Shop Talk

Some Production Plating Problems & How They Were Solved—Part 16

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1. Impossible figures.

We have been discussing the laws of Parkinson and Finagle, a form of technical humor. But, certainly, humor is not restricted to the written word. Since a mechanical drawing is the tool of the engineer, we should expect to find some surprises among them. As a matter of fact, there is hardly a company that does not have a drawing of some doodad created for the sole purpose of giving the shop a fit. (Hint to shop foremen: The best reply is a gigantic estimate.)

Let us have a closer



Figure 1-Impossible figures.

look at a group of drawings called impossible figures. They were thought of about 40 years ago and have been widely printed. I have selected three from a whole family of such bodies (see Fig. 1).

In sketch (a), cover the lower half, you see a tuning fork of square stock. Cover the upper half, you see three round rods. In sketch (b), cover the bottom half, you look at the top of a hollow cube. Cover the top half, you look at the bottom of that cube. In sketch (c), cover the right half, a hexagonal nut stands on one edge. Cover the left half, the nut lies flat.

What do you suppose is wrong? All of the three sketches have one thing in common. The eye sees a flat drawing but the brain interprets the lines to belong to solid objects. There would be no trouble if we could convince ourselves that these are merely flat designs on paper. We cannot. We try to compose familiar bodies with the conflicting information given. (R.L. Gregory covers more along this line in *Eye and Brain*, McGraw-Hill, 1966. Search in *ye olde* 21st century used book store, or www.abebooks.com.).

Each figure affects us differently. In the three-legged tuning fork, we can correctly interpret each end. We try

to ignore all those confusing lines in the middle. The nut seems to be bent and that satisfies us for the moment. But the cube is the most disturbing. The more you concentrate on it, the more it moves. We try to bend the edges in and out to find a stable solution but nothing helps.

Want the cube to settle down? Note that there are two spots where edges cross. Place a finger on one of the spots (either one) and the cube will straighten out. In the real world, both horizontal lines cannot be in front. We imagine the edge in the correct place under our finger.

This cube, by the way, is the work of the Dutch mathematician Maurits C. Escher. One of Europe's most original graphic artists, he has created a whole family of compositions called Relativities that you should look at only when you are sober. The cube is a small detail in his lithograph "Belvedere," one of the strangest buildings you can imagine (*The Graphic Works of M.C. Escher*," Oldboume Press, London, 1961. If not this edition, its successor may even be found in your neighborhood 21st century "big box" book store [Border's, Barnes & Noble, Chapter's, etc.] or www.amazon.com.). Perhaps these facts will help you invent your own doodads. Good luck.

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2. Decorative chromium plating on zinc die castings—Misplating.

The problem was the black smut which developed in the sharp recessed comers of a die cast radio grille during the process of copper, nickel and chromium plating. The part, a thin-walled radio grille, made of Zamak No.3 alloy, was copper, nickel and chromium plated in a full automatic machine. The difficulty was limited to this particular part.

Since a recess means a low current density area to a plater, the initial efforts to solve this problem were to try to improve the throwing power of the cleaner and the various plating solutions. The results of these considerable efforts were nil.

The solution to this problem was conclusively proven by a photomicrograph of the black smut area as shown in Figs. 2 and 3. It is evident that there were cracks in the sharp comer of the grime. The various solutions which entered this crack during the cleaning, acid dip and plating processes caused chemical reactions and gas evolution,

Based on an original article from the "Plating Topics" series [*Plating*, **55**, 258 (March 1968)]



Figure 2-Original magnification, 480X.



Figure 3–Original magnification, 190X.

which prevented plating in this area and resulted in the formation of the black smut.

When this was called to the attention of the die casters, it was found that the cracking was caused by too much flexing of the thin-walled grille during manufacture. When this flexing was eliminated, the black smut problem disappeared.

Louis H. Rupprecht, Yardley, PA

3. Stripping nickel - Etching of basis metal.

For several years our shop has been barrel nickel plating bolts manufactured to close dimensional tolerances. The bolts are made of heat treated AMS 6304 low alloy steel, which has a nominal chemical composition as follows:

Chromium, 1% Molybdenum, 0.55% Vanadium, 0.3% Carbon, 0.40-0.50%

In order to prevent laminated or non-adherent deposits, the current is not interrupted, nor is the barrel stopped during nickel plating.

The amount of nickel deposited is controlled by a precalculated number of amp-hr required for the necessary thickness of nickel. A minimum thickness of 5.0 μ m (0.2 mil) is required on the runout thread of these bolts. The thickness is checked by microscopic examination of sectioned bolts. Besides having to meet the thickness requirements, the bolts have minimum and maximum pitch diameter tolerances.

This restriction on checking the bolts only after the completion of the plating operation occasionally causes these undesirable results: under-minimum dimensions, over-maximum dimensions and under-minimum thickness. For these reasons, it was occasionally necessary to strip entire barrel loads of work.

Stripping was accomplished by immersion in a hot solution containing 180 g/L (24 oz/gal) of a proprietary stripping compound. No problems were ever experienced using this material over a period of several years. However, during a period of economizing in the plating department, it was decided to change from the proprietary premixed stripping compound to a similar material which consisted of the active stripping ingredient plus sodium cyanide added by the user. Both stripping compounds were purchased from the same supplier. After the new stripping mixture had been in use for a few days, the solution began to etch the steel basis metal. The solution was dumped and made up new, and as long as it was new no etching was encountered, but after it aged a few days etching began again.

The solution of stripping mixture was used as follows: Active stripping ingredient, 60 g/L (8 oz/gal) Sodium cyanide, 120 g/L (16 oz/gal) Temperature, 71-76°C (160-170°F)

The nickel plate work was simply immersed in the solution in stainless steel wire baskets 25 cm in diameter by 30 cm deep (10 by 12 in.). The baskets were loaded to within a few inches of the top. The temperature was controlled manually and no analyses were made of the solution. It was dumped at the discretion of the operator when the stripping rate became abnormally slow. The solution generally lasted three to four days. The stripping solution appeared to be operated in conformance to the supplier's published operating instructions.

The stripping solution was operated for a few months as outlined above, dumping it every few days. Occasionally a batch of work was etched. At the time this was thought to be the fault of the basis metal. Then within a few days a series of loads became etched in a solution that was thought to be in good working order.

At this point it was decided that some decisive action had to be taken to correct whatever was causing the problem. It was not understood why any etching was occurring with the new stripping mixture. None had been experienced with the stripping compound previously used. Supposedly, the only difference between the two was that the original stripping compound contained an active stripping ingredient plus sodium cyanide which were premixed by the manufacturer whereas the new stripping material was mixed by the user.

The supplier was questioned, and it turned out that this was not the case. The two materials were different. The unmixed stripping material was a stronger oxidizing agent, which could cause etching if local depletion occurred at the surface of the work. Agitation of the work was recommended. Over-heating of the solution also caused the solution to decompose rapidly. Also mentioned was that the high purity-low sulfur content sodium cyanide was not the best grade of sodium cyanide to use. Some sulfur was needed to help activate the nickel and increase the rate of stripping.

From the above information the following changes were made to the stripping set up. The stripping solution was analyzed every shift and equivalent additions of cyanide and stripping agent were made, based on the sodium cyanide concentration. For example, if the sodium cyanide was analyzed and found to have decreased to 75% of full strength, then 25% of a makeup of both cyanide and the stripping agent was added.

The temperature was reduced to 49-60°C (120-140°F) and an automatic temperature regulator installed to maintain this range. The sodium cyanide range was reduced to 75-90 g/L (10-12 oz/gal). Air agitation was installed around the steam pipes and beneath the work. As each new batch of stripping solution was made up, a small addition of sodium sulfide equivalent to 20 ppm (0.020 g/L) was made.

Since the changes were made a year ago, not one case of etching has occurred. An added bonus realized with the new changes and controls was an extension of solution life from three or four days to two weeks.

Before the above changes were made a few quick tests were made to determine the cause of the etching. A gallon of stripping solution that had caused etching, and several nickel-plated bolts from the same batch were tested in the laboratory. The solution was poured into four beakers. To the first beaker was added 30 g/L (4 oz/gal) of active stripping ingredient; to the second was



 Figure 4—Cathode efficiency curves for steel cathodes.
 3.

 Chromic acid (CrO_3) 3.

 Sulfate (SO_4) 0.

 Trivalent chromium
 0.

 CrO /SO_4 ratio
 10.

33.5 oz/gal 0.335 oz/gal 0.5 oz/gal or less 100:1

added 60 g/L (8 oz/gal) of sodium cyanide; to the third 20 ppm of sodium sulfide was added and nothing was added to the fourth. Four nickel-plated bolts were placed in each beaker and heated to 71-82°C (160-180°F) for 20 min.

The bolts in the beaker to which the active stripping ingredient was added were stripped without any sign of etching. The bolts in the other three beakers were etched. From these results it was concluded that a certain minimum concentration of the active stripping ingredient was required to prevent etching. This problem of etched bolts emphasized for us the need of chemical analysis and the proper employment of controlled operating conditions for even such a seemingly simple operation as stripping of plating.

John J. Laurilliard

4. Hard chromium plating—Increasing plating speed

The job was to plate 0.76 mm (30 mil) of chromium on a large order of steel rods $1.5 \text{ m} (5 \text{ ft}) \log x 6.4 \text{ cm} (2.5 \text{ in.})$ diameter. At first we started to plate according to the following standard conditions:

Bath composition: Chromic acid, 250 g/L (33 oz/gal) Sulfate, 2.5 g/L (0.33 oz/gal) Ratio, 100:1. Operating conditions Current density, 37.5 amp/dm² (2.5 amp/in.²) Temperature, 54°C (130°F) Plating rate, 28 μ m/hr (1.1 mil/hr) Plating time for 0.76 mm (30 mil), 28 hr.

The plating tank was $8\times5\times7$ ft (2.44×1.52×2.13 m) deep. Four anode bars and three cathode bars ran the length of the tank. Power was supplied by a motor-generator set [! - Ed.] which was opened up to full voltage and to almost the rated current capacity.

Loading and unloading were done only on the first shift, so that Monday morning's load came out on Tuesday afternoon and



Wednesday morning's load came out on Thursday afternoon. Thus, we started out running two loads a week. If we could have cut the plating time down from 28 to 23 hr, we would have been able to do five loads a week. However, since the motor-generator set was operating almost at full capacity, this would have had to be accomplished mainly by increasing the cathode current efficiency of the bath from the present 16.4% to 20.0%.*

According to the data, lowering the temperature from 54° C (130° F) to 49° C (120° F) would increase the efficiency from 16.4% to 18.2%. This, however, would also increase the bath resistance. Lowering the ratio from 100:1 to 75:1 would raise the efficiency to 17.7%. This would also decrease the throwing power. If both the above temperature and ratio changes were made simultaneously, the best that could be hoped for was an efficiency of 19.5%, 0.5% short of the requirement!

To further improve the situation we surrounded each rod with a set of anodes hung on a 22.9-cm (9-in.) diameter copper rod. This improved the plate distribution and decreased the bath voltage to allow a further increase in current density. This enabled us to obtain the required thickness in 23 hr and plate the five loads per week.

Most of the plating bath compositions and plating conditions given in the literature represent a compromise of many factors and are designed to give the best average deposit under the best average plating conditions. However, whenever one factor becomes an overwhelming requirement for a particular job (in this case, the plating speed), there is no reason why the bath composition or plating conditions cannot be varied to obtain the desired result. In doing this, however, one should have full knowledge of all the factors involved, including the effects of the changes upon the properties of the deposit.

S. J. B.

5. Cadmium plating—Silver contamination.

It is a rare occurrence to have a cadmium solution contaminated with silver. Our shop experienced this twice within a year. The effects of silver contamination in a cadmium solution are obvious. The plated work turns gray or purple when bright dipped. If heavily contaminated, the work will darken even before bright dipping.

Our first encounter with silver contamination occurred when an operator mistakenly filled the anode baskets of two 680-L (180-

^{*} These and the following data, taken from the graphs shown in Figs. 4 and 5, are slightly different from data the originally given in Modern Electroplating, (F.E. Lowenheim, Wiley-Interscience). The data in the figures are from files of the U. S. Naval Gun Factory.

gal) barrel tanks and one 455-L (120-gal) rack tank with silver ball anodes. Trouble showed up after the second load of work through one of the barrel tanks. The foreman checked with the operator and found that the only thing done to the barrel tank that day was the addition of anode balls. The foreman quickly checked and found the silver balls and removed them from all three tanks. The one barrel tank was dummied for several hours at normal current densities to eliminate the silver.

To prevent this from happening again, all the plating operators were informed of the situation and one operator was assigned to make all anode additions. In addition, when a box of silver anodes was opened, all anodes were used so that none would be left in the box to be confused with cadmium balls.

About a year later, all four of our 680-L (180-gal) barrel tanks mysteriously started to produce purple work. The anode baskets were checked for silver anodes but none were found. Hull cell tests were run but showed a good deposit. Attention was then focused on the plating tank, equipment and procedure. It was noticed that the operator had been using stainless steel lid clamps on the barrels. The clamps had previously been used on barrels on the silver plating line. During plating these clamps had become bipolar electrodes and silver had plated out on them. When the clamps were used in the cadmium solution, some of the silver dissolved and contaminated the solution. This source of contamination was eliminated by substituting plastic-coated clamps for the bare stainless steel clamps.

The anodes were removed from all the barrel tanks and examined. Many were found to have very slight white films. X-ray analysis showed that the films were silver. <u>All</u> the cadmium anodes were then given a prolonged treatment in a chromic acid / sulfuric acid solution to remove the silver and the cadmium solutions were dummied to remove silver.

We feel that we now have the experience to recognize and correct the problem of silver contamination in cadmium, but are hoping never to have to use it. As Oscar Wilde said, "Experience is simply the name we give our mistakes."

6. Anodized aluminum—Pitting.

We had a problem of deep-pitting of 2024-T3 aluminum after normal anodizing in 15% sulfuric acid for 25 min and dichromate sealing at 90°C (194°F). The pits were associated with rough machining marks on the surface. Careful examination of the specimens as-received enabled an accurate prediction of which specimens would exhibit pitting after anodizing and sealing. It therefore seemed apparent that the pits originated at inhomogeneities on the surface, probably as the result of local heating during machining. But this was not the end of the story!

A number of bare specimens predicted to exhibit the pitting failure after treatment were separated from the lot and treated in various ways. For example, a caustic etch prior to anodizing variations was applied, but this did not eliminate the problem nor did other variations of the process.

Anodizing specimens, unsealed, were carefully examined and pitting was not detected. However, after dichromate sealing, pits were clearly evident. Now the problem was becoming clearer. Titanium racks were being used which resulted in dissimilar metal corrosion of the aluminum at weak points in the anodic coating during dichromate sealing.

To test this theory, aluminum racks were used and lo and behold, no pitting! The dichromate sealing solution had been used for several years and had apparently become contaminated with sulfate drag-in. Unfortunately, a sample of the sealing solution was not saved, but a new dichromate sealing solution was made up and no further pitting has been encountered, using either aluminum or titanium racks.

In summary, the combination of three elements led to this unusual finishing failure:

- 1. Improper machining with dull tools.
- 2. Anodizing (and sealing) using titanium racks.
- 3. Contamination of the dichromate sealing solution.

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Technical Editor's Note: The edited preceding article [Plating, **55**, 258 (March 1968)] is based on material first compiled and contributed by Dr. Samuel Heiman, as part of the "Plating Topics" series. It dealt with everyday production plating problems, many of which are still encountered in the opening years of the 21st century. Much has changed ... but not that much. The reader may benefit both from the information here and the historical perspective as well. For many, it is fascinating to see the analysis required to troubleshoot problems that might be second nature today. This particular set of problems was compiled by Dr. Heiman and John J. Laurillard, CEF, for many years the compiler of the venerable "Plating IQ" feature here in Plating & Surface Finishing. In some cases here, words were altered for context.



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