Hull Cell Review

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This is the third in a series of reviews looking back on past practical articles. In 1976–1982, Dr. Donald Swalheim (now deceased) wrote and coordinated a series of articles entitled "AES Update." Much of this material is lost to many of us, since many technical libraries seem to relegate much dated material (arbitrarily defined as "ten years old") to the basement, cold storage or even the catacombs, if not the shredder. If you're lucky, older articles might be on microfilm. And not everyone can make a pilgrimage, at will, to AESF Headquarters in Orlando, where the most complete collection of AESF materials has its home. So, what follows are excerpts of this material, occasionally punctuated with my own comments in brackets []. For reasons of brevity or relevance to the present, some of the material has been omitted, but my overriding intent is to remain faithful to the original article.

In one interesting installment of the Update series, Joseph Jackson and Dr. Swalheim gave an excellent overview of the Hull cell. This indispensable tool has always intrigued me. Indeed, it was one of those "toys" that piqued my interest in plating in the first place. The idea that the plater can take an individual "snapshot" of a bath, "read" the panel and make corrections on the fly was intriguing. Besides, it made a great learning tool. I would later learn that the Hull cell wasn't always believed in by many. "We ain't shippin' Hull cells!" was a common message from the production foreman to the lab. Nevertheless, I never lost faith in the thing.

This AES Update article gave a good accounting of how it worked, and how it could be used in controlling nickel and chromium plating processes.

How the Cell Works

"A photo of the Hull cell is shown in Figure 1. The anode is placed against the wall of the square end of the cell. The cathode, which consists of a piece of sheet metal 7 x 10.2 cm in length $(2.5 \times 4 \text{ in.})$, is placed against the opposite wall. Note that the left end of the panel is much closer to the anode than the right end. The left end of the panel corresponds to the high-currentdensity extreme and the right end corresponds to the low-currentdensity extreme.

"The current density range across the face of the panel is shown in Fig. 2. The left side of the curves correspond to current densities on the face of the panel closest to the anode. For example, current density on a twoampere panel at a distance of 2.54 cm (1 in.) from the edge of the panel is about 6 A/dm² (50 A/ft²). Observe the low current densities on the right edge, the point of greatest distance from the anode. By conducting a single plating test, the plating characteristics over at least a tenfold change in current density can be observed.

"In practice, platers do not refer to the curves shown in Fig. 2 to establish current densities at various positions on the panel. The Hull-cell ruler (shown in Fig. 3) is used extensively because it is convenient. By placing the ruler at the bottom edge of the panel, current densities at different locations on the panel are readily determined. The numbers shown in Fig. 3 represent the primary currentdensity distribution ranges. Though this does not apply to all plating baths, it does, however, apply to nickel. For example, measuring nickel thickness at different positions on the panel would show a thickness distribution which agrees very closely with the values calculated from the current densities shown in Fig. 3."

Test Precautions

"Keep in mind that the current-tovolume relationship in a 267-mL Hull cell is much higher than a production bath. Therefore, chemical change from the first panel to the fifth panel can be dramatic. Consequently, some platers prefer to use a [larger] cell, particularly for testing nickel-plating baths.

"Conditions such as current and temperature must be duplicated to



Fig. 1—The Hull cell



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Fig. 3—Hull cell ruler.

guarantee consistent success with the Hull cell. The panels should be retained for at least several months; they are valuable references, especially if changes in plating performance are gradual.

"A special procedure is used to photograph Hull cell panels. In a photograph of flat panels plated with a bright deposit, the deposit appears dark-almost black. Experience has shown that a more realistic photograph of panels can be attained by imaging a patterned article, such as a screen onto the panel. In Fig. 4, the steel Hull cell panel on the left has a burnished area across its face, simulating polish marks. A clear image of the screen cannot be seen in the burnished area. The panel on the right was burnished in a similar manner and then plated at 30 A for 15 min in a bright nickel bath containing proprietary additives. Note that the polish marks have disappeared except at the extreme right end where the deposit corresponding to low-currentdensity plating conditions is very thin.

"Some plating characteristics which are readily evaluated with Hull cell tests are listed below:

- brightness % bright plating range
- burning
- leveling
- ductility
- covering power
- throwing power
- plating efficiency
- alloy composition

"The Hull cell is also used to determine the effect of factors influencing the characteristics of deposits. These factors are:

- additives
- chemical balance
- temperature
- impurities

- dummy electrolysis
- carbon treatment
- filtration

"A few selected tests of nickel and chromium will be described to illustrate applications of the Hull cell."

BrightNickel

"The leveling characteristic of nickel (and other deposits) has great commercial significance. Prior to the discovery of leveling additives in 1945, it was necessary to polish the basis metal to a smooth finish or buff the plated metal. Additives probably alter the polarization characteristics on the polish marks; the result is that nickel plates faster in the valleys of scratches and the final plated finish is smoother than the basis metal.

"To test the stretchability (ductility) of deposits, a plater usually bends the lower left-hand corner of the Hull cell panel back upon itself while holding



Fig. 6—*Control of catalyst concentration in chromium plating.*

the panel close to his ear and listening for a cracking sound. If no cracking sound is heard, the deposit is considered ductile. This test is satisfactory as a qualitative test for many production applications.

"Another application of the Hull cell in nickel plating is checking for zinc contamination, which is common when plating zinc die castings with copper, nickel and chromium. If the zinc die casting is not completely covered with copper in recesses, the acid nickel bath will dissolve exposed zinc. If the die castings fall and accumulate on the tank bottom, they dissolve chemically and the rate of zinc buildup will become excessive.

"In Fig. 5, the panel on the right, made from a nickel bath containing 0.5 gal/L of zinc, is dark in the low-current-density area. The panel is also dull and non-uniform in the middle-current-density range. As little as 15 to 30

ppm of zinc is capable of producing dark deposits in recesses of production parts. If zinc contamination cannot be avoided, the only corrective measure is 'dummy' electrolysis.

"Dummy' electrolysis refers to hanging cathode sheets on the bus bar during idle periods and plating out zinc (and other impurities) at low current densities.

"Experienced platers always look on the back side of the Hull cell panel. With low-current-density conditions, metal impurities at very low concentrations frequently plate-out as dark deposits before darkening appears on the front of the panel."

Chromium

"Chromium plating baths have very poor throwing power, even when the constituents are maintained at optimum concentrations. Control of catalyst concentration is probably the most important single factor.

"In Fig. 6, the steel panel at the upper left was pre-plated with bright nickel and then plated in a chromic acid bath containing the normal concentration of sulfate catalyst. The panel was plated at 5 A for a period of 5 min. Unlike most plating baths, chromium does not plate at low current densities. The panel at the lower left in Fig. 6 was plated in a bath containing no added catalyst and has bands resembling a rainbow. Obviously, a bath of this type is unsatisfactory for decorative chromium plating. The deposit consists of mixtures of oxides of chromium. Since the ratio of chromic acid (CrO_{2}) to sulfate catalyst is usually about 100 to 1 [the upper left panel], and since this ratio is critical, it is not surprising that a practical bath for chromium plating was not developed until the 1920s.

"In Fig. 6, the panel on the right, plated with a chromium deposit from a high-catalyst bath, does not show the better covering power exhibited on the panel at the upper left, plated from a bath containing a normal concentration of sulfate catalyst. Reviewing these photos, it becomes clear that the concentration of catalyst must be carefully controlled.

"A major problem in chromium plating is coverage near holes used for mounting plated parts. Fortunately, mixed catalyst baths, which usually contain fluoride-type catalysts, have better coverage near edges of holes. Prior to the development of mixedcatalyst baths, platers frequently plugged holes with stoppers to at least partially solve the problem. But, if problems still persist, punching holes in a Hull cell panel and then making the test may be useful. Even though the mixed catalyst may be at the proper concentration, other factors, such as contamination, can influence coverage near holes. The condition of the nickel bath is one major factor.



When conducting Hull cell tests, it is important to take a nickel-bath sample at the same time a chromium sample is taken. Plate the Hull cell panel with nickel for about 5 min. Then, after rinsing, plate the panel with chromium.

"If the mixed catalyst is at the proper level but the expected coverage is not obtained, mix equal parts of the old chromium bath and a new bath containing the same concentration of catalyst and repeat the Hull cell test. If coverage is significantly better, check the chromium bath for buildup of inorganic contaminants, which have an adverse effect on throwing power.

"If the problem is not related to performance of the chromium bath, the nickel-plating operation must be investigated. The activity of the nickel has a marked effect on coverage and appearance of chromium. If hold-up time between nickel and chromium plating is too long, nickel may become partially passive and lead to chromium-plating problems. Excessive brightener in nickel has a similar effect. Both troubleshooting techniques must be considered for a process that combines bright nickel and chromium." PRSF

Editor's note: The AESF Bookstore offers for sale an illustrated lecture booklet on the Hull cell. Order online (www.aesf.org) or call 1-800/334-2052.