SOLUTION AGITATION AND MIXING

by Ted Mooney

Finishing Technology, Brick, N.J.

In a few cases, solution agitation is employed with the intent of causing a mechanical scouring action. For example, in a spray washer, the cleaning fluid is caused to impinge forcefully on the work for this purpose. Similarly, in ultrasonic cleaning tanks, the cavitation created by the transducer is intended to induce a scrubbing of the surface of the work. In an electrocleaning tank, again, the gas liberated at the work surface fulfills the same objective. In electroplating processes, very high-energy agitation has been found to discourage formation of metal whiskers and to increase deposit hardness by promoting dislocations.

These examples of agitation, however, are the exceptions to the rule. In the metal-finishing theater, the normal role of solution agitation is a simple one—just another in a long list of requirements that must be met if we are to ask the real physical world to give credence to our man-made theories. That is, our calculations of plating rates and efficiencies, rinse ratios, and required reaction times, are invariably based, for simplicity's sake, on the supposition of solution homogeneity.

All we ask of an agitation system is that it generate sufficient mixing action that this supposition not be found presumptuous and wanting. But as in all real-world situations, things aren't as simple as they first appear.

HOW MUCH IS ENOUGH?

One doesn't generally describe the degree of agitation in superlative terms; it is neither outstanding nor abysmal, rather it is adequate or inadequate. But adequate cannot be interpreted except in context.

On the one hand, a hard-chrome plater may find that a daily hoeing-up of the bottom sludge in the plating tank ensures that the catalyst remains soluble in the proper proportion; for this plater, this constitutes adequate agitation. At the other extreme, a researcher knows that one can never totally negate the brake on theoretically possible plating speed, which is imposed by polarization and boundary layer phenomena; for the researcher, no combination of violent solution impingement, ultrasonic vibration, and pulsed current is ever sufficient to bring homogeneity all the way down to the microscopic level.

Between these extremes, the typical metal finisher may require that the agitation system assure general solution uniformity as well as provide enough turbulence to prevent excessive ion depletion or gas accumulation at the anode and cathode surfaces. In a pollution control system, the plater wants the agitators to provide sufficient mixing so that the reagent chemicals become intimate and react with each other, rather than pass placidly by each other as ships in the night.

THE BAD WITH THE GOOD

A complication with agitation systems is that they sometimes introduce extraneous factors and bring new problems.

The ubiquitous air agitation system can turn the process tank into an effective scrubbing system for concentrating the airborne dirt collected by the blower; it can cause roughness by stirring up bottom sludge; and it will oxidize the solution, which often will prove to be deleterious.

The work movement developed by a cathode rocker can cause interrupted current and

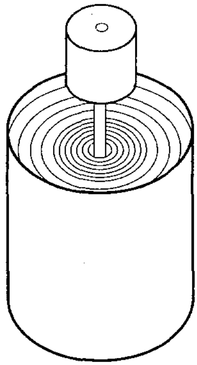

Fig. 1. Rapid solution movement, but minimal mixing.

consequent laminar plating; in extreme cases, it can cause the work rack to walk out of its proper position.

Propeller-type mixers, commonly used in pollution control reaction tanks, can dice up the precipitated floc and impede its settleability/filterability. Circulation pumps can, through cavitation, wreak havoc by volatilizing solution components.

Despite these potential problems, agitation is usually a requirement—and a surfeit more generally acceptable than a shortage.

AGITATION VERSUS MIXING

Another complicating factor is the troublesome word agitation itself, because it implies a need for violent solution movement, whereas the usual actual requirement is for proper mixing—and the two are not necessarily congruent.

To clarify this, consider a cylindrical tank with a centrally mounted paddle-type mixer as shown in Fig. 1. Such a system might be employed in diluting a reagent, or in a pollution control reactor, or for batch carbon treatment of a nickel solution. The mixer will cause the contents to swirl rapidly, but actual mixing will be minimal (to appreciate this assertion, think about the fact that each droplet of solution is following an essentially fixed orbit around the mixer shaft). Actions taken to disrupt this orbiting, including installing baffles or moving the mixer off center, will cause the mixer's power to be absorbed in the desired shearing action rather than being available to rotate the contents as a whole, with the result that the solution may appear to the casual observer as less agitated.

Another example of movement, but little mixing, can occur with the typical rotating plating barrel illustrated in Fig. 2. There may be much agitation both within and outside of the barrel envelope, but little mixing through the envelope. Again, whether or not the mixing is sufficient depends on the particular requirements. Typically, the barrel rotation provides sufficient solution interchange to allow the plating process to proceed satisfactorily; but, conversely, rinsing will be improved if the barrel is momentarily lifted out of the rinse tank (allowing it to drain and refill) instead of being left immersed.

In deciding how to agitate a particular solution, the principal factors to consider include how much agitation is actually required, and what side effects are foreseeable.

AGITATION METHODS

There are countless casual forms of agitation: manual paddling, convection currents from heating and cooling coils, the disturbances caused by barrel rotation and movement of work

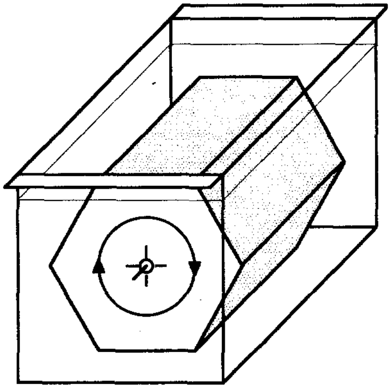

Fig. 2. Good mixing within barrel, but little between the inside and the outside.

in the tank, the solution motion resulting from the use of a filter pump, the mixing induced by the evolution of hydrogen at the cathodes, and so on. But in terms of practical engineered systems, we can restrict the discussion to air agitation, cathode oscillation, propeller type mixers, and circulation pumps—with a caveat that ultrasonic transducers and pulse plating rectifiers, each covered elsewhere in this *Guidebook*, are also actually agitation units in their own right.

AIR AGITATION

If air is forced to the bottom of a liquid-filled tank, and allowed to exit through a perforated pipe, the resulting bubbles will rapidly expand and race toward the liquid surface. Figure 3 conveys the general idea.

Air agitation has its undesirable facets. It will stir up bottom sludges and anode sludges, which, if not properly filtered, will cause roughness in the plating. It can cause excess foaming. It is poorly suited as a substitute for a mixer because powdered and low-density chemicals will tend to float on the surface rather than being drawn down into the mixing zone. It is rarely applied in pollution control operations because of its tendency to cause flotation of the precipitates. Thoughtless design or improper maintenance can mean that the air conveys inordinate volumes of oil and atmospheric dust into the process tank. Further, by its nature, the air will provide an oxidizing potential; while acid zinc baths might profit from this through oxidation and precipitation of iron, air agitation is never used in acid tin baths because the tin itself would oxidize, and rarely in cyanide solutions where it promotes formation of troublesome carbonates.

These limitations notwithstanding, air agitation is sufficiently simple, inexpensive, efficient, and generally applicable that it is probably the most common method of producing agitation in the metal-finishing shop today.

Air Sparger Design

The perforated pipe can be made of any material compatible with the solution and temperature involved, PVC being most common. The usual design calls for holes on about 4- to 6-in. staggered centers as shown in Fig. 4; the specified hole size is usually 3⁄32 to 1⁄8 in.,

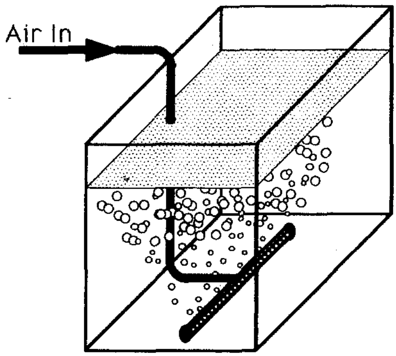

Fig. 3. Air-agitation concept.

since smaller holes may plug too easily. An alternative to the traditional hand-drilled spargers is the newer porous pipe designs, which can save a lot of fabrication effort.

In order to promote even distribution of air along the sparger, it is important that it be installed in a level plane and that the cross-sectional area of the pipe be larger than the combined area of the holes. Pipe sizes as small as ½-in. diameter may meet this latter criteria, but for most production-size installations, it makes sense to use a minimum pipe size of 1 in. for mechanical rigidity.

General solution homogeneity is virtually assured with even a single air sparger, so rarely is more than one used in a rinse tank; however, preventing ion depletion or gas accumulation at the cathode of a plating tank may require multiple lanes of air spargers for full coverage, since the air tends to rise almost straight vertically and a single air pipe is usually credited with delivering only a 6-in. wide swath of generous local agitation.

Plastic pipes charged with air will have enough buoyancy to float, so they must be secured to the tank bottom or equipped with plastisol-coated metal weights. It is often recommended that the air pipes be positioned well off the bottom of the tank to minimize disturbance of accumulated sludges, but in reality the pipes are invariably set directly at the tank bottom.

To preclude the possibility of solution siphoning out of the tank when the air supply is shut down, a small hole should be drilled in the riser, an inch or so above the solution level.

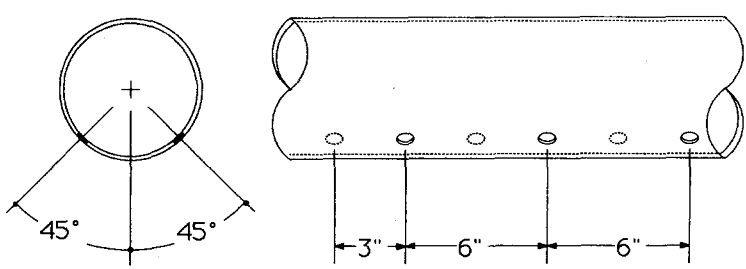

Fig. 4. Typical drilling of air-agitation sparger.

Air Blower Sizing and Selection

The air blower size is specified in terms of its output capacity in cubic foot of air per minute (cfm) and the back pressure against which it pumps. A good rule of thumb for initial calculations is to plan on providing 1 to 2 cfm for each foot of sparger pipe.

Back pressure is sometimes expressed in inches H_2O. Because two things cannot occupy the same space at the same time, to propel air to the bottom of a tank requires, in turn, lifting the column of liquid that stands above it up and out of the way. Thus, pumping air down to the bottom of a 48-in. deep water tank requires a static pressure of 48 in. H_2O (equivalent to 27.7 oz/in^2); but, because many of the liquids to be agitated weigh more than water, and because there are dynamic pressure losses associated with the pumping, for a first-cut approximation the back pressure can be estimated at an ounce per inch (48 oz/in^2 for a 48-in. deep tank).

The use of a conventional air compressor to supply the air is discouraged because of the high probability of introducing oil into the agitated tanks. Further, the cfm versus back-pressure ratings of air compressors align poorly with the usual requirements for agitation air.

For large installations, with a resulting need for copious volumes of air, a multistage turbine blower may be a good match. For most small to average size installations, the cfm versus back pressure needed is usually in a range not particularly well suited to traditional fans, turbine blowers, or compressors; in recent years, however, the development of the regenerative blower has filled this niche quite well.

In installing a blower, the need for filtration of the air cannot be overemphasized; read instructions carefully regarding proper filter types. Also double check the vendor's suggested method for adjusting air flow rates (for some blowers it is imperative that the outlet not be throttled but that, instead, excess air be dumped).

CATHODE ROCKER OSCILLATION

To obtain the requisite relative motion between work and solution, it is generally easier and more efficient to move the work than the solution. Thus, cathode rocker agitation is very widely used in printed circuit board (PCB) manufacture, nickel and precious metal plating, and wherever air agitation is undesirable.

The work movement can be vertical, horizontal, or a combination of the two. In many cases, the direction of motion is inconsequential; in other cases, for example in PCBs with plated-through holes, motion in one particular plane can be far more effective in propelling fresh solution to the point of interest than movement in the perpendicular planes.

For small tanks, the simple single-rod system shown in Fig. 5 is an off-the-shelf accessory that provides horizontal agitation. If vertical agitation is desired, it can often best be implemented with a see-saw arrangement that will minimize energy consumption and wear and tear, such as is shown in Fig. 6.

Whichever plane of oscillation is chosen, care should be taken in selecting and mounting the components to ensure that grease from the rocker will not leak into the tank, and conversely that racks lifted out of the tank will not drip corrosive chemicals onto the rocker system. In trying to provide for long service life, simple rollers of Teflon or polyethylene riding on stainless steel axles can be expected to endure the plating room environment more successfully than even the finest metal bearings.

The speed and stroke will vary depending on the application, but 15 to 40 cycles per minute with a stroke length of 2 to 6 in. covers the great majority of cases. Smooth motion suffices to prevent localized ion depletion with minimal risk of contact breaks, but a trip-hammer effect is especially well suited for dislodging troublesome gas bubbles in electroless plating operations.

For large installations and where the work is to be oscillated in several tanks, it is possible to fabricate a ladder-shaped framework, such as is shown in Fig. 7, to sit atop the tanks and move all the workloads in tandem. This approach is widely implemented in

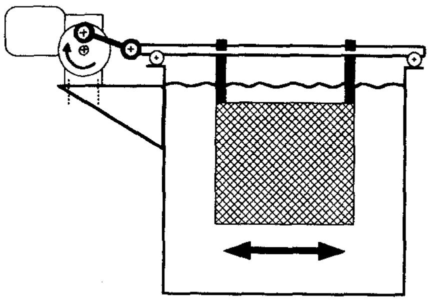

Fig. 5. Horizontal oscillation.

production plating of printed circuits. The ladder must have sufficient integrity that the oscillatory energy is not lost to structural flexure. Again, plastic bearings and corrosion resistant construction should be used.

PROPELLER MIXERS

Although rarely used directly in plating operations, propeller mixers have individual applications at which they excel. A propeller mixer generates a vortex, which pulls material down from the liquid surface and blends it into the body of solution; none of the other agitation methods has this capability, so none are as efficient at mixing dissimilar or reluctant constituents.

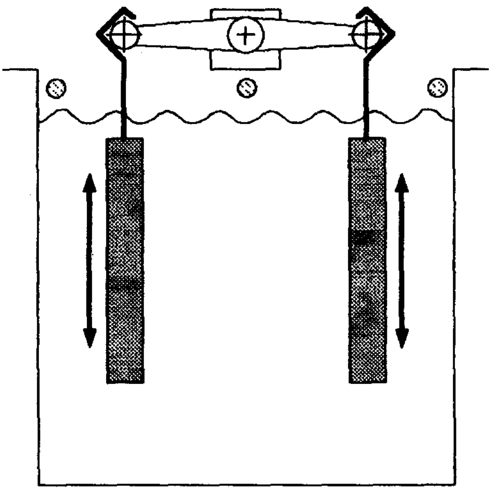

Fig. 6. Vertical oscillation.

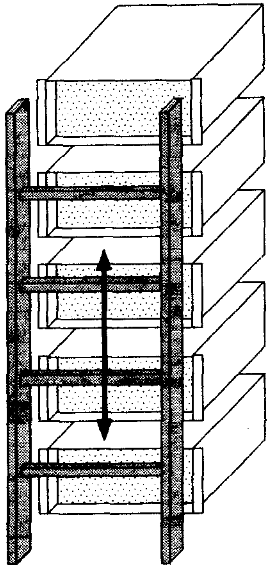

Fig. 7. Horizontal ladder oscillation.

Propeller mixers are at home in blending operations, making up stock solutions, batch carbon treatments, and in pollution control reactors.

Direct-drive designs (1,800 rpm) are fine for most operations, but in critical pollution control installations, the extra cost of gear reducers to achieve slower speeds and avoid mutilating the floc, which would hamper its settleability, is usually justified. The gear drive mixers will utilize larger propellers so that they impart the same blending power into the solution but with lower blade tip speeds.

The mixer sizing is based on the volume of solution and how thorough a blending action is required; but the required size hinges so heavily on the viscosity of the solution that to include abbreviated selection charts here might do more harm than good. Detailed selection charts, as well as guidelines for maximizing the blending action, are available from the manufacturers.

For simple mixing needs, portable agitators are sometimes equipped with flat paddlelike blades in lieu of propellers. These units may be fine for the easy mixing jobs, but they cannot generate the whirlpool that is needed to pull buoyant constituents down into the mixing zone.

CIRCULATION PUMPS

Circulation pumps can be used for agitation and mixing, typically by laying the discharge pipe of the recirculation system along the bottom of the tank in the same fashion as an air agitation pipe, perforating it with holes on periodic centers, and pumping the recirculating solution through it. The majority of the pump's energy is lost to turbulence right at the pipe/solution interface, so this approach has not been very popular.

The recent development of engineered eductor systems, however, is rapidly changing this situation. In this approach, an eductor is mounted at each of the discharge holes to improve the mixing efficiency greatly. The pump propels the primary solution through a nozzle, but the

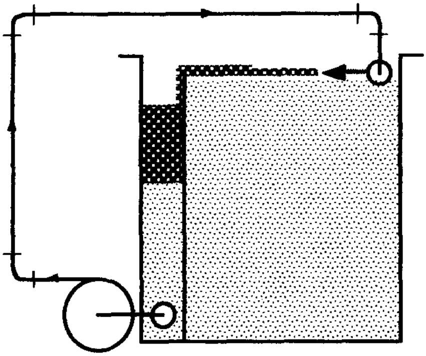

Fig. 8. Grease skimmer.

nozzle is mounted inside a venturi bell, which induces a large secondary stream to flow laminarly through the bell as well. The result is efficient mixing.

Eductor systems can often deliver benefits similar to air agitation systems, while not drawing in dirty shop air, nor aerating or oxidizing the solution.

Pumps are also commonly employed with other aims in mind, and in meeting their primary objectives, they may serve to mix and agitate the solution. For example, circulation pumps that are installed to skim away floating grease on cleaning tanks will deliver solution agitation as a side benefit (see Fig. 8).

On systems employing circulation pumps, care should be exercised in limiting the amount of process solution that is at risk of being lost to drain in the event of a malfunction or improper valve setting. Also, caution should be used to ensure that safety is not compromised; the pump shown in Fig. 8 must be low pressure and the holes in the skimmer pipe must be large lest partial blockage raise the possibility of squirting alkaline cleaning solution at an operator.

CONCLUSIONS

Engineered agitation systems are indispensable in most metal-finishing shops. But agitating the solution invariably affects the process to one degree or another, so care must be exercised in the application.