The Hull cell for Decorative Electroplating

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Introduction

Back in the 1930s, I doubt that Dr. Richard O. Hull, when applying for a patent for his test plating cell, ever dreamed that this unique tool would be the main service tool in the decorative plating industry in the year 2008. Most of the decorative addition agents in the world would be developed by the use of his Hull cell (Fig. 1). The cell would also be the main service tool for controlling decorative plating processes, especially copper, nickel and chromium. With a little imagination, one can custom-shape panels to simulate almost any situation a plater may face (Fig. 2). These can vary from panels with shelves to pick up roughness and pitting, tight "V" shapes to plate very low current density areas checking for metallics, saw pattern-sided panels to check for fine nodulations in high current densities, and perforated panels simulating low current density areas throughout the panel. Hull cells can stand in for a chemical analysis when an analysis is not available.

Working with Hull cells breaks down into two categories: (1) properly plating panels and (2) properly interpreting panels. You will find very few photographs of plated panels showing the many conditions achieved, simply because it is virtually impossible to photograph a panel with its highly reflective surface. Hazes, clouds and speckling just do not photograph. Most information on panels relies on drawings to depict conditions. I have always recommended building a library of panels tuned to your operation. After plating your normal test panels, and before discarding the test solution, plate additional panels from solutions deliberately contaminated with the possible contaminants in the line. This will allow you to display conditions for future reference and training. Since the plated surface is very active, and subject to oxidation, such panels should be stored in Ziploc® plastic bags.

Equipment

Hull cells are available in two sizes, 267 mL and 1,000 mL. In decorative plating, the 267-mL size is recommended. The 1,000-mL cells are required in baths using very high current densities, such as acid copper plating on grounding rods, which use current densities up to 600 A/ft². The larger volume is required to compensate for temperature increases and current-carrying capacities. Hanging cells are also available which extend down into the actual plating tank.

Table 1

Panel amperage (267-mL Hull cell panel)

Amperage, A	Current density range, A/ft²
1.0	0.5 - 40.0
2.0	1.0 - 80.0
3.0	1.5 - 120.0
5.0	2.5 - 200.0

Hull cell

The 267-mL cell was designed to plate a deposit on a steel or brass panel over a selected current density range. As shown in Fig. 1, the cathode panel is placed at an angle with respect to the anode face. Thus the local current density is highest at the end closest to the anode, while conditions at the other end are at a low current density. Table 1 shows the current density ranges produced at various applied currents.

Electrodeposition is based on average current density values. When plating at an average of 40 A/ft², we also observe what the deposit looks like at 2.0 A/ft² as well as 80 A/ft². Since plating problems usually start in the low current density areas, and work up as well into higher current density areas (as well as in the other direction), we are able to see problems before they are in the cur-

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rent density range in which we are plating on the part - sort of a "soothsayer" of plating conditions.

The 267-mL volume was selected to simplify calculations. An addition of 2.0 g to the cell equals 1.0 oz/gal in the bath. One milliliter in the cell equals 3 pints/100 gal in the bath. The advantage of the Hull cell is that one can work by trial and error until the correct addition is established, consuming only a small volume of the bath. Brightener additions may be made this way, choosing the best results and then adding that volume to a fresh bath. It is recommended that no more then three panels be plated per test volume, as bath conditions change quickly in that small volume of solution.

Hull cell rule

A graphic representation of the current density ranges shown in Table 1 is available in the form of a handy Hull cell rule (Fig. 3). By placing the panel on a Hull cell rule, one can observe the current density range of interest.

The Hull cell rule allows you to view current density ranges for 1.0 to 5.0 A panels (as tabulated in Table 1). It also contains formulas to calculate additions, as well as a millimeter rule to measure chromium coverage.

Hull cells available for different applications

Because of the different chemical environments involved in the various decorative plating baths, a number of cells are available specific to the application (*e.g.,* copper, nickel, chromium, etc.):

1. Standard non-heated, non-air agitated Lucite Hull cell, recommended for cyanide zinc and cadmium solutions.

2. High-density polyethylene Hull cell, recommended for chromium solutions

3. Non-heated air-agitated Hull cell for baths requiring agitation, recommended for acid copper and chloride zinc.

4. Heated, and air-agitated Hull cell, recommended for semi-bright and bright nickel solutions.

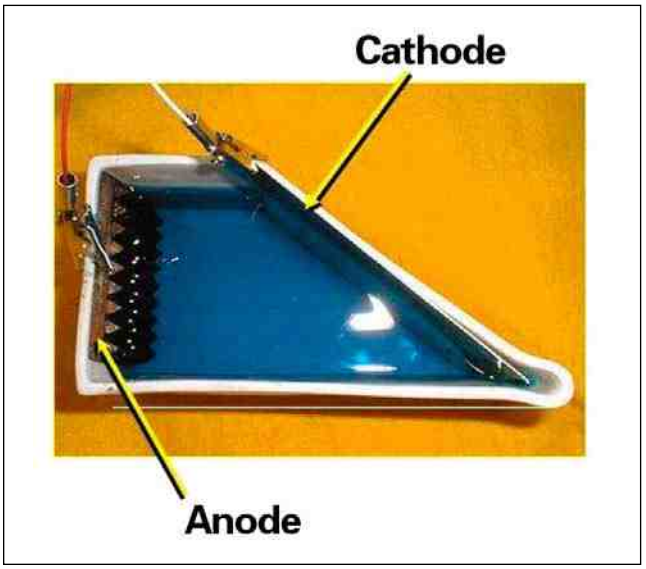

Figure 1—Overhead view of the Hull cell configuration.

Power supplies

Rectifiers should have a DC output of at least 10 A at 12 V, with a maximum ripple of 5%. Multiple Hull cells may be processed with one rectifier, by connecting them in series

Agitation

A Hull cell may be air agitated with a standard aquarium air supply with a needle valve control. Paddle agitation is also available for non-air-agitated baths, such as cyanide copper.

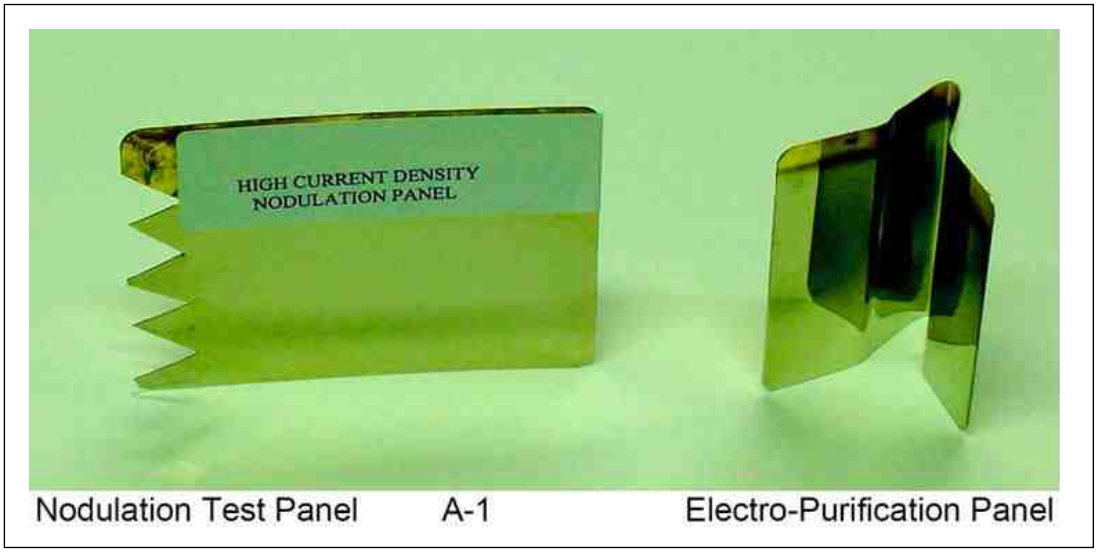

Figure 2—Examples of specialized Hull cell test panels.

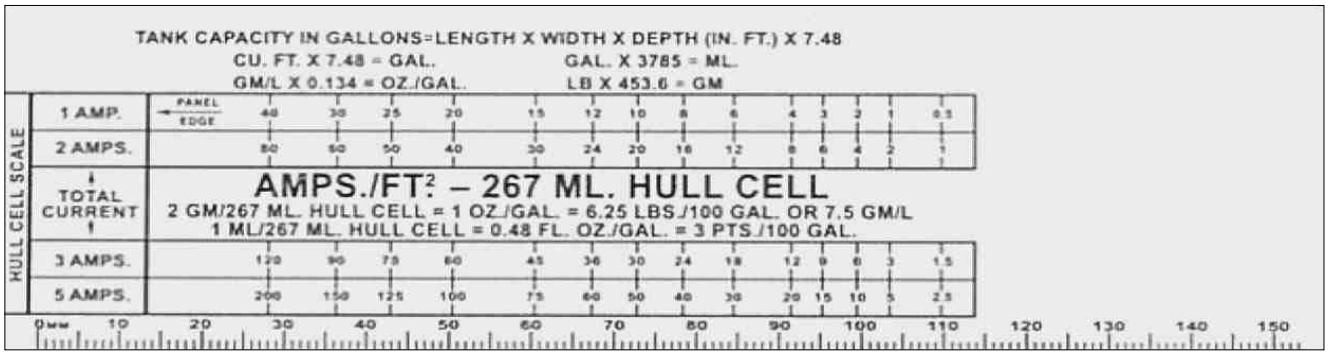

Figure 3—Hull Cell rule.

Panels

Panels are available in both brass and steel. Brass panels have a strippable coating that is peeled off prior to cleaning. This coating is easily removed on new panels. However, as panels age, this film becomes quite difficult to remove. It is important to maintain a supply of fresh panels. Panels are lustrous with very fine vertical polishing lines. Panels should be examined prior to use to be sure there are no surface imperfections or pitting.

Steel panels have a thin electroplated zinc deposit on them, which is stripped in hydrochloric acid prior to use. Care must be taken that a clean acid is used, as zinc builds up, and panels will develop a smut that must be physically removed. I prefer brass panels over steel for nickel. Polished brass mirrors back the nickel deposit.

Cleaning of panels

Producing a good panel requires good cleaning. Panels should be cathodically cleaned. This is accomplished in a 2,000-mL stainless steel beaker. A hot plate sized to maintain a temperature of 180°F is recommended.

1. Cathodically clean for 2.0 min at 5.0 to 8.0 A.
2. Cold water rinse.
3. Acid dip in 10% hydrochloric acid.
4. Cold water rinse

Panels should be placed immediately in the cell and plated.

Additive additions

The recommended concentration of many additives may be as small as 0.1 vol%. Because of the relative scale of a Hull cell test, it is difficult to pipette an addition that small. Diluting additives to 10% allows you to make a 1 mL add which is more precise.

Process analysis - bright nickel

A standard panel for bright nickel is plated for 10 min with moderate air agitation at 2.0 A. The panel should be bright over the complete range, exhibit good leveling, with a slight swirl in the low current density area. The panel should be free of speckling, have good ductility and adequate coverage on the back. Leveling is determined by the degree of visible polishing lines. In a well balanced bath, virtually no lines will be visible except for the last 3/16" of the panel (lowest current densities). When the panel is bent 180°, cracking should not be heard.

Common nickel problems

1. Dullness
Dullness usually arises from low secondary brightener. The Hull cell panel lacks overall brightness, especially in low current densities. Panel polishing lines are visible. The panel may also display a bluish cloud. To correct, make a 10% solution of the secondary additive. Add 1.0 mL in each subsequent Hull cell test until a bright deposit is achieved.

2. Roughness
Roughness may not be apparent on the vertical surface of the panel. It is necessary to cut and form a shelf panel, where a horizontal surface is created. This will allow particulate matter to settle on the "shelf," replicating the condition where roughness can occur. To correct, filter the solution through a Buchner Funnel and Whatman #42 filter paper. Rerun the panel to assure the problem is solved.

3. Stardusting
Stardusting is caused by micron-size particles from breakdown products. To correct, obtain a solution sample volume large enough to produce two samples (267 mL × 2 = 534 mL minimum). Plate a 30 min / 2.0 A panel. If stardusting is visible, to the second sample, add 1.0 mL of a dispersant wetting agent. Plate the second Hull cell panel. If free of all stardusting, make an equivalent addition to the bath.

4. Pitting
Pitting is caused by organic contamination. To correct, 0.2 vol% of wetting agent should be added to the sample bath. Run a second Hull cell panel. If pitting is still present, the solution is filtered through a Buchner funnel with #42 Whatman filter paper coated with activated carbon. A third panel is run and inspected.

5. Metallic impurities
Metallic contaminants start as black bands in the low current density areas. Zinc will appear as zebra stripes. To correct, a V-shaped panel is formed which fits into the low current density area of the cell. A panel is plated at 0.2 A for 10 min and examined. A time sequence may be calculated using this panel to determine the electropurification time needed to remove the metallic contaminants.

Process analysis - decorative hexavalent chromium - fluoride/sulfate bath

Chromium baths may be totally controlled with a Hull cell with a little practice and learning how to interpret the panels. Care must be taken on handling the electrical contacts. Any loss of current will cause a white wash pattern, leaving you to wonder if the problem is chemical or poor contact. Chromium should be plated over a freshly plated nickel panel, preferably over the nickel being used in the plating line. I prefer to nickel plate my panel, rinse well and place it in the cell, make electrical contact, then pour the chromium into the cell at 1.0 A, gradually increasing the current to 5.0 A for 2.0 min. This procedure simulates the automatic programming used on most automatic plating machines. Coverage across the panel will vary from 60 to 85 mm for the average bath. The coverage range corresponds to 75 to 30 A/ft^2, as per the Hull cell rule shown in Fig. 3. The goal is to extend the coverage as much as possible, *i.e.,* to the lowest possible current density. The deposit should be free of white wash and rainbow staining. The normal panel is rinsed and wiped dry. To check for staining, the panel may be air dried.

Common chromium problems

1. High current density burn
High current density burn is related to either low sulfate or a high chromic acid-to-sulfuric acid ratio. To correct, a series of tests with additions of sulfuric acid is performed.

2. Poor coverage
Poor coverage is related to either high sulfate or a low chromic acid-to-sulfuric acid ratio. To correct, a series of tests with additions of barium carbonate (to lower sulfate) is performed.

3. Whitewash
Whitewash is connected with low fluoride. To correct, a series of tests with additions of the fluoride catalyst is performed.

4. Rainbow stain
Rainbow staining is also related to low fluoride. As with white wash, a series of tests with additions of the fluoride catalyst is performed to determine corrective action.

5. High current density halo
A high current density halo is related to high fluoride. A series of tests with additions of boric acid (reducing fluoride) is performed to determine corrective action.

Process analysis - acid copper

Acid copper Hull cell panels are quite representative of the plating bath. That is, additions to the cell accurately reflect the results to the work in the bath. An air agitated cell is used with vigorous agitation. Panels from a bath in balance are bright from high to low current densities. Acid copper baths level well, and this is demonstrated on the polished brass panel. Panels are plated at 2.0 A for 10 min.

Common copper problems

1. Low copper sulfate
Low copper sulfate in solution produces a high current density burn in the Hull cell panel. Incremental adds of copper sulfate in the test solution will determine what should be added to the tank. However, see (2) below.

2. Low sulfuric acid – High current density burn.
Low sulfuric acid in solution also produces a high current density burn in the Hull cell panel. Incremental adds of sulfuric acid in the test solution will determine what should be added to the tank. Since both low copper sulfate and sulfuric acid induce the same effect, the Hull cell tests should be done in tandem, *i.e.*, one test with an increment of copper sulfate added to the original solution, and a second test with an increment of sulfuric acid added to another sample of the original solution. Whichever of the two is more effective in reducing the high current density burn can help to weed out the culprit.

3. Low carrier additive
Low carrier additive in solution results in cloudiness in the mid- to high current density areas of the Hull cell panels. Further, nodulation can appear on the panel edges. To correct, 1.0 mL of the carrier additive should be added to the 267-mL test volume, with the Hull cell result evaluated to see if more is required.

4. High carrier additive
High carrier additive produces a cloudy deposit with low current density skip plate. Before running the Hull cell test, the solution is filtered through a Buchner funnel with #42 Whatman filter paper coated with activated carbon, to reduce the additive.

5. Low secondary additive
Low carrier additive in solution results in dullness in the low current density areas of the panels. 0.2 vol% of the secondary additive should be added in the initial corrective Hull cell test..

6. High secondary additive
High secondary additive in solution produces “worm tracks” throughout the panel. The test solution is filtered through a Buchner funnel with #42 Whatman filter paper coated with activated carbon, to reduce the additive.

Summary

The Hull cell is a very diverse tool with unlimited possibilities in the control of electroplating baths. Use your imagination in designing panels to exhibit particular plating problems. Assemble a library of panels for future reference and training. We have discussed decorative applications only. The Hull cell will help you solve problems in any electrolyte that will deposit metal. As long as there is plating, there will be Hull cells.

The various test conditions for Hull cell testing of the various solutions used in decorative plating are summarized in Table 2.

Table 2

Summary of Hull cell test conditions for decorative plating processes

Electrolyte	Cell	Agitation	Temperature	Current	Time	Panel
Cyanide Copper	L	Mech.	160 °F	5.0 A	5 min	Brass
Acid Copper	L	Air	75 °F	2.0 A	10 min	Brass
Semi-bright Ni	L	Air	145 °F	2.0 A	10 min	Brass
Microporous Ni	L	Air	145 °F	1.0 A	3 min	Brass
Bright Ni - R	L	Air	145 °F	2.0 A	10 min	Brass
Bright Ni - B	L	Air	145 °F	1.0 A	5 min	Brass
Chromium	HPE	None	110 °F	5.0 A	2 min	Ni/Brass
L - Lucite; HPE - High density polyethylene						

About the author

Ralph Dixon has been serving the metal finishing industry for the past 50 years in all phases, from technical field service to sales management with world class suppliers. He specializes in decorative nickel and chromium finishes to the appliance, automotive and motorcycle industries. He is currently involved as a consultant in the promotion of decorative plating processes in the United States, and South America with Basically Nickel Inc.

AESF Foundation Research Program

The AESF Research Program began in 1919 when Dr. William Blum asked the Society to help fund research efforts of the National Bureau of Standards (now the National Institute of Science and Technology). This initial request paved the way for the expansion of the AESF Research Program in 1944 to support universities and colleges, industrial companies, and independent research centers and laboratories. This program will continue to expand and thrive under the direction of the AESF Foundation.

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- University of South Carolina, "Development of New Process for Plating Thin Films of Zn-Ni-P-X, etc."
- Pennsylvania State University, "Development of Environmentally Friendly Corrosion Prevention Deposit on Steel"
- University of Cincinnati, "Improved Silane Film Performance by Electrodeposition"
- McGill University, "Effect of Material Characteristics and Surface Processing Variables on Hydrogen Embrittlement of Steel Fasteners" (part of a 3-year research project)
- University of South Carolina, "Development of Ni Based High Wear Resistance Composite Coatings"

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