Info KRAFT

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Getting The Best Out of DC and Pulse Rectification

Introduction

Many years of experience of installing and servicing DC and pulse rectifiers has demonstrated that the basic concepts of achieving optimum plating performance are either often ignored or not fully understood. Arcing saddles, overheated cables or busbars and the use of unnecessarily high voltages typically show up a poorly designed or maintained installation. There is a certain "iron logic" about the rules governing current distribution and it is perhaps surprising how often these simple rules are ignored.

Current Distribution

With a 100% cathode efficiency, the thickness of copper deposited on the cathode surface from an acid electrolyte is directly proportional to the flow of electrons.

$$Cu^{++} + 2e^{-} = Cu$$

The more e^-'s, the more copper.

It therefore follows that the only way you can improve copper distribution is to optimise the distribution of current flow over the plated surface.
Primarily Ohm's Law determines the distribution of current throughout the plating cell.

$$U = I \times R$$

U = Voltage (Volt) I = Current (Amp) R = Resistance (Ohm)

It further follows that, using a common voltage source, electrical resistance is the only way that current distribution can be improved, by trying to make U the same over the whole plated surface.

The Path of Least Resistance

The sources of resistance between a plating rectifier and the plated surface are varied. In order to optimise current flow, we need to look at each one. Figure 1 shows a simple bath arrangement where, outside the actual cell, there is only one current path and the result of any high resistance is hot conductors and a waste of electrical power. Hot conductors and contacts will quickly deteriorate and the problem will become worse. However, for multiple cables and current paths, a change in one resistance can completely change the current distribution within the cell.

Cable Resistance (R_{Cable})

The cross-sectional area of the cable(s) or busbars must be sufficient to carry the required current without getting hot. When the cable temperature increases, the electrical resistance also increases making the situation even worse. When hot cables cool, acid from the plating solution tends to get sucked inside the insulation, leading to corrosion and a difficult and expensive replacement.

Obviously the length of the cable also determines the resistance of the cable and, when multiple cables are used, the length of cable to each anode/cathode rail will determine the current distribution to the plating cell, but probably not as much as you might think (See Figure 3). Where it is necessary to use longer cables to one end of a plating cell, the increase in resistance can be offset by increasing the cross-sectional area of the longer cables i.e. bigger cables, or more cables.

When multiple cables are used and the temperature of some cables is higher than others, **it is the cooler cable or connection which has the problem.**

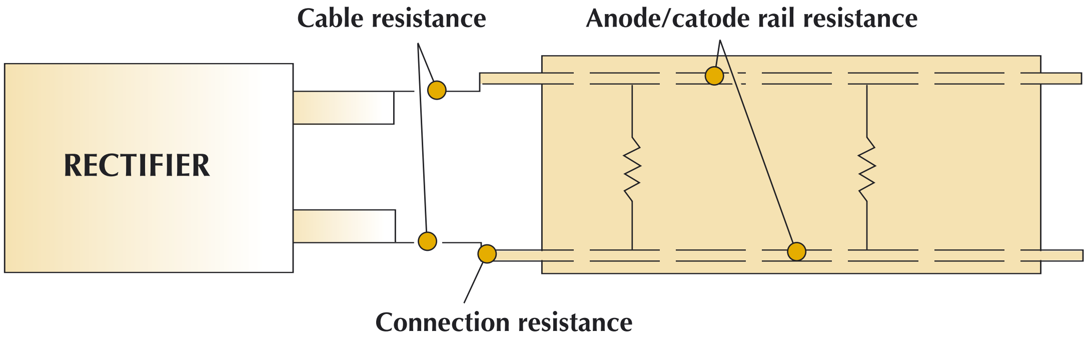

Fig. 1 *Sources of Resistance for a Simple Plating Cell*

Connection Resistance (R_{con}) (or Contact Resistance)

Permanent connections comprising cable lugs and bolts are least likely to cause problems if properly made with clean surfaces. Ingress of chemicals will cause corrosion so even permanent connections must be regularly cleaned and maintained. Use of conductive grease (Electrolube™) will help to keep air and corrosive chemicals away from the contact surfaces.

The main source of high R_{con} is the flight bar connection to the cathode rail, the cathode saddle. Problems here can be due to poor design, poor maintenance or a combination of both.

Contact Resistance Theory Applied to Saddles

When two rigid surfaces come together, the electrical properties of the contact materials and the area of contact will determine the contact resistance.

If two flat surfaces are put together, the actual area of contact will be very small as they will only actually touch at a maximum of three sites. **This is regardless of the actual size of the contact surfaces.**

The only way this area can be increased is by the increasing the pressure between the surfaces. This can be made more effective if the surfaces are brought together with a wiping action that deforms the surface. This will also help to remove corrosion and dirt from the surface. It will also be more effective if the contact material is soft enough to deform under pressure.

The effect of any dirt or corrosion will increase contact resistance and heat build up.

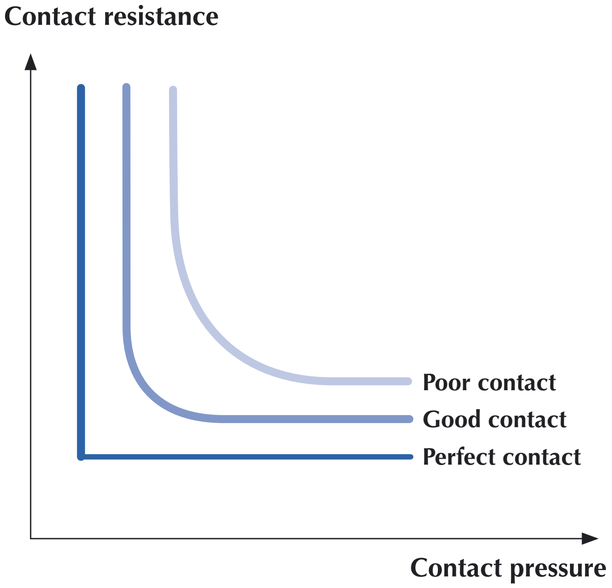

Fig. 2 *Typical Contact Resist. V Contact Pressure*

Contact Cleanliness

Keeping saddle contact surfaces clean on a typical plating plant is obviously a major challenge. Understanding and eliminating the factors that contribute to contact degradation should help to minimise corrosion and extend maintenance periods or delay plating problems.

Factors that assist corrosion of contact surfaces are:

Oxygen

Corrosion is due to the oxidation of copper. Without oxygen corrosion cannot occur. Use of small amounts of conductive grease will help to keep oxygen away from the surface.

Water

For properly designed saddles, there should never be water on the contact surfaces. The practice of spraying water to cool saddles is a bad one as it accelerates the corrosion process which leads to heat build up.

Electric Current

You have to live with this one but, what really causes the problem is potential difference across the contacts. This can be caused by the use of inappropriate materials but is most likely caused by high contact resistance (volt drop) across the contacts.

Sulphuric Acid

Too vigorous air agitation and poor extraction is an obvious factor here. Use of eductors has made a significant contribution by reducing overspray.

Temperature

A hot saddle will corrode much faster than a cool one as the heat generated will accelerate any degradation of the contact. **However, if only one of the two saddles is hot, it is most likely that the cool one is not working at all, and the hot one is carrying too much current.**

Anode/Cathode Rail Resistance

The resistivity of the anode and cathode rails can be calculated from the resistivity of the material and the cross-sectional area. The resistivity will lead to a voltage drop along the rail which will depend on the current flow ($U = I \times R$). This is the main determining factor in the current distribution within the cell because it determines the actual voltage at any point along the rail, where the anode or rack are connected.

The voltage at any point on the anode/cathode rails is also determined by the cable lengths to each end of the rails. This is not as big a factor as it might appear.

The effect on current flow for uneven cable lengths is shown in Figure 3,

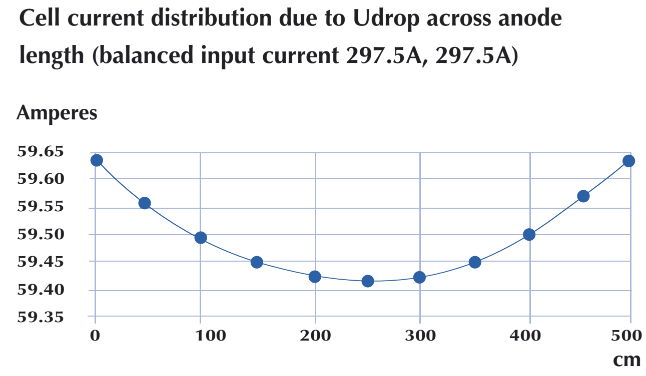

Fig. 3 Current Distribution across the Anode Rail due to Cables

Cell Resistance

The cell resistance is the total resistance between the anode and the cathode and is shown schematically in Figure 4.

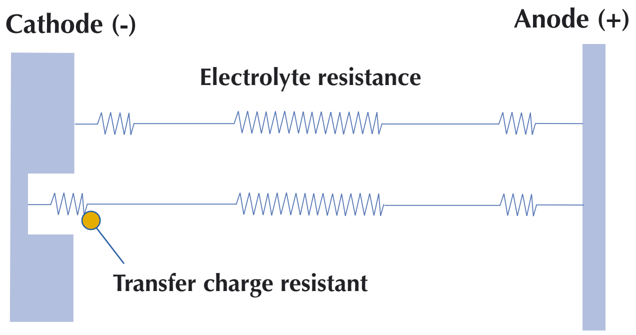

Fig. 4 Cell Resistance

The total cell resistance for the infinite number of current paths between the anode and cathode is made up of the transfer charge resistance and the electrolyte resistance.

The electrolyte resistance is primarily dependent on the ionic concentration of copper and sulphuric acid and the temperature of the electrolyte. Current distribution over the cathode can be varied using electrolyte resistance by changing the geometry of the cell, e.g. moving anodes. This is known as primary distribution. Deterioration in anodes or anodes not making contact can seriously change primary current distribution in a way that is not obvious.

The transfer charge resistance is the resistance of the actual deposition process and depends on current density, additive characteristics and temperature.

This can be broken up into three distinct resistances as follows:

Diffusion Layer

The concentration of metal ions in the diffusion layer reduces with increasing current density. As the metal ions become depleted at the cathode surface, the resistance of the diffusion layer increases.

Activation Resistance

Caused by the passage of depositing ions between the cathode surface and the solution, varies with current density.

Film Resistance

Due to adsorbed organic additives. For acid copper processes, the common organic additives used for printed circuit boards have a deleterious effect on current distri-bution using direct current and they therefore tend to make metal distribution worse. Reverse pulsed current can be used to produce a significant increase in this resistance in the high CD area, causing re-distribution of the current into the low CD areas.

Summary

The performance of DC electroplating can be optimised by careful attention to the many resistance paths in the plating plant. Conversely, poor design and contact problems can lead to poor plating performance.

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