Troubleshooting Decorative Electroplating Installations—Part 1

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To help practicing electroplaters better cope with electroplating problems that occasionally happen in their plating lines, an attempt was made to analyze the causes of problems and offer answers in the most practical possible fashion. Because of the large number of possible plating variables and the complex nature of some electroplating systems, a generalized, systematic approach to troubleshooting is presented. For reasons of clarity, no theoretical explanations are offered and technical language is used in the simplest and most straightforward form. A decorative nickel/chromium system is used as an example, with the emphasis given to the preplating and nickel electroplating step sequences. Troubleshooting of the final chromium electroplating step is given elsewhere in detail.[1]

It is far better to avoid trouble by practicing close control than to have to remedy problems. The Chinese thought it wise to pay a doctor to keep them well and pay was withheld when illness occurred. The analogy with electroplating may not be immediately obvious, but, logically, control of electroplating operations by a master plater, or a trained laboratory staff, affords insurance against troubles that may cause costly rejects or shutdowns.

Successful decorative electroplating is not for amateurs. There are many technical pitfalls, some of which can be solved by book learning, but others can be overcome only through experience. A master plater, and even more, the troubleshooter, is one-third artist, one third technician and one-third technologist-—a rare breed indeed! One must have an integrated worldview of the whole of the deposition process, not just the electroplating steps. Base metal composition, heat treatment, cleaning and activation cycles, intermediate electroplated layers, the addition agent system(s) employed, etc., are all factors that can affect the appearance and properties of the final decorative deposits. Despite this, it is not witchcraft. Many dedicated scientists and practical technologists have spent years unraveling the solutions to many of these mysteries using established scientific methods.

Mysteries indeed remain and likely always will, but the true expert master-plater has studied the technical literature and has solutions to many problems at his fingertips. True, it may appear magical, but advanced technology will seem magical to persons lacking the broad expertise needed. Decorative Ni-Cr electroplating is no exception, and while it may conceptually seem a straightforward type of electroplating, it can, in reality, often be rather difficult and challenging.

Why, then, is there still so much mystery surrounding trouble-shooting of, for example, bright, decorative nickel electroplating installations? There are at least eight reasons:

1. Nickel is perhaps the most used and versatile metal in the electroplater's repertoire. It has been in use more than 125 years. It is an essential element of any Cu/Ni/Cr or Ni/Cr decorative system from both practical and theoretical points of view. Advancements in Ni electroplating technology have expanded utility and value of the process while increasing diversity and complexity of electroplating lines. The quality of base metal and nickel thickness have been kept barely acceptable. This in turn caused the speed of electroplating lines, current densities and brightener concentrations to be maximized, which together artificially made the process *more difficult to control.* The need for reliable technical information about electroplating processes is more critical than ever.
2. Rack electroplated, bright nickel is seldom used alone as a final finish. It is usually applied in combination with one or more other metallic deposits; for example, as part of the series that can consist of cyanide, acid copper, semibright nickel, bright nickel, particle nickel, and chromium electroplated layers. Consequently, this multiplicity of electrodeposits and processing steps contributes inevitably to the *complexity* of the system and to concomitant troubleshooting.
3. The bright nickel bath itself contains several ingredients, including *multiple addition agents* used to force optimum leveling and brightness. Any journeyman troubleshooter can testify to the geometrical increase in difficulty of controlling any process bath as the number of components increases. All this makes problem solving rather more complicated than just locating a given problem in the left-hand side of a column on a troubleshooting chart and matching it to its unique cause in the right-hand side where general or most common answers are given.
4. Many faults that occur early in the processing cycle are not detectable on parts until they are at or near the end of the complete cycle. The most obvious example of this is inadequate cleaning that is not evident on a part until after it is electroplated with bright nickel. This *lag effect* complicates the task of pinpointing the true source of trouble.
5. To further complicate matters, the same electroplating defect can result from several different sources. Of course, all electrodeposition baths exhibit this problem of source identification to some degree, but perhaps few to the extent of a bright nickel electroplating solution. For nickel, usually *several possible causes* can yield any given imperfection. Thus, matching problems with their causes is not as simple as it sometimes appears.
6. Bright nickel electroplating is an *unforgiving and sensitive* process. Many minor faults that are invisible to all but the most discriminating eye have a significant effect on the quality of the final finish. Likewise, the electrolyte has no inherent cleaning ability of its own, so there is very little room for error in the pretreatment cycle compared with some other finishing processes.
7. Some problems can go undetected for some time before they affect quality to the point where rejects occur. For example, it may take a number of hours or days before a deficiency in the cleaning cycle can drag or carry enough impurities or soils into the nickel electroplating solution to cause noticeable rejects. Such *delayed effects* as this can make it acutely difficult to identify the real source of trouble.

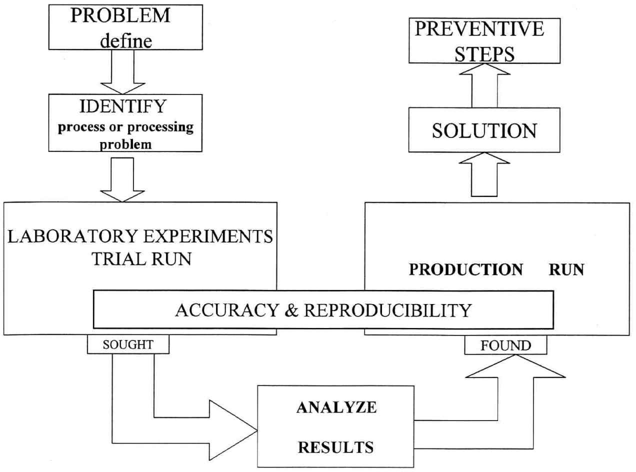
8. At times, more often than not, suppliers of proprietary nickel electroplating processes have not been especially forthright in passing on troubleshooting and technical service information to finishers. This *lack of information*, is generally a carry-over from the days when suppliers passed on only a minimum of operating information to customers, thinking that this would increase their worth and importance in the customers' eyes.

Rationale

Unfortunately, there is a lack of worthwhile articles offering an extended discussion of essential practical troubleshooting methodology. There are two noteworthy exceptions, however, that deal comprehensively with troubleshooting of bright nickel electroplating installations.[2,3] Nevertheless, only relatively few other references have properly emphasized what must be done to overcome the natural complicating effect that the above considerations have on troubleshooting situations. Instead, troubleshooting articles usually consist of extensive lists of faults, causes, and remedies that apply to bright nickel processing lines, without describing an orderly and systematic approach to troubleshooting in general.

This does not mean that these sources of information are inconsequential and unimportant. They can be consulted and used in all problem-solving situations. Attempting to use them, however, without systematically narrowing the scope of investigation can be inefficient and time-consuming. Time is a precious commodity when electroplating lines are down. Minimizing the scope of a troubleshooting investigation calls for generating a questionnaire of essential inquiries. This helps focus the investigative effort toward those steps in the total processing cycle that are the most probable location(s) of problems. A secondary benefit to this approach is that it organizes the thought process in a manner that eliminates much of the unnecessary mystique, fiction, and sometimes drama, that are associated with troubleshooting and problem solving (TPS) electroplating installations.

Clearly, because no two electroplating installations are the same, there is no such thing as a universal questionnaire that applies to every electroplating production line. Undoubtedly, there are certain questions that would apply in every case, but there are also other questions that apply only to a given installation. Accordingly, each plant must generate its own list of questions that consolidate both matters that are universally applicable, as well as those idiosyncratic questions that are unique to the given installation and to parts that are processed.



Design of troubleshooting process.

A series of sixteen suggested basic steps is offered, eight of which are given in this installment. They should prove helpful in generating such a questionnaire, one that will be most helpful in reducing the time needed to identify and resolve problems.

Troubleshooting Methodology

I. Identify the problem.

II. Define the problem:

Process problem?
Operational (processing) problem?

III. Correct the problem.

IV. Test solution of problem.

V. Record corrective steps.

VI. Set up procedure to prevent recurrence.

1. Confirm the existence of a problem

Random occurrences of defects should not be mistaken for typical production performance. Once there has been confirmation that *there is a problem*, the extent to which the problem exists should be identified.

The recommended objective analytical approach to troubleshooting of electroplating processes is vital, both for the troubleshooter/problem solver, and for training and teaching plant personnel to troubleshoot their own processes.[4] This is described in general form in the figure. The causes of problems can be divided into two general categories: process problems and operational problems. For this discussion, process problems are defined as deviations from the recommended control range of solution chemistry. It is important, while searching for solutions to a problem, to keep in mind that something *has* changed. The obvious task is to pinpoint what has been changed, and then develop a remedial response. On the other hand, operational problems can be outlined as defects initiated from sources other than the electroplating bath chemistry itself. The table lists six steps of the troubleshooting methodology involved for a broad, but systematic approach to troubleshooting electroplating lines.

2. Defining the type of problem

Despite all the previously mentioned factors unique to decorative nickel electroplating that complicate troubleshooting efforts, there is only a finite number of defects that occur on a bright nickel electroplating line. The following is a partial list of problems that covers more than 95 percent of those commonly encountered:

a. Stains, hazes, clouds or streaked patterns
b. Darkness and/or dullness of as-plated deposit
c. Pitting
d. Roughness, on a micro or macro scale
e. Poor adhesion, laminations, peeling and blistering
f. Poor coverage of nickel or chromium deposits in low-current-density areas
g. Brittleness and/or "burning" of the plated finish
h. Reduced cathodic and/or anodic efficiency and low electroplating speed
i. Insufficient leveling
j. Orange peel

The *type* of problem must be defined before consulting the reference information that lists the various causes and remedies of many electroplating defects, or one's own experience.

3. Extent to which the problem exists

Once the existence of a problem is confirmed, the next step is to identify the *extent* of it. Is it evident to the same degree on all processed parts, or just a few? Unless there is a gross malfunctioning of the line, problems rarely occur on every piece; however, when this happens, it usually results from a single major fault, such as one of the rectifiers being turned off, or a temperature being too low or too high in one of the processing tanks.

In addition, it is important to determine where on the part the defect can be seen: on all surfaces, on horizontal surfaces, or just on vertical surfaces? The more evident the problem is on all surfaces, the more likely that it is the result of a single and often major source. Likewise, problems that occur only on horizontal surfaces usually result from the presence of solids in one of the processing tanks—generally either in the copper tank (if copper is a part of the total processing line) or in the nickel tank. Another possibility is that the resulting roughness is caused by lifting parts through a layer of soils that has collected on top of one of the processing tanks, most likely in one of the cleaning tanks.

It is also important to determine at *what current densities (CD)* the problem is most apparent. Can it be seen at all current densities? Just at high CD or just at low CD? As a rule, problems that are evident at all CDs are the result of faults in a processing step other than one of the plating tanks.

4. Where on the rack does the defect occur?

If parts are rack-processed, is it at the top, the bottom, the center or at the corners? If the problem occurs at a corner of a plating rack (fixture), is it the corner that exits the various processing tanks first (*i.e.*, the leading edge), or last (*i.e.*, the trailing edge)? Problems that occur only on parts taken from the top or bottom of a rack, but which are not necessarily current density specific, usually are the result of insufficient or excessive time in one of the pretreatment steps. Another possibility, when a problem is evident only on parts taken from the top of a rack, is that the solution level is too low in one of the processing tanks. Problems that occur only on parts taken from the center of a rack are generally low-current-density related, and usually result from a problem originating in one of the electrified processing steps: an electrocleaner, an electrolytic activator, or one of the electroplating tanks.

Problems that occur on parts racked in the leading edge area of a plating rack (fixture) generally result from electrical faults in the entry area of a chromium electroplating tank.[5] Similarly, defects evident on parts racked in the trailing edge area are usually caused by electrical problems in the exit area of a nickel plating tank. Reversing the position of a rack after it exits the nickel tank, but before it enters the chromium tank will usually confirm these suspicions. If a leading edge fault remains in the same area on the rack after reversing the leading and trailing edges, it usually means the problem exists in the chromium tank. On the other hand, if the location of the problem moves upon reversing the position of the rack, the nickel plating tank is usually the source of the problem.

This list of questions is, of course, not all-inclusive. It should be complete enough, however, to illustrate the type of qualifying questions to ask to properly *define* the difficulty so that problem solving efforts can be more efficient.

The easiest problem to solve is the one that occurs on every processed part, but this rarely happens. Generally, a problem is only evident on a portion of the production parts. As a result, a systematic, analytical approach is necessary. The place in the total processing cycle where the fault can be seen must be identified; then the procedure is to work backwards from this point, examining each step of the cycle to pinpoint the prime location and cause of the trouble.

5. Selecting the best testing methods

Tests must be selected that will provide the greatest measure of information, while *expending the fewest parts.* This minimizes costs, as well as simplifying data analysis. For example, it is often helpful to switch the position of two racks in the cycle to determine the effect of skipping a given step in the total cycle. In these cases, it is most efficient to couple the testing of the results of eliminating one step in the total cycle, with the effect of doubling the time spent in another processing step. After identifying these two steps, the racks can be switched back from these portions of the cycle.

In general, plating defects that are current-density-specific result from something that is out of specification in one of the electrified processing steps. The easiest way to determine whether a given step in the cycle is causing the current-density-related problem is to reposition the parts on the plating fixture while they are in this particular portion of the total cycle. In these cases, it is obviously not necessary to move entire racks. Simple transfer of parts from one location on a rack to another location on the same rack will do (*e.g.*, from a high-CD area to a low-CD area, or from the front to the back of the rack). If the location of the problem changes as the location of the part on the rack changes, it is reasonable to assume that something is happening (or not happening) in one of the electrolytic steps ahead of this portion of the cycle and causing the given defect. Likewise, if the defect does not move with the part, but remains in the same location, it is reasonable to assume that the processing step in question is causing the difficulty, or at least contributing to it.

Another useful test is simply to rotate the part 180° to transform the top surface before a given step to the bottom surface. This is an especially practical approach in instances where shelf roughness is a problem and the task is to determine the particular step in the total cycle that is creating or introducing it. In these cases, it is easy to test whether a single step is responsible for the roughness by rotating a part just while it is in the tank in question. The part should be examined after it has completed enough of the total cycle to the point where the defect can be seen. Obviously, this same approach will test specific process steps for pitting tendencies.

Changing the location of a part on a rack, or its position, is not always the best way to test whether given steps in the processing cycle are causing difficulties. In cases where hazes or cloud patterns are evident on parts after plating, the pretreatment portion of the cycle is often the source of trouble. The most effective way to screen the individual steps of the pretreatment cycle is to partially wipe an area on a part just before it enters the questionable tank. If the hazes or clouds cannot be seen where the part has been wiped, but are still evident in the adjacent areas, it is logical to assume that the pretreatment cycle is not removing a deleterious, residual film responsible for the haze or cloud. By using a white paper towel or rag, it is easier to observe when the hand wiping removes soil or smut. Correspondingly, the wiping process must begin immediately ahead of the first plating tank after which the defect can be seen, then systematically worked backwards from this point to identify the step in the total cycle that is responsible for the residual film. If wiping with a paper towel or rag has no effect on the haze or cloud, the same process must be repeated, using more aggressive cleaning, such as with a clean Scotchbrite™ pad. If this eliminates the problem, it is safe to assume that the interfering film is quite tenacious and a more vigorous pretreatment cycle should be considered.

If wiping parts with a Scotchbrite™ pad does not remove the haze or cloud, it is more than likely that the problem is not a result of anything occurring in the preplate portion of the plating cycle. Instead, the plating and post plating portions of the line should be evaluated.

6. Variation of one parameter at a time

This is one of the most important guidelines to follow. Admittedly, this is many times difficult to do in the face of often-extreme pressure to restore full production capability as rapidly as possible. Nevertheless, changing conditions one item at a time is the only method to obtain a positive answer a problem. Changing several things at once may more quickly eliminate the difficulty, but it does not provide an exact identification of which change had what effect on overall quality. In other words, it does nothing that will lead to a permanent solution to the problem. Worse than that, it does nothing that will simplify solving the same problem the next time it occurs.

7. Maintaining limited production

Problem solving is difficult, if not impossible, without processing actual production parts, even when it involves generating a limited number of rejects. Moreover, problem solving is much easier when there is an uninterrupted flow of work through the line. Repeatedly filling and emptying a processing line may produce fewer rejected parts, but it also introduces more variables that complicate problem solving. This is notably true in cases of electrical problems. The only way of properly investigating them is by testing when there is a rack at each station in the line. Operating with a series of empty stations will produce entirely different results.

Another approach to restore at least limited production is to go back to a process cycle that has worked in the past. If this cannot be done, experiments can be tried with different processing cycles, such as double cleaning, and/or acid dipping or by using longer plating times. The extent to which these changes can be carried out depends upon the physical limitations of the line involved. Another possibility is to operate with fewer parts on each plating fixture or workbar.

There are times when problems are evident only on parts of a certain size or configuration. In these cases, another option is to run as many parts as possible that can be processed without problems, but simultaneously to allow processing of a limited number of the parts that exhibit the given defect. Otherwise, there is no method to measure progress. Of course, the long term goal is to resume normal production. In the short term, however, operating with an altered cycle that allows limited production is better and often less traumatic than losing production entirely.

8. Off-line testing

When feasible, as many things as possible should be tested off-line. It should include as many steps in the total cycle as workable, including often overlooked rinse tanks and even drying steps, if they appear to have any effect on the observed defect.

The most important consideration is to *duplicate* production conditions as closely as possible. In particular, it is critical to match dwell times, traveling times above the various processing tanks, and transfer times between tanks. It is also important to try to match the amount of agitation that occurs when processing pieces on-line. Often, the easiest way to isolate a single processing step, while duplicating the remainder of the production cycle (including dwell times, transfer times, CDs, etc.) is to use an auxiliary, small, off-line processing tank. A tank, or even a lined 55-gal drum, can be placed next to the production tank that is to be bypassed in a given test. The test consists of removing one or more parts from a rack as it is about to enter the tank in question and running them in the auxiliary tank instead, while carefully matching processing parameters. As the rack exits the regular processing tank, the parts are removed from the test tank and replaced in their original locations on the production fixture. The location of each piece processed in this manner should be marked, and the number of the workbar or hanger to which the rack is fixed should be recorded.

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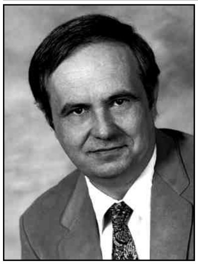

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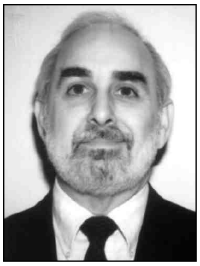

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