Troubleshooting Decorative Electroplating Installations - Part 2

N.V. Mandich & W. Saas

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 fashion possible. 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.

Continuation from the June 2000 issue:

9. Laboratory plating tests

The Hull Cell is an important and useful tool for day-to-day solution control, especially for trouble-shooting. It is an extremely powerful test method, regardless of its basic simplicity, especially when compared with other electroplating controls, such as titration, electrochemical instrumental methods, or spectrophotometry, all of which usually measure one variable at a time. A single Hull Cell (HC) test, or short test series, can potentially show the limits of the acceptable electroplating current density ranges, detect the presence and amounts of organic and inorganic impurities, leveling, throwing power, approximate concentration of primary constituents, and addition agent concentrations. It can also be used to control deposit morphology, alloy composition as a function of current density, agitation effects, average cathode efficiency, evaluate covering power of competitive electroplating systems, appraise competitive additive systems as to their brightness, electroplating range, heat stability, life, compatibility, etc., as well as other variables. One does not need to be confined only to the visual examinations of HC panels. For example, hardness of the deposit can be tested under different electroplating conditions, (*e.g.,* CD) in which there is interest. Similarly, the deposition thickness, porosity, throwing power, and many other properties can be tested on the panel under different, defined conditions.

Producing and interpreting Hull Cell or other electroplating cell panels requires only an average amount of skill, but at least a fair amount of experience. For this reason, line operators or foremen should be encouraged to collect and save panels that exhibit various faults for future reference.

The tests in the Hull Cell and similar testing cells are, in essence, qualitative procedures that provide semi-quantitative or quantitative answers. The qualitative answers are obtained from observations of plated panels. For example, when the electroplating bright range is found to be reduced in the low CD area of the panel, it is likely that concentrations of brightening addition agents are low and that an adjustment is needed. Similarly, a rough, dark, and irregular appearance in high CD areas may indicate metallic impurities. Pitted deposits often suggest the need for a reduction in surface tension, accomplished by adding wetting agents to the bath. Cracked deposits often mean that excessive addition agents, or a high concentration of decomposed addition agents is present. Poor coverage in low CD areas can be the result of the same fault.

Managers and supervisors of plating operations need not actually perform HC plating tests themselves, but they should nevertheless be able to discuss and interpret the results of such tests intelligently.

10. Selection of best testing methods

The most effective test to be used is the one that provides quick results that closely duplicate the problem that is seen during full production. This prevents wasted time and effort "chasing ghosts." As mentioned before, ideally, when testing, the regular processing cycle should be used for everything but the individual cycle step under investigation.

If off-line testing does not duplicate the problem using standard test samples (*e.g*., Hull Cell panels), running production parts in an auxiliary tank is in order. If parts are too large to allow this, the next best alternative is to run small sections cut from production parts, using racking geometry that approximates production conditions. If the problem can be seen at this point, logic suggests the problem cannot be the result of any of the processing steps that follow the one under study. In addition, since the fault was not apparent on another base metal (*i.e*., the Hull Cell stock), a parameter may be of the range that only has an effect on certain base metals. An example would be too high a temperature, pH or concentration of the cleaner(s). It is unlikely that this would have a measurable effect on steel-based metal parts, but it could have a significant effect when processing copper, bronze, brass, or die-cast parts through the same cleaner.

If, alas, off-line testing still cannot duplicate the defect, instead of testing in the off-line tank, the next step is to try running parts of a known-quality base metal on the production line in place of regular parts. Hull Cell panels are usually accessible and offer the additional advantage that they allow for the complete elimination of the cleaning cycle. The thin zinc coating on the panels can easily be removed in a small volume of freshly made-up acid. Wiping parts with a clean, wet sponge or towel will remove any smut on the surface and provide a reproducible part that can be inserted into the production line immediately ahead any of the processing tanks. If this is properly done and the problem can be seen on Hull Cell stock, it is safe to assume the tank under study is the source of the difficulty.

11. Recognition of the most influential parameters.

It should be remembered that all the parameters that can be measured on a processing line do not have an equal impact on quality. In a nickel plating solution, for example, the parameters that have the greatest effect on performance are those that can change the quickest: pH, temperature, agitation patterns, concentration of the secondary brightener portion of the addition agent system, current to the cathode, entry and exit currents on nickel and chromium plating tanks, etc. Accordingly, these are the factors to examine first when faced with a troubleshooting/problem-solving situation. Only

after examining these aspects is there reason to check the other operating parameters.

It is important to keep in mind the *degree of change* that each of these parameters can undergo before it will have a significant impact on the line performance. For example, a 10-percent change in pH or temperature will have a much more dramatic effect on quality than will a 10-percent change in boric acid concentration.

12. Records must be diligently documented & maintained

The results of all tests and observations, including the results of modifications made to the total cycle that have no apparent effect on the problem, must be recorded. Production parts must be labeled in a manner that reflects the differences in processing cycles, or steps that have been screened, regardless of whether they have a noticeable effect on performance. It must be remembered that it is often just as valuable to know which steps have the *least effect* on total performance as it is to know which ones have the greatest effect. Also, it shoud be kept in mind that changing just one or two steps in a long electroplating cycle seldom solves most troubleshooting situations. Usually, several changes must be made before a problem can be accurately identified and the appropriate alterations made to the cycle to eliminate substandard work. This must be done in a stepwise fashion, and the only way to keep track of each modification is to document everything by writing it down.

13. Objectivity

Experience has demonstrated a number of times that independent thinking must be exercised that permits stepping back from the proverbial trees to see the forest. The troubleshooter/problem-solver must be objective. The problem-solver cannot approach any troubleshooting situation with the attitude of already knowing the cause of a particular problem before starting any tests. It is important to make the most efficient use of prior troubleshooting experiences, but not if it means losing objectivity. To solve a problem permanently, the troubleshooter must identify and treat the cause, not the symptom. This can be accomplished only by maintaining an unbiased point of view.

14. Domino & Additive Effects

In addition to the previously mentioned time lag and delayed effects, there is always the possibility of experiencing additive and/or domino effects. In the former case, each separate process step or bath condition is slightly out of balance in such a way that it interacts with other steps to produce the overall defect. An example would be a weak acid dip after nickel plating, plus insufficient activation in the beginning of the chromium bath, resulting in passive chromium deposits ("white wash").

In the case of domino effects, problems in one process step negatively affect a following process. An example would be overcleaning in the anodic electrocleaner, which can darken or even slightly etch parts being processed. This, in turn, can lead to an (erroneous) overdose of a brightener, which produces a residual brightener film on insufficiently rinsed parts. If activation cannot completely remove this film, the final chromium deposit can exhibit "white wash" chromium hazes.

These simple examples show that the entire process must be methodically checked. If not, problems might only be partially fixed, a "Band-Aid" approach, soon to reappear or change for the worse. Some problems are fairly simple and straightforward and can be logically solved with standard background knowledge. For other problems, only the most skilled experts may observe and connect the discrete bits of data into quick, practical, and workable solutions.

15. Knowledge

Persons in charge of electroplating departments, electroplating engineers and chemists—even ambitious master-platers—must be in the forefront of knowledge in their fields of expertise. Book knowledge is not reserved solely for academicians. It is expected of them to be up-to-date, even ahead, of their own staff experts. Those who expound the virtues of a traditional electroplating technique will be regarded as passé by coworkers, or worse, by their superiors as well. One essential area of knowledge is "hands-on" knowledge, supported by close familiarity with recent technologies. Too many electroplating engineers, chemists, and master-platers subscribe to old myths that have been dispelled by previous studies. They need to keep up with the recent technical literature, therefore, or they will be purveyors of obsolete traditions. Clearly, they need to be well versed and proficient about the latest electroplating developments and new and emerging technologies. If, for example, a marketing department asks about the merits of composite deposits, or pulse-reverse techniques, or trivalent vs. hexavalent decorative chromium electroplating, one cannot beg off with a "Let me check at the library and get back to you later."

The most effective problem-solvers possess general knowledge across many fields, especially solid basics of chemistry, engineering, metallurgy, manufacturing, and electronics. This aids them, not only in seeing the "big picture," but also in conversing with engineers, R&D personnel, or management, in terms they understand.

An in-house library of relevant books, technical papers and troubleshooting reference information must be established, developed, and kept current. While there is a large number of books published on chromium electroplating, [5-12] there are only two[12,13] (one is out of print[13]) on nickel electroplating. Fortunately, there is an outstanding book available on the subject.[12] Also, books on analytical and process control[14-23] must be available, as well as books dealing with fundamentals.[24-29]

16. Preventive maintenance

No worthwhile discussion of troubleshooting concepts would be complete without stressing the importance of preventive maintenance. Is has been proven over and over that production difficulties and high operating costs are inversely proportional to the degree of overall control and preventive maintenance that is exercised. In other words, the more time and effort that are put into catching and solving problems while they are minor, the less difficulty there will be maintaining a high quality and efficient operation. A few simple things can be done to prevent problems before they happen:

i. Timely recording of all additions to every tank in the processing cycle. This should include dates when tanks are replaced and made up fresh, as well as when the electroplating tanks are treated to remove various impurities. Having this information is extremely beneficial. It streamlines trouble shooting and provides very useful cost analysis information, even when there are no problems.

ii. Good housekeeping must be diligently maintained throughout the plant, especially in the areas near the processing line(s). This will minimize the possibility of

foreign matter accidentally entering any of the tanks.

iii. A reference file of HC panels and parts that illustrate certain problems and their remedies. Not only is such a file an invaluable aid during the troubleshooting situation itself, it is also very helpful as a training tool for new employees.

iv. Different aspects of the processing line must be routinely scrutinized and reported. Most finishers agree that incorporating simple, but essential records, such as those listed in Table 2, into their plant practices is acutely beneficial.

Finally, the obvious question is: why aren't effective, modern preventive and troubleshooting systems, complemented with current knowledge, universally applied? It is our experience that many platers become mired in the status quo because they and/or their employees prefer a known past to an unknown future. Unfortunately, resistance to change is nearly universal. Many platers either prefer not to use the basic electroplating principles, have forgotten them, or do not know them, because the first suspicion of a problem usually results in placing a phone call to the current supplier of electroplating chemicals, potential supplier, or consultant, not necessarily in that order.

In certain situations, the problems can persist, despite efforts by the master-plater and others involved in the troubleshooting efforts. Rather than keeping the plating lines down and/or generating rejects, it may become necessary to call for an outside master-consultant who can often provide independent and unbiased judgment, and present new ideas and a fresh approach.

Conclusions

A worthwhile, methodical approach to troubleshooting electroplating problems begins with the understanding that "No effect takes place without a cause."[30] This quotation is from Michael Faraday, who literally galvanized the Industrial Revolution at the beginning of the 19th century. This is another way of saying, "The defect is the symptom, not the problem." This principle is the most important one to be absorbed by electroplaters. Understanding this principle changes the "tank jockey" into a skillful, professional finisher. The skilled master-plater, when faced with a problem, considers: "What are the *causes* of these rejects? Why is the finishing bad today when it was good yesterday?" Then the master-plater searches for and finds the causes, finds the answers, then implements corrections.

Efficient line handling and troubleshooting decorative electroplating installations, if done properly, need not be complex or unduly intricate. First, the existence and the type of problem that is occurring must be identified. The next step is to determine whether it is a process or an operational problem. Once this question is answered accurately, the search must begin to disclose the causes, to find the corrective answers, to test them, implement corrections and, finally, to set up a fool-proof mechanism for preventing future problems from the same source. The single most important rationale is establishing and following a logical procedure in analyzing the total circumstances. This can be thought of, figuratively, as drawing up a road map that creates a series of forks in the road. At each fork, one or more questions should be asked. The answers to the questions dictate which of the two paths to follow. As in the classical programmed instruction model, when the selected path does not result in the desired result, one can return to the last successful fork on the path. This process can be continued until all the sources of difficulty are identified and all the necessary corrective steps are taken to restore high quality, profitable, error-free electroplating. This approach must be used in troubleshooting electroplating systems to obtain consistently high quality and reliable production results.

Table 2
Routine Control Procedure

Control Item	Frequency of Control
Bath Analysis	Weekly
Plating Tests	Weekly (more often under heavy production)
Pretreatment solutions	Twice weekly
Solution levels	Each shift
Temperature controllers	Each shift
Ammeters/Voltmeters	Each shift
Addition agent feeders	Each shift
Anode baskets	Twice weekly
pH of Nickel solution	Each shift
Solution flow through filter	Each shift
Uniformity of agitation	Each shift

Summation of Troubleshooting Technique

The general troubleshooting technique can be outlined in six basic steps. Each step must be taken in sequence as a logical progression:

- *Analysis*—an evaluation of the available data to identify the existence of a problem.
- *Synthesis*—the development of definition and probable causes of the problem and suggestions for the corrective measures required.
- *Testing*—laboratory experiments, followed by small-scale pilot or production runs to test not only the solution of the problem, but reproducibility of the solution as well.
- *Implementation*—incorporation of the actual permanent corrective procedure into normal shop practice.
- *Preventive maintenance program*—to minimize any future problems, an effective preventive maintenance program should be established.
- *Personnel training program*—all personnel involved directly or indirectly in electroplating operations should be educated and trained in all technical aspects related to the job, including the all-important prevention steps.

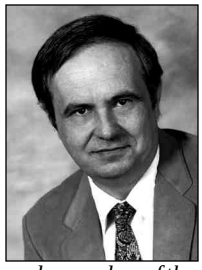
Editor's note: *Manuscript received, January 2000.*

References (continued from Part 1)

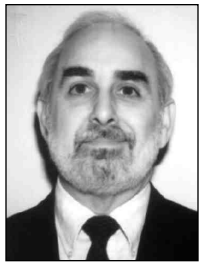
6. J.D. Greenwood, *Hard Chromium Electroplating*, 3rd ed., Robert Draper Ltd., Teddington, UK, 1984.
7. R. Morisset, *Chromium Electroplating*, Robert Draper Ltd., Teddington, UK, 1954.
8. R. Weiner, & A. Walmsley, *Chromium Electroplating*, Finishing Publications, Ltd., Teddington, UK, 1980.
9. R.K. Guffie, *The Handbook of Hard Chromium Electroplating*, Gardner Publ., Cincinnati, OH, 1986.
10. G. Dubpernel, *Electrodeposition of Chromium from Chromic Acid Solution*, Pergamon Press, New York, NY, 1977.
11. C. Peger, *Chrome Electroplating Simplified*, 4th ed,, Hard Chrome Electroplating Consultants, Cleveland, OH, 1981.
12. J.K. Dennis & A. Such, *Nickel and Chromium Electroplating*, 3rd ed., Woodhead Publishing Ltd., Cambridge, UK, 1993.
13. R. Brugger, *Nickel Plating*, Robert Draper Ltd., Teddington, UK, 1966.
14. W. Nohse, *The Hull Cell*, Robert Draper Ltd., Teddington, UK, 1970.
15. K.E. Langford, *Analysis of Electroplating and Related Solutions*, Electrodeposition and Metal Finishing, Teddington, UK, 1951.

16. D.G. Foulke & F.E. Crane, *Electroplaters Process Control Handbook*, Van Nostrand, New York, NY, 1963.
17. A.F. Bogenschutz & U. George, Analysis and Testing, Finishing Publications Ltd., Teddington, UK, 1985.
18. *Metal Finishing Guidebook*, **Vol. 95**, No. 1A, Elsevier Publishing, New York, NY, 1998.
19. *The Canning Handbook*, 23rd ed., W. Canning Ltd., Birmingham, UK, 1982.
20. *Tables and Operating Data for Electroplaters*, Portcullis Press, Redhill, UK, 1975.
21. R.B. Saltonstall in *Electroplating Engineering Handbook*, 3rd ed., A.K. Graham, Ed., 1973; Ch. 8.
22. L.J. Durney, *Electroplating Engineering Handbook*, 4th ed., Van Nostrand, New York, NY, 1984; Ch. 8.
23. R. Armet, *The Modern Electroplating Manual*, R. Draper Ltd., Teddington, UK, 1965.
24. W. Blum & G.B. Hogaboom, *Principles of Electroplating and Electroforming*, 3rd ed., McGraw-Hill, New York, NY, 1949.
25. E. Raub & K. Muller, *Fundamentals of Electrodeposition*, Elsevier Publ., New York, NY, 1967.
26. F.A. Lowenheim, *Electroplating*, McGraw-Hill, New York, NY, 1978.
27. F.A. Lowenheim, *Modern Electroplating*, 3rd ed., Wiley, New York, NY, 1974.
28. J.N. West, *Electrodeposition and Corrosion Processes*, Van Nostrand Reinhold, London, 1971.
29. J. Dini, *Electrodeposition*, Noyes Publications, Park Ridge, NJ, 1993.
30. Pearce Williams, *Michael Faraday*, Libr. of Congress Catalog Card No. 65-19542, p. 22.

About the Authors



Dr. N.V. Mandich, CEF, FIMF, is president of HBM Electrochemical & Engineering Co., 2800 Bernice Road, Lansing, IL 60438. He holds the Dipl-Ing degree in chemical engineering from University of Belgrade, Yugoslavia, M.Sc. in theoretical chemistry from Roosevelt University, Chicago and a Ph.D. in applied electrochemical engineering from Aston University, England. He is an AESF Certified Instructor and a member of the AESF Hard Chromium and Pulse Electrodeposition Electroplating Committees and a Fellow of the Institute of Metal Finishing. He twice received (1991,1995) AESF Board Recognition Awards and two silver medals for best published research papers (1997). He has published nearly 100 papers, 6 book chapters, and has 12 U.S. patents published or submitted.*



William J. Saas is president and owner of Taskem, Inc., a manufacturer of proprietary products to the metal finishing industry based in Cleveland, OH. He has been active in the metal finishing industry for more than 40 years. He has worked as a plater and as a supplier in almost all aspects of metal finishing. He holds a BS in chemical engineering and an MBA from Case Institute of Technology. He has been a member of the Cleveland Branch of AESF for 35 years and served on the Technical Education Board of the AESF for seven years, and is an active speaker at AESF Branch meetings. Mr. Saas recently completed a three-year appointment as a trustee for the Metal Finishing Suppliers Association (MFSA), and currently serves as their representative to the Government Advisory Committee (GAC), which he also chairs. He has also served as one of six Industry Representatives to the Metal Finishing Sector of the Common Sense Initiative for the past five-and-one-half years, a re-invention of the program created by the EPA.

** To whom correspondence should be addressed.*