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EDUCTOR AGITATION

Reprinted from "THE PLATING SPOT" Column by David Hemsley
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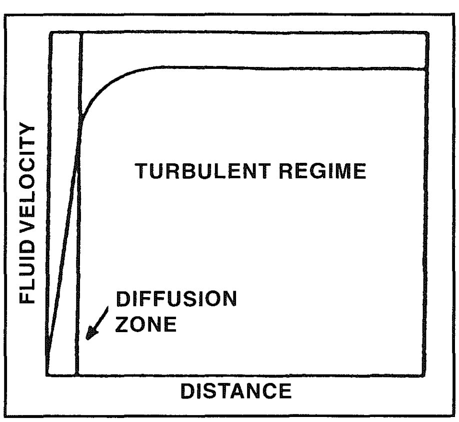
The subject of agitation in plating operations is close to my heart. That is perhaps not surprising, having spent my formative years at Harwell as part of a chemical engineering team optimizing the mass transfer of uranyl nitrate from aqueous to immiscible organic solvents, and later on as a process engineer in the fertilizer industry, at a time when the manufacture of wet process phosphoric acid by a hemihydrate route was all the rage. In both these processes, reaction rates were a function of agitation; or turbulence to give it its proper name.

The success of most process operations in pretreatment and plating is also dependent upon turbulence, whether it be a hot soak cleaning stage, plain rinsing, or a plating system. In the first two examples, we are concerned with removal of soil or surface films in a purely physical manner. On the other hand, an electroplating process is concerned with electrochemical reactions at the cathodic and anodic surfaces. Nevertheless, it always surprises me how successful these operations are in commercial reality when one considers just how low a level of turbulence is used. The question remains, however: how much better would these various processes operate if higher levels of turbulence were used? More specifically, could down to earth production values such as output, quality or material efficiency be enhanced?

It seems to me that there are several misconceptions about turbulence within our industry. Over the years, David Gabe and his team at Loughborough have produced some useful work applicable to metal recovery using electrochemical reactor technology, and more recently, an analysis of air generated turbulence. Even so, industry's traditional approach to the need for turbulence is to use low pressure air, or mechanical movement of the cathode bar.

Turbulence is necessary to satisfy three key process needs. Firstly, that concentration gradients resulting from the point source addition of maintenance chemicals are minimal. Secondly, that irrespective of the varying ionic and other chemical depletion rates which stem from geometric considerations, e. g. the shape and array of the work to be processed, the concentrations of important species are essentially the same throughout the operating environment. Finally, localized turbulence is necessary to reduce the so-called diffusion or boundary layer on the surface of the work. This boundary layer has a notional thickness which can be described by the concentration gradients of the active species and is a function of viscosity, temperature, density and velocity. The thickness of this layer frequently determines the rate of chemical or electrochemical reaction, i.e. the deposition rate. Thus, we have the limiting current density rate at which the speed of plating is restricted by the speed at which the metal ions being deposited can be replaced by fresh ions moving through the barrier layer.



Turbulence can be characterized by a dimensionless group called the Reynolds Number (NRe).

A Reynolds Number below 2,000 indicates laminar flow and that the boundary layer is relatively thick. Above a Reynolds Number of 2,000, fluid flow moves into the turbulent region. A Number of 20,000 to 100,000 represents turbulent conditions where the boundary layer is relatively thin. At constant temperature, the only variable is linear velocity. So now we see the importance of power in generating turbulence. No power - No turbulence.

Air agitation

A heavily air agitated plating tank may look as if a high level of turbulence is being generated, but the power used to generate that turbulence is a fraction of 1kW. The energy needed to gently sway a printed circuit board through the process fluid by mechanical agitation is even less. Trying to drive an autocatalytic copper plating solution through the tiny holes of a modern circuit board by "cathode rod" agitation is to all practical purposes useless. On the other hand, the high power input and hence high linear electrolyte velocity in a continuous wire or tube plating plant allows the use of a very high current density with a high cathode efficiency. Plating rates several times higher than that achieved in a static air agitated electrolyte are thus entirely feasible.

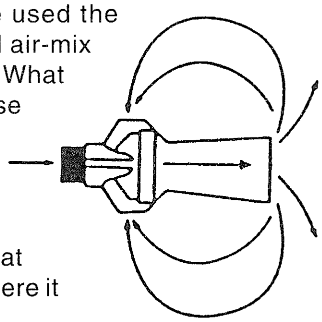
There is not much to be said for air agitation other than that it is cheap to install and operate. I suppose that there is some virtue in deploying the air agitation distribution pipework directly below the plating racks, so concentrating what limited energy there is as close to work as possible.

The two most effective ways of generating turbulence in a process tank are direct turbine agitation and turbulence through pumped recirculation. The disadvantages of turbine agitation are its space requirement and the need for tank wall baffles. The only limit to this type of agitation is the ability to retain work on the jigs. Pumped recirculation also has a similar power input limitation.

The key disadvantages of both methods is that a high level of turbulence exists throughout the process tanks. Power is thus wasted. There is absolutely no point in developing high turbulence in tank corners.

Eductor generated turbulence

Recently SERFILCO has launched an eductor generated turbulence concept into the plating industry. There is, of course, nothing new about eductors; motor car carburetors have used the eductor system to move and air-mix fuel for more than a century. What is exciting about its recent use in plating is that an eductor can use a powerful hydraulic flow and use it to maximize turbulence in the active volume of the plating tank. That is to say, it puts the power where it is needed - at the work face.



How does the eductor concept work? An eductor is simply a venturi from which the reducing and throat sections have been removed. In their place is an orifice nozzle, as shown in the simplified diagram above.

The hydraulic pressure gradient around the high velocity nozzle is such that the surrounding process liquid is sucked into the venturi. The combined stream is ejected from the venturi at a lower velocity, thus setting up a circulating flow of the process fluid around the eductor. Judicious location of the eductors - several are required for a typical process tank - ensures that the circulation pump power is used to best advantage. Do not make the mistake of believing that the eductor gives you something for nothing.

It merely converts a high pressure, high velocity, low volume flow to a low pressure, low velocity, high volume flow with the key advantage that a closed loop circulation (turbulence) is developed within a localized fluid volume.

So what are the practical advantages and benefits of the eductor concept in plating operations? Well, there are more advantages than are apparent at first sight.

The conventional way of developing turbulence in the UK is the use of low pressure air. For most applications, sparged air does an effective job. However, consider the following disadvantages:

1. Sparged air becomes humidified and, therefore, abstracts significant latent heat from process fluids - most processes need heating rather than cooling.
2. Sparged air carries out sub-micron mists of the process fluid components. These mists may constitute a health hazard.
3. Sparged air may cause unwanted oxidation reactions, e.g. the conversion of cyanide to carbonate.

The eductor concept has already demonstrated its value at Prestige, Ltd. Here the replacement of conventional air agitation by the SERFILCO eductor system in a large non-ventilated nickel plating tank has reduced the nickel content of the air around the tank from a marginal $0.1 mg/m^3$ to a level in the range of $0.01 - 0.02 mg/m^3$. The capital cost for installing a fume extraction system would have been at least £30,000.

Another advantage of the eductor system at Prestige is the improved plating quality.

The variation in brightness from the bottom to the top of the plating jigs noted with the air agitation system has been eliminated. Not least, nickel brightener consumption has been reduced by 20 percent. Not yet known, but I do hope that someone checks it out, is the potential for an increase in plating rate.

SERFILCO has done an excellent job in promoting an alternative to air agitation. All success to its endeavor, even if its literature does suggest that the company has found a way round the first law of thermodynamics. This is the type of development, along with water and energy conservation, that is needed to maintain on-going cost reductions that will help keep plating the No. 2 in surface finishing.

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