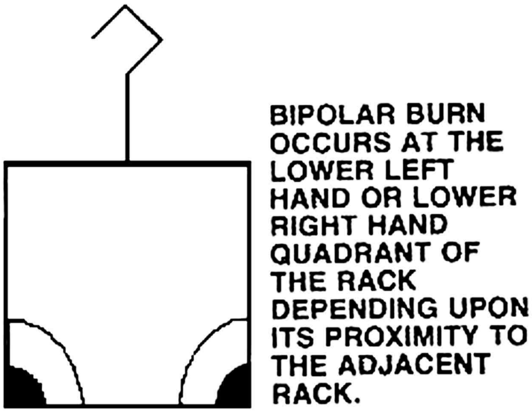


Fig. 1—Areas on rack affected by bipolarity.

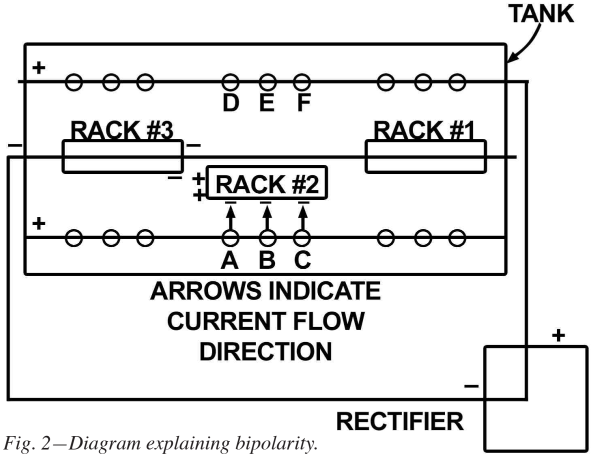


Fig. 2—Diagram explaining bipolarity.

Nuts & Bolts: What This Paper Means to You

In 1976, V.E. Guernsey published a widely read and widely cited article, that is still talked about on the Internet, entitled "Those Elusive Little Amperes," covering that vital subject, stray currents, something that had been given little attention [*Plating & Surface Finishing*, **63**, 38 (February 1976) and **63**, 44 (March 1976)]. Twenty-eight years have passed and the subject is no less important. Now a family enterprise, this article is the first part of an update on the subject. The second installment will be published next month.

The terms "bipolar currents," "stray currents" and "ripple" are terms which pretty much pertain to the electroplating trade**.** Even though these are familiar and recognizable, we find an aura of mystery and misunderstanding surrounding them. To the practical plater these are intangibles, which send him home at night with a vicious headache and an overwhelming desire to commit hara-kiri. If he should suddenly find himself on his knees, his first words of prayer are usually "please make it disappear before tomorrow morning." To the engineer who also winds up with his share of the joy, it sends him off to his books for more profound definitions and postulations which state it shouldn't happen, but it did. We have experienced all of these feelings during 55+ years in plating.

Problem solving can be long and involved if only trial and error are your companions. The short cut, if any, is an understanding of plating fundamentals and their interrelationship. Practical plating experience, common sense and patience are also good companions to have on your side. The problem in writing an article such as this is not where to begin but where to stop, because each predication is based upon a supposition and when one changes, the other must also. For example, during the course of solving a problem, statements without end have been prefaced with the words "do you suppose" or "is it possible that," and each logical supposition must then be pursued and discarded or pursued in another direction in light of each new development. It is for this reason that one does not find too much written on technical service, since the lines of pursuit to a problem and their nuances can be staggering.

Much progress has been made in electroplating in the last few years, but the essence of getting the job done still falls on the shoulders of the practical plater or practical plater-engineer. The authors firmly believe this gentleman has too long been undervalued as electroplating has become more sophisticated, and there has been a tendency to lose sight of the importance of the fundamentals of practical plating with emphasis on the knowledge of "how to do it." It is the writers' conclusion, after many years of job shops and technical service, that 90% of all plating problems can be resolved by going no further than the basic fundamentals.

Fundamentals, which you probably have encountered on various occasions without recognizing them, are the electrical parameters, which go hand in hand with electroplating. Many people are familiar with electricity and many are familiar with plating, but seldom do the two meet. Hopefully, this article will bring some of these basics together, providing better understanding and facilitating problem solving in these two related areas.

Bipolar Currents: Origin & Explanation

How many times have you seen patchy, irregular areas of white on the bottom corners of your rack after chromium plating? How many times have you seen it appear and then disappear, seemingly without reason? Although these conditions may seem to be without reason, like many things, the reasons are only obscure because we are not in possession of sufficient information to direct us to the source of the problem. In this particular case, the reason could be a bipolar current or bipolar burn manifesting itself by normal visual means.

Generally, in electroplating we are most concerned with bipolarity and bipolar burns in bright nickel-chromium systems since the condition is common and its effects are, of course, rejects. In these systems, it originates as the rack exits from the bright nickel or as it enters the chromium solution. A rack that suffers from bipolarity is both positive and negative at the same instant, but in different areas. That area of the rack, which is positive, has an anodic current, which selectively passivates the nickel resulting in what we call a bipolar burn. The portion of the rack having a negative charge will, of course, not be affected. Regardless of its origin, the visual appearance and location of the bipolar burn is usually the same: patchy, irregular white areas of chromium on the bottom corners of the rack.

In electroplating, we think of bipolarity as a current flow (amperes), which passes from the anode through the solution to the cathode by way of an intermediate conductive carrier, the intermediate carrier being a disconnected dead rack. (Remember, this is a practical paper so, for simplicity's sake let's not become involved with the direction in which the current moves but consider it as moving in the same direction as the metal being deposited).

For example, a rack disconnected from the cathode bar, but still immersed in the nickel solution, would exemplify an intermediate ion carrier. By the same definition, a rack immersed in a chromium solution, and before making contact on the cathode bar, could also be included in this definition. This rack, in either of the above cases, now occupies a place in the solution between an electrically charged live anode and cathode, and becomes an integral part of the solution. However, it does have one difference. Since the rack and parts are metal, it has a several-fold better conductivity than the plating solution. Current inherently follows the path of the least resistance, and the rack, even though disconnected, becomes a means of transporting a portion of the current through the solution because of its better conductivity. As a result, that portion of the disconnected rack closest to the anode becomes negative/cathodic and no harm occurs. Unfortunately, that portion of the rack closest to the adjacent, electrically-live, rack being plated now becomes positive/anodic. The result is passive nickel and a bipolar burn, false burn or whitewash, whichever you prefer, visible after chromium plating.

So that we all use the same terminology, a bipolar burn also has several other names such as false burn, whitewash, and some incorrectly label it a chromium burn. Make no mistake. These same terms can correctly describe similar appearing rejects, which are not related to a bipolar problem. This jagged, white, irregular pattern or bipolar burn that occurs on the lower corners of the racks differs from a true chromium burn. A true burn can occur at any high current density area and is due to the excessive current density for the given solution, temperature, catalyst ratio, thus forcing the chromium to plate out of the bright range. It is usually characterized by a heavy, gray color that fades out, becoming a lighter and lighter gray until it disappears into a bright chromium deposit. Normally the true chromium burn is not extensive, can be buffed out and occurs only on sharp points or protruding areas of a part or parts.

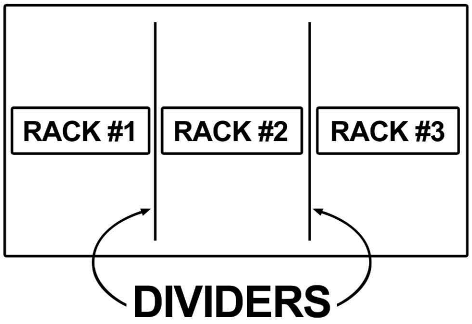


Fig. 3—Prevention of bipolarity in chromium tank (top view of hand line).

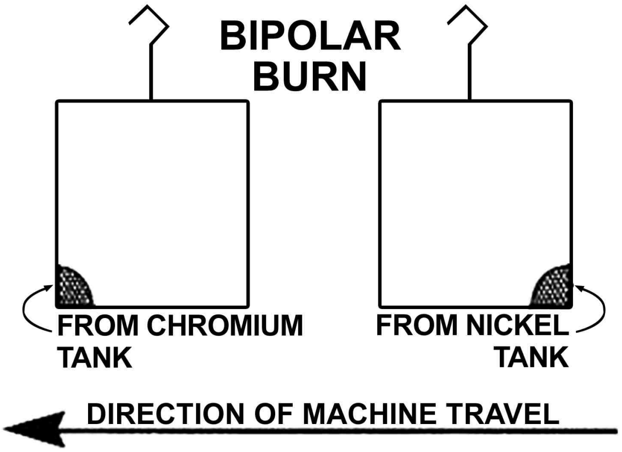


Fig. 4—Position of bipolar burn on racks processed in a full automatic.machine.

By way of further clarification, whitewash or false burn occurring only on the top of a rack would not normally be considered bipolar since bipolarity generally affects only the lower left or lower right hand corners of the rack.

If we can represent a rack as a square, the dark areas in Fig. 1 would be those portions of the rack most severely affected by bipolar burning. The outer lines would show the possible extent of false burn if the condition became more pronounced.

Bipolarity in Nickel & Chromium Hand Lines

Let's look at a top view of a nickel tank in a hand line, explaining by diagram how bipolarity works (Fig. 2). Rack #2 is shown as being offset, which is exactly the position it would be immediately after disconnecting/lifting from the cathode bar. Anodes A, B and C originally supplied current for rack #2. After disconnect, they will begin to feed a bipolar current to racks #1 or #3, or both, through rack #2. In this example, we have shown #2 being pulled from the tank much closer to #3. Therefore, the current will leave anodes A, B and C and find the most desirable route (path of least resistance) to rack #3. This route will be from the anodes through the solution to rack #2 where it is shown as negative/cathodic, then through rack #2, leave rack #2 at the plus signs and enter rack #3. Rack #3 will not be affected, but rack #2 will have a bipolar burn after chromium plating on the lower left hand corner of the rack since the nickel deposit was forced to become anodic in that region. Had rack #2 been pulled closer to rack #1, the bipolar burn would have occurred on the lower right hand corner. In extreme cases, both lower corners would be affected. Bipolarity can also occur if the rack is sitting on the cathode bar but has lost electrical contact. The longer the operator takes to remove the rack from the solution, the more extensive the passivation will be and the more extensive the bipolar burn after chromium. No bipolarity will exist on the

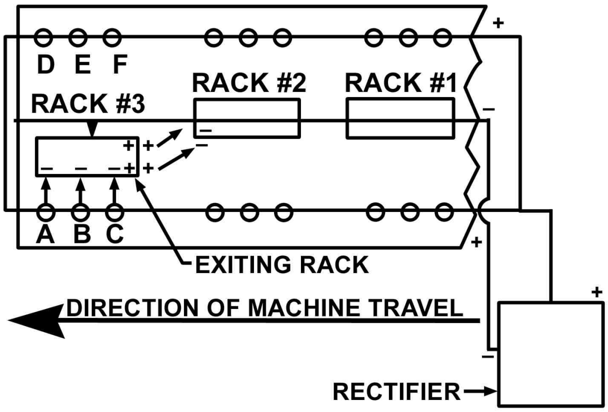


Fig. 5—Mechanism of bipolarity in nickel tank (top view, full automatic).

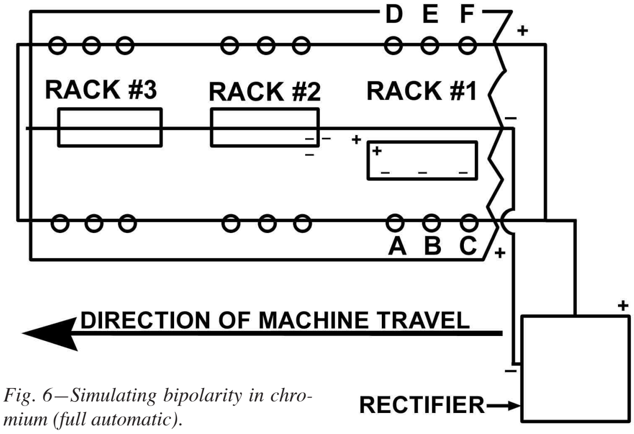


Fig. 6—Simulating bipolarity in chromium (full automatic).

lower right corner of #1 or on the lower left corner of rack #3 since there is no adjacent rack.

Anodes D, E and F would very likely have no effect since the longer distance means greater electrical resistance. Thus any current flow from these would be almost negligible.

Bipolar conditions that occur as a result of the rack entering a chromium bath also cause passivation of the nickel and result in the same jagged white pattern. The same explanation applies as it did for nickel, except that it occurs as the rack enters the chromium solution, without a live lead and before contact with the cathode bar rather than after. This can be readily visualized if you refer to Fig. 2, and consider the tank to be chromium and the rack to be entering the tank rather than leaving.

Considering only a hand line, how does one reach a positive conclusion that it is or is not a bipolar problem, remembering that it can come from either the nickel or the chromium or both? There are two things that are almost axiomatic. First, the bipolarity, as previously described, will not exist with only one rack in the tank (stray current, yes; bipolar, no). Second, as the distance between racks becomes greater, the resistance will increase and the amperage will decrease, thus diminishing any chance of a bipolar passivation or burn. This suggests that if you have a multiple bay chromium tank, plate only one rack at a time in the chromium to determine if the problem is originating there, or following the second item above, double the distance between racks in both nickel and chromium. If the bipolar burn or problem disappears, chances are good that you have identified it. This is suggested only as a means of identifying and ascertaining the origin of the bipolarity, and not as a corrective measure.

A corrective method which can be used for the nickel would be to take an electric extension cord, strip the fixtures from both ends, bare the wires, attach one end to the cathode bar of the nickel tank, and put an alligator clamp at the other end. Before pulling the rack from the nickel, attach the alligator clamp to the rack and then remove the rack from the solution. This neutralizes any possible bipolar problems by applying plating voltage to the rack during its entire exiting period.

In passing, it is conceivable that if one could pull the rack from the nickel tank fast enough, the bipolar problem would be nonexistent. However, in this case, the hand, which tries to be quicker than the eye, loses many parts in the bottom of the tank.

The live lead, as suggested for hand tanks, can be cumbersome, so let us approach this problem a little more practically. Considering only the nickel now, our recommendations have been to maintain a good clean active nickel deposit by judicious use of brighteners, pH controls, continuous carbon pack and just good plating practices, since bipolar problems are magnified when these are disregarded. However, today's requirements for fast brightening nickels make this problem more pronounced and difficult to cure, and the live lead, as suggested above, may be the only avenue of escape.

The authors have seen instances where the bipolarity was traced to a nickel tank in a hand line. When the nickel was taken out, given a batch carbon treatment, dummied and put into good condition, the bipolar problem immediately disappeared. After two to three months of operation, it began to show a bipolar burn pattern again after chromium plating. At this time it was taken out, carbon treated again, and again the problem disappeared. There was occasion to do this several times, and in each case the problem repeated itself, proving that the bipolar current still existed, but its effect diminished with a good clean active nickel deposit.

Another method that may be more convenient is to place a cathodic cleaner, at low temperature 46 to 54°C (115 to 130°F) between the nickel and the chromium, or a cathodic acid to remove this passivity before chromium plating. There are many proprietary activators on the market designed to handle this problem, and the supplier should be contacted for his best recommendations.

Now that we have taken care of the bipolar problem from the nickel, we may also be faced with one in the chromium. Since this is a hand line, we do have some alternatives and we must have proven that the bipolarity is originating in the chromium, not the nickel, as previously discussed.

1. If this is a proprietary chromium bath using a fluoride-type catalyst, we can batch load, *i.e.*, shut off the chromium rectifier, put in all the racks, turn on the rectifier that has been pre-set to about 3V, and then raise the plating voltage. The hydrogen gas created at the low voltage will also help clean any oxidized nickel parts. The conventional chromium baths (sulfate-catalyzed), unless operated under special conditions, are not too satisfactory when batch loaded. Stray currents of the wrong polarity and intensity may preclude batch loading unless corrected in any type of bath. (Check anode supports and heating coils etc., if stray currents are suspected.)
2. With a two-bay chromium tank and light racks (and we emphasize light racks), the operator can put in two racks at a time with the current on. This will avoid the problem. Both racks, of course, should make contact with the cathode bar at approximately the same time and, normally, the plating voltage should be reduced for entry.
3. If you must use the one-in/one-out technique on a multiple-bay chromium tank, loose fitting dividers made of wire-reinforced glass, or rigid sheet plastic, resistant to chromium, can be suspended between the racks. There should be space at the sides and bottom to allow for solution circulation while preserving current isolation. This is illustrated in Fig. 3.

In essence, separate bays are being made for each rack in one chromium tank. There are many other ways to avoid or correct bipolar problems in hand lines, but most are impractical or require such close attention as to be impractical, particularly under production conditions.

Factors Affecting Bipolarity

There are many factors that can cause, or influence, the degree of a bipolar burn. These are listed below for reference and better understanding.

1. With close rack spacing, bipolar problems become more severe, explaining in many cases why wider racks in an automatic will be subjected to bipolar burns, while narrower racks are not. Remember, rack centers will remain constant.
2. A bipolar problem becomes more severe with higher voltages. For example, racks with greater area require higher amperages and higher voltages, thus aggravating an existing problem, if not creating a new one.
3. It becomes more severe when switching from mechanically-agitated nickel to an air-agitated nickel. Again, we use higher voltages for the air-agitated nickel.
4. When changing from a higher concentration chromium bath to one of lower concentration, here again higher voltages are often employed to achieve the necessary current density because of the lower solution conductivity.
5. A bipolar burn becomes more severe as the entry or exit times become longer. Longer racks would also fit into this category.
6. As the activity of the nickel decreases, bipolar burn after chromium will begin to develop rapidly. This was mentioned earlier.
7. It will be more severe as the brightener content in the nickel deposit increases or as the bath becomes contaminated. Excessive additions of brighteners will create a brightener imbalance, and higher pH values also tend to promote a more passive nickel. Greatly reduced chromium coverage can also be expected. Most of these are to be expected in view of today's demands to produce brighter nickel deposits in shorter times, thus compounding bipolar problems.
8. A bipolar burn will be more severe on parts having projecting points, since there will be a concentration of bipolar current in that area and a closer proximity to the adjacent rack. If the rack is unhooked and held in the solution, by accident or by design, bipolar or false burn will be much more extensive. An understanding of these fundamental relationships is necessary if one is to locate the origin and cure a bipolar problem.

Bipolarity & Llive Leads – Full Automatic Lines

Probably the bulk of bipolar problems that a suspecting plater or serviceman is exposed to are those associated with return type or so called "full automatic" machines. Generally, the manufacturer makes provisions for the installation of a live lead on the exit end of the nickel tank and a special live lead for entrance to the chromium. Even at that, malfunctions, bad maintenance and misunderstandings as to how these live leads work or should work in order to avoid bipolar problems, are the subject of many rejects, long hours and headaches.

All bright nickel and chromium automatics should be equipped with live leads and all live leads, of course, should be equipped with an ammeter and voltmeter. A bipolar burn, false burn or whitewash, whichever you prefer to call it, can readily be identified in this system. If the bipolarity exists in the nickel, then the false burn will be on the lower trailing corner of the rack after chromium plating. If it is occurring in the chromium, the false burn will be on the lower leading corner of the rack. This is demonstrated in Fig. 4 (Note the direction of machine travel). For proof, turn the rack around before chromium plating. If the burn moves from the trailing corner to the leading corner the bipolar current originates in the nickel. Otherwise, look towards the chromium. In either case a check of the live lead would be in order. Make sure the contact riser bar is greased to prevent chattering (current interruption) and that the shoe is making contact for the entire length. This applies mostly to side arm machines.

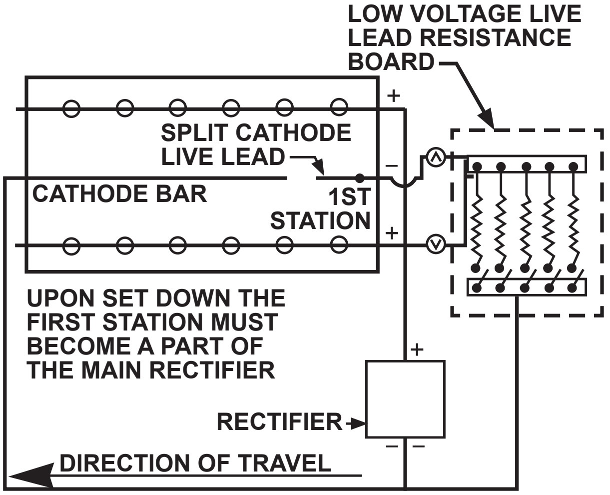


Fig. 7—Prevention of bipolarity in chromium using a reduced voltage parallel cathode circuit as the live lead.

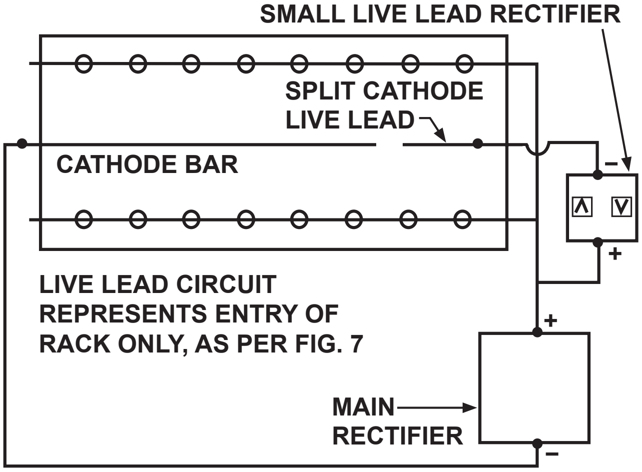


Fig. 8—Split cathode/common anode with separate small rectifier (top view of tank).

Figure 5 illustrates the mechanics of bipolarity when occurring in the exit station of a bright nickel tank. The bipolar current path is essentially the same as Fig. 2, but with this difference. Its normal occurrence is only in one station unless there is a temporary loss of contact of the other racks as they travel toward the exit. For example, in the nickel tank, it would happen in the last station, and on the shaded area as indicated in Fig. 4. We have offset the exiting rack to indicate a complete cathode disconnect. Let's do it this way to simulate a malfunctioning or non-existent live lead. The current now flows from anodes A, B, C, D, E and F and will feed current through rack #3 to rack #2, placing an anodic or reverse current on those areas marked with a plus. The result, of course, is passive nickel and false burns (bipolar burn) after chromium plate.

The thought, we are sure, has already occurred to you that the simple solution to prevent bipolarity in the nickel tank is to remove the anodes from the exiting or last station. In this, you would be absolutely correct. However, remember that when you remove the anodes, the rack becomes a low current density, dummy, and let's see you try to chromium plate that! The usual results are low- to medium-current density white staining after chromium, with more than the usual amount of misplate thrown in.

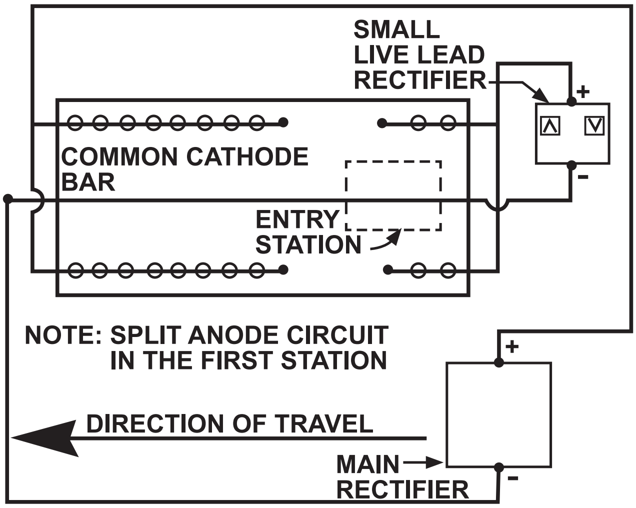


Fig. 9—Common cathode-split anode with separate small rectifier (top view of tank).

A live lead installed to correct a bipolar problem in the exit station of a bright nickel tank is quite simple and, usually, full tank voltage is applied as it lifts out. (Normally, higher current density nickel deposits contain less impurities and brighteners. Therefore, most installations prefer exiting at full tank voltage to take advantage of the more active nickel deposit.

To effect this, a flexible cable is attached from the cathode bus bar directly to the lift out station in one type of machine, while other machines employ a vertical copper slide bar in the last station. With this type, an extra shoe is added to the side of the existing shoes on the carrier, which maintains contact with the slide bar as the rack is lifted from the last station. This vertical copper slide bar is spring loaded from the side or back in order to maintain a positive contact. In other types of machines, it is sometimes more complicated, imagination and engineering skills may be necessary. At any rate, a live lead is a necessity along with the proper ammeter and voltmeter.

Types of Live Leads for Chromium – Full Automatic Lines

A live lead installed to prevent bipolarity as the rack enters the chromium tank is much more sophisticated and delicate, requiring closer control, more equipment and some knowledge of just how a chromium bath thinks. Live leads for chromium take many different forms. These are listed later with some comments on experiences the authors have had in working with them. Entry into the chromium can be by the way of vertical slide bars or flexible cable in much the same manner as nickel, described above.

To simulate bipolarity in the chromium tank in a full automatic, refer to Fig. 6. Put rack #3 back in place and offset rack #1, which would be the entry station. The anodes A, B, C, D, E and F will now feed through disconnected rack #1 during entry, to rack #2, causing a bipolar passivation or false burn on the lower leading corner (left in the diagram) of rack #1.

Before considering the live lead for chromium, we must recognize the fact that we cannot enter the chromium tank with a rack that has full plating voltage applied to it. To do so would result in what we call a *flash burn*. Its appearance is very similar to a bipolar burn but is the result of applying too much current to the *very first point of the part entering the solution*. As you can clearly see, this could appear at any place at the bottom of the rack and on that piece or pieces which first encounters the chromium solution. We must therefore enter the chromium solution at reduced voltage, not only to prevent this, but also to supply some activation before initiating full chromium plating voltage.

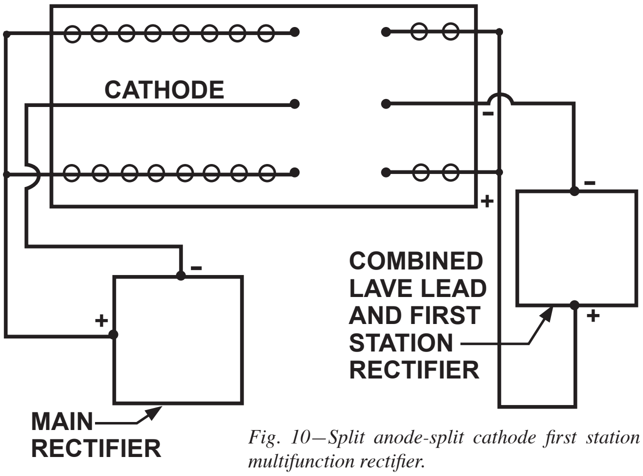


Fig. 10—Split anode-split cathode first station multifunction rectifier.

Proper entry voltages for all live leads described in the following paragraphs will be between 2.0 and 3.5V_{DC} with the normal more closely approaching 2.5V_{DC}. This voltage should be observed and standardized when the rack is immersed about halfway into the chromium solution. Proper voltage is where good work is obtained, and will be a matter of cut and try, since there are many variances from installation to installation, as well as variances in rack sizes and area.

The first and oldest type of live lead used for the prevention of bipolarity in chromium was the use of a parallel circuit from the main rectifier with parallel knife-switch rheostats in series with the load so that the proper entry voltage can be chosen. This type of resistance board can be adapted to any size of machine. Small machines would probably require up to 10A, while medium size automatics conceivably might require 25A. Large, double file automatics with large rack areas sometimes require as much as 50A. Generally, five positions are sufficient, and the resistor wires should be calculated to provide the necessary division of current. Remember, the total for this current is a function of average tank voltage and the right choice of parallel resistors. Your electrician's advice and experience will be necessary if you plan to fabricate your own. Again the amperage reading should be taken when the rack is about halfway submerged. Figure 7 illustrates this type of live lead.

This system is nowadays almost obsolete and has one operational drawback. As the area of the work in the chromium tank varies, the main rectifier voltage and amperage must be raised or lowered to prevent burning or misplating of the work, thus causing a corresponding rise or fall of power in the live lead current. Accordingly, the live lead voltage may need adjustment. Otherwise flash burning, as described in the preceding paragraph, can occur. In the opposite direction, white staining can occur in the medium to low current density areas when this voltage is too low. It is very important to note here that low current density and medium current density staining can have many other sources, but since this is a matter for another subject, it cannot be included here.

Split Cathode – Common Anode/Separate Small Rectifier

The second system, and the most popular type today (Fig. 8), utilizes a split-cathode live lead for the first station with a separate, small auxiliary rectifier, well filtered to reduce ripple. The rectifier can be of the laboratory type 6V, and from 5 to 50A capacity, depending upon conditions previously discussed. Note that the anode is common to both rectifiers, while the cathodes are only common when the machine sets down. This system provides for excellent current and voltage control and normally needs very little adjustment even though tank voltage is varied to accommodate smaller or larger loads.

Common Cathode – Split Anode/Separate Small Rectifier

Another system which one rarely sees is the common cathode, split anode bar (Fig. 9) with a separate small live-lead rectifier. Here, again, a small rectifier would be used (as specified for Fig. 8) to provide the proper entry voltage into the chromium. Frankly, there is no real advantage to this system over the others and it is not recommended because it has been the authors' experience that so-called stray current problems are more prevalent, probably because the two anode systems are at different voltages, especially when the first station is empty. In all cases, one set of anodes is anodic and the other cathodic and plating can take place between them. Trouble shooting in this system, when grounds are present, has been difficult. Although the cathode is common at all times, the entry current can still be controlled since the anode bars are split.

It should be noted that in this system, when the rack sets down in the first station, it will have only the low amperage and voltage of the small rectifier, since the anode bar is split. Therefore, this system should only be considered where the rack moves almost immediately from the first station into the second station upon setdown. The delay time at the low amperage should be a 5-sec duration or less. Otherwise there will be a sensitivity to low current density and medium current density staining as discussed under the section "Bipolarity and live leads – Full automatic lines."

Split Anode/Split Cathode – First Station Multifunction Rectifier

Another basic system that is being used is the split anode-split cathode system using a multifunction first station rectifier (Fig. 10). This rectifier supplies the current for the live lead and must be timed to the synchronous movement of the machine so that it performs the following sequential functions:

1. Low voltage entry-approximately 2 to 3V.
2. Ramp or slope up to strike voltage (Ramp-up time, 5 to 10 sec).
3. Hold strike voltage for 5 to 10 sec at 40 to 60% more voltage than normal.
4. Return to the normal plating current density of the first station.
5. Transfer to the second station and main rectifier.

The advantages of this system are:

1. Better nickel activation by virtue of the scrubbing action of the hydrogen gas which is liberated in each area of the part just prior to chromium deposition.
2. The programmed strike voltage increases chromium coverage.

Some of the problems that can develop in this system are:

1. Arcing may occur when transferring from station one to station two, depending upon the type of equipment involved. This can sometimes be taken care of by reducing the voltage on the first rectifier just prior to transfer.
2. Plating of the anodes between station one and station two may occur as explained under Fig. 9.
3. This system is not recommended for the average plating shop or automatic but only where severe problems of coverage or activation are encountered

To prevent burning of the work if there is a wide variance in rack area and sizes, the work should be grouped and the rectifier voltages changed or a constant current density rectifier may be used. A word of caution is in order. Silicon controlled rectifiers (SCR) should have ripple correction at the low voltages since heavy ripple can strongly influence the quality of the chromium deposit. In any event, you should contact your rectifier supplier and ask him to provide you with the proper information in order to avoid this problem.

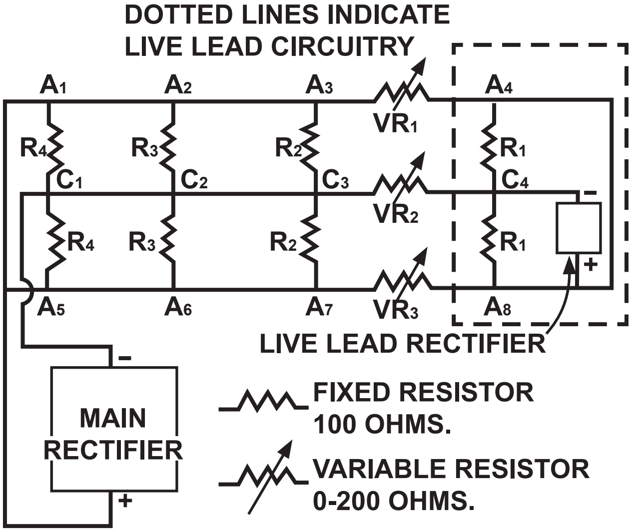


Fig. 11—Simulated chromium tank for experimentation.

In all the foregoing systems, once the rack has bottomed out in the first station, the delay before initiating either full plating current density or before initiating ramp (slope) control should be less than 5 sec. Failure to do so can sometimes result in low current or medium current density staining. Once again, this time is dependent on various factors. These would include bath parameters, type and condition of bath and the like.

Before leaving the subject of bipolarity in chromium, one important consideration should be noted. Removal of the anodes from the first station in the chromium has also been used to avoid bipolarity. This is truly a form of Russian roulette since it is usually a means of obscuring some other problem. One often finds that as the plating parameters change, other problems unfold and experimentation is again needed to find a suitable arrangement of current, time, bath ratio, anodes and temperature before acceptable work can be obtained. For instance, the arrangement after a day of work might be one anode on one side, with very little tolerance as to how far it could be moved one way or the other along the anode rail, and a complete failure of this system the next day.

The authors found out early on that the most you get out of doing this is sore muscles and a few days' grace before the game of musical anodes starts again. It may take a lot of looking, but correction of the problem at the origin is usually the best solution. If you have no anodes in the first station and consistently produce good work, my only comment is "lucky you."

If any readers have an academic interest in live lead circuitry, you can breadboard a circuit which simulates a chromium tank, and by the use of batteries or rectifiers and one or two volt-ohm-milliammeters (VOM), and provide yourself with background information on how live lead voltages and amperages are affected by changes in tank conditions (Fig. 11).

This represents a purely resistive load and simulates a split anode-split cathode live lead system. The resistors were standard 1/2 watt 5% 100-Ω resistors. The connections were made using Fahnestock clips for easy insertion of a milliammeter. Variable resistors VR_1, VR_2 and VR_3 were approximately 0 to 200 Ω.

Points A_1 through A_8 represent the anodes while points C_1 through C_4 represent the cathodes. Resistors R_1 through R_8 simulate the resistance between anode and cathode and are a much larger value than the normal resistance between anode and cathode.

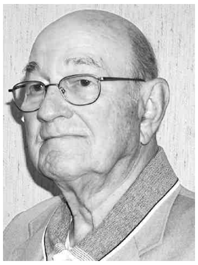
These were selected so that small power supplies could be used without burning up resistors. The live lead circuitry is enclosed by the boxed-in dotted lines. It may be a little difficult to think of points such as A_1 and C_1 as being an anode and a rack until you remember that anodes and racks are only points at which the current enters or leaves the solution and the resistors represent the resistance of the solution between them.

With modifications and imagination, this setup can simulate almost any type of live lead previously described. In addition, by using two power sources of different voltages, we can more closely simulate tank conditions. Resistors VR_1, VR_2 and VR_3 are shown as variable resistors, and would represent the resistance of the solution between racks in the case of VR_2, and between the anodes in the cases of VR_1 and VR_3. In our previous work, the authors recall having something like four pages of figures indicating current flow and voltage differences under the various conditions involving the multitude of variables one can get into in a live lead system.

Remember, you can remove, change or vary any resistance along with two voltage sources, and by insertion of an ammeter and voltmeter, polarities and current flow can be demonstrated. For example, to convert to a common anode-split cathode, just remove resistors VR_1 and VR_3 and replace with a bare wire. Have fun!

To be continued … *The second installment of this article will be published next month (July 2004).*

About the Authors



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Jeffrey Guernsey attended Ferris State College in Big Rapids MI. He served for 8 years in the United States Coast Guard as an electronics technician in the Great Lakes area and New York City. After leaving the USCG he joined Electroplating Consultants International and has obtained his CEF-SE and an Associates degree in chemistry and is currently Chairman of the AESF Tulsa Branch and president of Electroplating Consultants International.