FILTRATION AND PURIFICATION OF PLATING AND RELATED SOLUTIONS AND EFFLUENTS

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This introduction reflects the response needed by platers for quality control, to meet just-in-time deliveries, and to achieve zero rejects. It also addresses the need for platers to continue to reduce solid waste after neutralization and employ filtration wherever possible to recycle or lengthen the service life of cleaners, etchants, and rinses.

Filtration usually includes the use of carbon for undesirable organic impurity removal, which years ago also doubled as a filter media along with other forms of filter aids.

Today's acceptance of granular carbon in many situations has lessened the need for powdered carbon and almost eliminated the weekly or monthly batch purification treatment. There are, however, some occasions when powdered carbon may be the only answer, and for that reason a separate piece of equipment held aside for such a need should be considered.

Platers who appreciate the value of filtration must first understand that it is not as much an art as it is a science. The requirement of a science is to have an orderly body of facts, facts that can be correlated and anticipated results yielded. Although there has been some work done in this area over the last 5–10 years, platers must still rely on experience to a great extent.

In the past, it has been suggested that the plater decide the level of quality sought and, using statistical quality control, determine if this goal has been achieved. It is further recommended that the plater needs to know the parts per million of contamination (solids) so that the necessary size or dirt-holding (solids) capacity of the filter could be established. The plater must also know the nature of the solids, which would be critical to success. Slimy, stringy, or oily contaminants blind a dense filter media surface quickly, whereas coarse, grainy, sandlike particles build a thick cake and still allow solution to pass, which provides for continued solid/liquid separation.

By first assessing these factors, platers can ascertain what results can be achieved. For example, slimy solids would require more surface area, whereas gritty particles could get by with less area (i.e., less solids-holding capacity).

However, all filter media are not manufactured in the same manner, for instance, filter paper, cloth, and plastic membranes provide a single junction to stop solids. Filter aids can enhance the ability of the filter media by creating a porous cake, which improves surface flow, but to really be successful a continuous mixing of filter aid and solids must be coordinated to maintain suitable porosity.

Other types of filter media can provide the necessary junction to stop solids but are built in such a manner as to achieve results from a combination of surfaces or juncture points, which achieve the solids retention by impedance. Thus, it is possible for continuous solid/liquid separation to be maintained over a longer period of time.

Most filter media are rated according to the size of particles that they are capable of stopping. Such a rating is based on laboratory tests and expressed in micrometers. A coarse media would be 100 μm; a dense media would be 10, 5, or 1 μm. The number suggests that at an efficiency level of 85 to 99%, all such particles would be stopped, whereas if the micrometer retention level is expressed in "absolute" ratings, 100% of the stated micrometer size and larger sizes would be removed. It further stands to reason that the coarser media will offer more solids-holding capacity, and the denser media will offer less solids-holding capacity.

Next we discuss where these troublesome solids come from and how they can be most effectively removed.

DIRT LOAD

The "dirt" (impurities) in a working plating bath can come from drag-in, anodes, water, and airborne sources. For their efficient removal, the system must be designed for the amount and type of contaminants present in the plating tank; these vary for each installation. Even without prior operating experience, an estimate of the dirt load can be made by reviewing the cleaning and plating processes to select and size the equipment needed.

A filter with insufficient dirt-holding capacity will require frequent cleaning or servicing. The rapid pressure buildup in the system as solids are retained increases the stress and wear of pump seals. By minimizing the dirt load, maintenance of the filter and pump can be reduced considerably. Even after thorough cleaning and rinsing, some solids and contaminants cling to parts, racks, and barrels. Thus, they are dragged into the plating solution. The amount of drag-in contamination depends primarily on the type of parts, plating method (rack or barrel), cleaning efficiency and rinsing cycles.

In most plating plants, the type and amount of parts being processed may vary considerably. For trouble-free operation, the filtration system should be designed for the heaviest work load and most difficult-to-clean parts. Drag-in contamination with barrels is high, due to incomplete draining of cleaners and difficulty in rinsing of loads. Filtration and purification on automatic barrel lines must be continuous, and equipment must be of sufficient size to minimize servicing and work interruption.

The amount of drag-in can often be reduced by improving the pretreatment. With the conversion of many vapor degreasing processes to aqueous cleaning, proper maintenance of cleaners and electrocleaners is of greater importance, particularly with machined or buffed parts carrying oil and lubricants. Recirculation and coalescing with an overflow weir on cleaner tanks will effectively skim off oil and scum, which would quickly foul the filter medium and carbon. More effective descaling will minimize the dirt load. Several countercurrent rinse tanks and a final spray rinse with clean water will also reduce the drag-in contamination. Due to the nature of the cleaning process, contamination of the solution with organic soil (oil, wetting agents) and/or inorganic (metallic) compounds is sometimes unavoidable. These can generally be controlled by carbon treatment at the rinse tank before plating.

Filterability depends on the nature, amount, and size of suspended particles, which, in turn, are contingent upon the type and chemistry of the plating solution. Generally, alkaline solutions, such as cyanide baths, have slimy or flocculent difficult-to-filter insolubles, whereas most acid baths contain more gritty solids, which are relatively easy to filter even with a dense filter media. A quick test of a representative sample with filter paper in a funnel will determine the nature and amount of solids present. This test will also indicate the most suitable filter medium. Bagging of soluble anodes will materially reduce the amount of sludge entering the plating bath. Airborne dirt from ceiling blowers, motor fans, hoists, or nearby polishing or buffing operations may fall into the plating tank and cause defective plating. Good housekeeping and maintenance will, of course, reduce dirt load and contamination of the plating solution.

Prevention of deposit roughness is perhaps the foremost reason for filtering plating solutions. Better covering power with less chance of burning is also achieved with a clean bath. In addition to suspended solids, the plater also has to contend with organic and inorganic (metallic) impurities, which are introduced into the solution primarily by drag-in. If this contamination is allowed to build up, it will affect deposit appearance. Continuous or periodic purification of the solution with activated carbon and/or low-current-density electrolysis (dummying) will often remove these impurities before a shutdown of the plating line becomes necessary.

The trend of Environmental Protection Agency (EPA) regulations is to severely restrict the amount of suspended solids and dissolved metal impurities in wastewater discharged to sewers and streams. To comply, plating plants have had to resort to some chemical treatment of their effluents to precipitate the metals as hydroxides. The filtration of these hydrated sludges is difficult and requires special separation equipment. Closed-loop systems, recycling, and recovery are being employed and require greater attention to filtration and purification.

Most filtration systems consist of a filter chamber containing the filter media and a motor-driven pump to transfer or circulate the solution from the plating tank through the filter. The many filters and pumps on the market today make it possible to select and justify a cost-effective filter system for each and every solution, regardless of volume.

When engineering a filter system for a plating installation, it is necessary to first establish the main objectives, such as: high quality finish—maximum smoothness and brightness; optimum physical properties—grain size, corrosion, and wear resistance; or maximum process efficiency and control—covering power, plating rate, purification, and clarification.

Then the following factors must be considered before selecting the size and materials needed for the filter media, chamber, pump, and motor:

1. Dirt load—suspended solids, size, kind, and amount; also soluble organic and inorganic impurities.
2. Flow rate—turnovers per hour for a given volume of solution necessary to maintain clarity.
3. Frequency of filtration and purification—batch, intermittent, or continuous required to remove dirt and contamination and filter servicing interval desired.

When agitating solutions with air, a low-pressure blower is usually employed. This makes it virtually impossible to achieve good filtration of the air while keeping the solution clean, because the plating solution then acts like a fume scrubber.

If effluent regulations make it necessary to remove or reduce total suspended solids (TSS) from wastewater, the amount discharged per hour or shift can be readily determined. For instance, a 100 gal/min (gpm) effluent containing 100 ppm TSS (100 mg/L) will generate 5 lb of solids per hour, as calculated below:

$$100 \text{ gpm} \times 3.79 \text{ L/gal} \times 100 \text{ mg/L} \times 60 \text{ min/hr } (1000 \text{ mg/g} \times 454 \text{ g/lb}) = 5 \text{ lb/hr } (2.3 \text{ kg/hr})$$

Therefore, the filter must have sufficient capacity to hold approximately 40 lb of solids/8 hr of operation. A horizontal gravity filter would be the most cost efficient for this dirt load and would operate automatically; however, if dryness of the retained solids is to be achieved, then a filter press would be recommended.

Filtration and/or purification during nonproductive hours makes it possible to remove dirt at a time when no additional contaminants are being introduced into the tank, such as insolubles from anodes, chemical additions, plus that which would otherwise be dragged in from improper cleaning of the work. Again, individual tank operating characteristics and economics will determine the ultimate level of acceptable quality.

This brings up an important consideration. Contamination by organic compounds, inorganic salts, wetting agents, and oils is not removed by filtration, but by adsorption on activated carbon. Some plating solutions, such as bright nickel baths, generate organic byproducts during plating. It cannot be assumed that both types of contamination increase at the same rate. A batch treatment, therefore, may eventually become necessary, either because of insoluble or soluble impurities. A check of clarity, flow rate, and work appearance and a Hull cell test will indicate the need for transfer filtration and/or carbon treatment.

If analysis shows that the concentration of insolubles (in ppm) has increased, it would indicate that the solution is not being adequately filtered. Therefore, transfer pumping of the solution through the filter should be employed as the quickest way of getting all the solids out at once and returning the clean solution to the plating tank. Soluble impurities can be detected by inspection of the work on a Hull cell panel. Pitting, poor adhesion, or spotty appearance indicates the need for fresh carbon. Here again, it may be desirable to completely batch treat the solution to restore it to good plating quality; however, since this necessitates shutting down the plating line and requires considerable labor, every effort should be made to maintain solution clarity and purity continuously, without having to resort to such batch treatment.

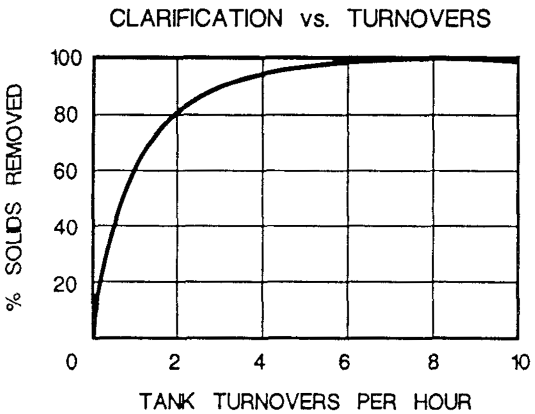

Fig. 1. Higher clarification is achieved by increasing the number of tank turnovers per hour.

FREQUENCY OF FILTRATION AND PURIFICATION

Since it is desirable to plate with a solution as free of suspended solids as possible, the quickest way to achieve clarification is by transfer pumping all of the solution from one tank, through a filter, to another tank (batch treatment); however, to maintain both clarity and uniform deposit quality, continuous recirculation through a filter is most effective. Although continuous filtration is more desirable, there are some plating installations that require only intermittent filtration, because relatively small amounts of solids are present. In other cases, it is necessary to filter and purify the bath continuously, even when not plating.

A high flow rate is essential to bring the particles to the filter as quickly as possible and to prevent settling of dirt on parts being plated. Although plating in a solution completely free of solids would be best, this ideal can be approached only in the laboratory. Some contamination always exists, and must be accepted. Continuous filtration at a high flow rate can maintain a high level of product quality by keeping suspended solids to a minimum. As Figure 1 indicates, four to five complete tank turnovers effectively remove 97% of all filterable materials if no additional solids are introduced. Since, in many installations, the rate at which contamination is introduced is higher than the rate at which it is removed, the impurities and solids gradually increase with time unless filtration is continued even during nonplating periods.

The greater the turnover rate, the longer the plating bath can be operated before the reject rate becomes too high and batch (transfer) filtration is necessary. In practice, contaminants are not introduced at a steady rate; for instance, most are introduced with the parts to be plated and, therefore, at the moment of immersion the degree of contamination is sharply increased until it is again reduced by the action of the filters. It then increases again when more parts are put into the tank for plating.

Figure 2 indicates the reduction in flow caused by the dirt buildup in the filter on a day-to-day basis, where one week's filtration would be effected before service of the filter becomes necessary. This reduction in flow rate could also have been representative of a longer time interval between filter cleanings. Graphically, it indicates why platers may experience roughness at varying intervals in the plating filtration cycle. The amount of solids increases in the tank as the flow rate decreases to a level that may cause rejects. After the filter is serviced, the increased flow rate agitates any settled solids. Therefore, it is advisable to delay plating of parts until the contaminant level is again reduced by filtration to within tolerable limits. This phenomenon generally occurs in a still tank, since the dirt has more chance to settle. For this

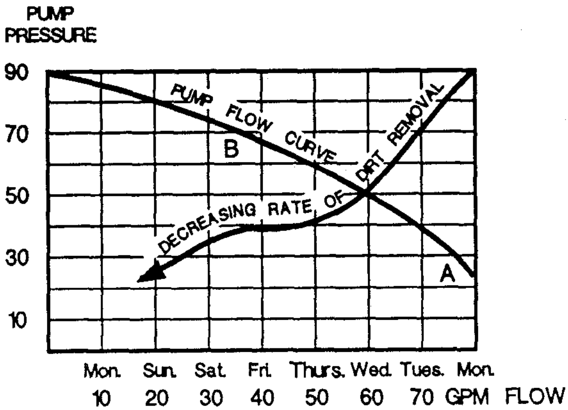

Fig. 2. Clean filter at point A will flow 4,800 gph and dirt removal is maximum. Flow rate has dropped to 2,000 gph at point B. Situation applied to a 2,000-gal tank would represent a reduction in flow from almost 2.5 tank turnovers per hour to one tank turnover per hour during a time interval of one work week. If filter continued to operate without servicing, the rate of dirt removed would soon be less than the rate of dirt introduced into the system. The time interval during which the filter is performing effective filtration will be determined by job conditions.

reason, when the solution is pumped into a treatment tank, sludge may be found on the bottom of the plating tank.

Dirt in an air-agitated tank can settle any time after the air is shut off. If carbon and/or a filter aid is used in the filter during the continuous filtration cycle, it should be borne in mind that, as these solids are collected on the media, the pressure increases appreciably, reducing the initial flow rate by almost 25% and the overall volume pumped through the filter by as much as 50% before servicing is necessary (Fig. 3). Frequent laboratory checks will verify the amount of insolubles in the plating tank, which will tell whether a uniform degree of clarity is being maintained or whether it is increasing slowly toward the reject level. More frequent servicing of the existing filtration equipment will increase the total volume pumped and, in turn, maintain the lowest possible level of contamination and minimize the need for batch treatment.

It is, therefore, necessary for the plater to determine the particle size to be removed and then select the media that provides the most solids-holding capacity. Then, knowing the efficiency of the media, multiply it by flow rate so that all of the solution passes through the filter in a certain period of time, such as 1 hr or 1 min. Note the small amount of solution that is filtered in 5 min if a rate of one turnover per hour is used (Fig. 4) as compared with the amount that would pass through at a rate of ten turnovers per hour (assume a 100-gallon solution):

At one turnover per hour,

$$1 \times 100 \text{ gal/60 min} = 1.6 \text{ gpm} \times 5 \text{ min} = 8 \text{ gal filtered}$$

At ten turnovers per hour,

$$10 \times 100 \text{ gal/60 min} = 16.6 \text{ gpm} \times 5 \text{ min} = 83 \text{ gal filtered}$$

The point here is that if nearly the entire solution is turned over every 5 min, then the plating bath will exhibit a high degree of clarity and purity. The net result should be fewer rejects caused by occlusion of particulate matter in the deposit.

In modern electroplating, no area that can result in improved quality should be

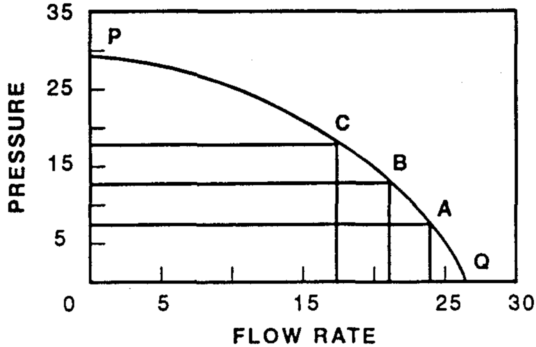

Fig. 3. Typical flow versus pressure curve. Q represents the maximum open pumping against no restriction, whereas P represents the pressure that the pump can develop at zero flow. A might indicate the pressure drop across a depth type media or a bare support membrane, whereas points B and C indicate the reduction in flow caused by the addition of filter aid and carbon, respectively.

overlooked. The plater can use the principles of high tank turnover and solution velocity to his advantage in his quest for zero rejects.

During recent years the flow rate through the filter, or tank turnover as it is referred to, has increased to two or three per hour or higher for most plating solutions (see Table I). This means that 1,000 gallons require a flow rate of at least 2,000 to 3,000 gallons per hour (7.6–11.5 m^3/hr); however, platers should recognize the need and employ turnovers of 10 or even 20 times per hour when all solids must be removed (see Fig. 1).

Alkaline solutions may require even higher flow rates for more effective solids removal by recirculation. Depending on the filter medium and its retention efficiency, flow rates in the range of 0.5 to 2 gpm (2 to 8 Lpm) per square foot of filter surface area are obtainable. Although 5 gpm per 10-in. (25-cm) cartridge is permissible, flow rates under 1.5 gpm per cartridge offer better economy. In fact, at a given flow rate with a cartridge filter, servicing, cartridge cleaning, or replacement can be reduced significantly by increasing the size of the filter. For example, *if the size of the filter was multiplied by four the annual amount of filter cartridges consumed would be cut in half, and the filter itself would operate unattended for at least four times as long before cartridge cleaning or replacement was necessary.* This is an important consideration to reduce media consumption.

It has also been found that the effective life of surface filters may often be tripled by doubling the surface. By increasing the dirt-holding capacity and reducing the frequency of filter servicing and replacement, the cost of filtration on a per month or per year basis is substantially reduced.

TYPES OF FILTER SYSTEMS

After estimating the dirt load and determining the flow rate and filtration frequency required, a choice of filter method and medium must now be made. The most common types of filters used in the plating industry are discussed below. These filters may be placed inside or outside the tank.

In-Tank Considerations:

Tank space
Motors located over fumes
Limited size of filter (less service life of media if used on pump suction)

Table I. Guide to Filtration and Purification of Plating Solutions

Process	pH	Temp. (°F)	Filtration	Turnovers/ hr [a]	per 100 gal.[b] Surface Area	per 100 gal.[b] No. Filt. Carts.	Media Fiber/ Core [c]	Porosity (μm) [a]	Carbon Treatment
Anodizing	1	60–90	Optional[d]	1–2	3.5	1	U/U	15	No
Nickel acetate seal	5.5	200	Desirable[d]	2–3	7	2	U/S	15	Batch/Continuous
Brass, bronze	10	100–200	As required[d]	2–3	7	2	U/U	15	No
Cadmium	12	100	As required[d]	2–3	7	2	U/U	30	No
Chromium, hexavalent	1	110–130	Optional[d]	1–2	3.5–7	1 or 2	M/U or glass[e]	15	No
Chromium, trivalent	2–3.5	75	Continuous	2–3	10.5	3	U/U	1–5	As needed
Copper acid	1	75–120	Continuous	2–3	10.5	3	U/U	15	Batch/Continuous
Copper cyanide	11–13	70–150	Continuous	2–3	10.5	3	U/U	15	Batch/Continuous
Copper, electroless	14	100–140	Continuous	1–2	7	2	U/U	3	No
Copper fluoborate	1	70–120	As required	1–2	3.5	1	U/U	15	As needed
Copper pyrophosphate	8–9	110–130	Continuous	2–3	7	2	U/U	10–20	As needed
Gold acid	3–6	80–125	Continuous	2–3	7	2	C/U	1–5	Periodic
Gold cyanide	7–12	75	Continuous	2–3	7	2	C/U	5	Periodic
Iron chloride	1	195	Continuous	2–3	7	2	U/U	15	Yes
Lead fluoroborate	1	100	Continuous	1–2	3.5	1	U/U	15	No
Nickel, bright	3–5	125–150	Continuous	2–3	7–10.5	2 or 3	C/U	15–30	Yes
Nickel, semi-bright	2–5	130	Continuous	2–3	7	2	C/U	15	Yes
Nickel chloride	2	120–150	Continuous	2–3	7	2	C/U	15	Yes
Nickel, electroless	4–11	100–200	Continuous	2–3	7	2	U/U	15	As needed
Nickel sulfamate	3–5	100–140	Continuous	2–3	7	2	C/U	15	Yes
Nickel, Watts	4	120–160	Continuous	2–3	7	2	C/U	15	As needed
Nickel–iron	3.5–4	135	Continuous	2–3	7–10.5	2 or 3	C/U	15–30	Yes
Rhodium acid	1	100–120	As required	1–2	3.5–7	1 or 2	U/U	5	Periodic
Silver cyanide	12	70–120	Continuous	2–3	7	2	C/U	5	Periodic
Tin acid	0.5	70	As needed[d]	1–2	3.5	1	U/U	15	As needed
Tin alkaline	12	140–180	As needed[d]	3–4	10.5	3	C/U	30	No
Tin–lead (solder)	0.5	100	Continuous	1–2	3.5	1	U/U	15	Periodic
Tin–nickel	2.5	150	Continuous	1–2	7	2	U/U	15	Yes
Zinc acid chloride	5–6	70–140	Continuous	2–3	14	4	U/U	15	As needed
Zinc alkaline	14	75–100	As needed[d]	2–3	10.5	3	U/U	30–50	Optional
Zinc cyanide	14	75–90	Continuous	2–3	10.5	3	C/U	30–100	No

[a] Increased turnover allows for use of coarser media to increase solids holding capacity. As many as 20 turnovers have been used on critical applications.
[b] (Surface area measured in sq. ft.) Increasing number of cartridges improves efficiency, reduces pump velocity and reduces amount of cartridges used.
[c] C - Cotton, U - Polypropylene, S - Stainless Steel. Depending on tank size and space, select appropriate in-tank or out-of-tank pump with nonmetallic solution contact. Either sealless magnetic or mechanical seal horizontal pumps are most common. For electroless plating solutions, a water flushed double mechanical seal pump, or vertical sealless pump is required.
[d] For best results, continuous filtration should always be considered.
[e] Immersion-test filter media fibers to select most cost effective.

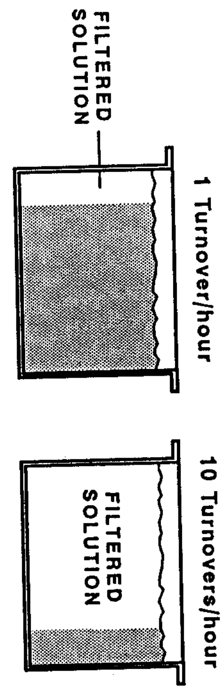

Fig.4. Comparison of filtered volumes for 100 gal of solution after 5 min of filtration at respective turnover rates.

Out-of-Tank Considerations:

Remote possibility for easy service
Employ sealless magnetically coupled pumps or direct-drive with single or double water-flushed seal
More suitable for use with slurry tank for chemical or filter aid/carbon addition or backwashing
Larger dirt holding and flow capacity from cartridges or surface media

Cartridge Filters

Cartridges offer both surface and depth-type filtration characteristics, providing various levels of particle retention at different efficiencies (nominal and absolute), manufactured in natural and synthetic (plastic) materials to provide a wide range of chemical resistance, flow rates, and particle retention capacities. Pleated-surface media offer initially higher flow rates, are available with a choice of porosities (usually in the denser range), and are sometimes given an absolute particle-retention rating.

Depth-type media are available in 1- to 100-μm particle retention and, because of the variety of porosities available, they are sometimes best suited to handle high-dirt-load conditions. This is a result of the manner in which the depth-type cartridge filter is manufactured. Basically, it consists of a series of layers, which are formed by winding a twisted yarn around a core to form a diamond opening. The fibers, which are stretched across the diamond opening, become the filter media. Succeeding layers lock the previously brushed fibers in place and, since there is the same number of diamond openings on each layer, the openings become larger due to the increase in circumference; other fiber-bonded types also increase density across the depth of the media.

During filtration, the larger particles are retained on the outer layers of the cartridge where the openings are large, whereas the smaller particles are retained selectively by the smaller openings on succeeding inner layers. This, then, makes it possible for an individual cartridge to have a dirt-holding capacity equal to 3.5 ft^2 of surface filter area of the same density. Cartridges having a 15- to 30-μm retention will often hold 6 to 8 oz of dry solids before replacement is necessary, whereas cartridges of 10 μm down to 1 μm will have a dirt-holding capacity of perhaps 3 oz to less than 0.5 oz. These figures merely indicate that the coarser cartridges have greater dirt-holding capacity, are more economical to use, and can be used longer before replacement.

Also, as pointed out earlier, dirt loads vary from tank to tank, and cartridges should be selected according to the individual requirements. A dense cartridge having less dirt-holding capacity will load up more quickly, increasing the pressure differential and, therefore, reducing the flow (Fig. 5). Using coarser cartridges (greater than 30 μm on zinc, for example) that have greater dirt-holding capacity and a longer service life may make it possible to clarify the plating tank more quickly because of the high obtainable flow rate. This will be accomplished

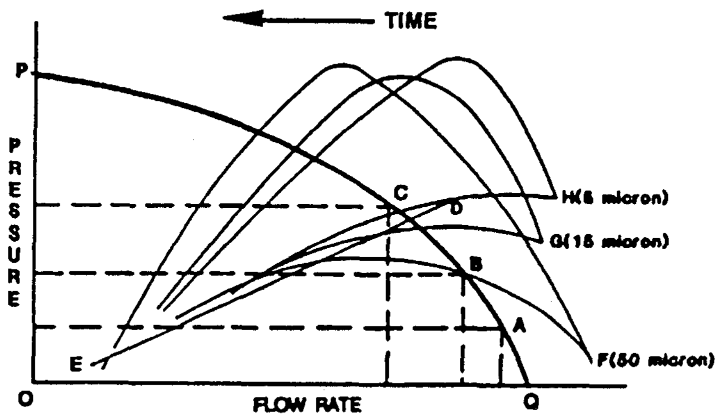

Fig. 5. In comparison with Figure 3, these curves show the effect on the rate of contaminant removal by using a coarser filter medium. Dirt pickup may increase for a while due to more effective filtration; the solids pickup increases the filter medium density after which it decreases as flow rate is also reduced. A, the highest possible flow rate; B, addition of filter aid reduces flow; C, addition of carbon; D, maximum dirt particle removal; E, no flow.

at less cost. Usually two cartridges (three on zinc, tin, and cadmium) are recommended for each 100 gal of tank capacity.

The pump should provide a pumping rate of at least 100 gph (two tank turnovers per hour) for each cartridge. Usually, a cartridge life of 6 weeks on nickel or 4 weeks on zinc can be expected, with some tanks running as long as 12 weeks; however, much depends upon dirt load, hours of plating, and so on. With cartridges, a higher dirt load can be retained in the filter chamber because of the coarseness of the filter media. Higher flow rates can usually be employed during the entire lifespan of the cartridge. This is due, in part, to the higher head pressures of pumps employed without chancing the rupture of a cartridge. Since all of the dirt is retained on and in the cartridge, the cartridge filter can be turned off and on at will, unless the cartridges are precoated. Cartridges are changed with very little maintenance expense and no solution loss; however, simplicity of use is perhaps the most predominant single factor in their selection.

Precoat Filters

Precoated filters consist of a membrane (leaf, sleeve, or screen) such as paper, cloth, ceramic, sintered metal, wire mesh, or wound cartridges. These membranes support the diatomite or fibrous-type filter aid, which has been mixed in a slurry of water or plating solution and picked up by the membrane openings. The dirt is retained on the outer surface of the cake. When the pressure has increased and the flow rate has decreased to a point where filtration is no longer efficient, the dirt and cake are washed from the membrane. Paper membranes are discarded and replaced.

The ability to obtain long runs is dependent upon proper selection of the foundation media, coupled with a coarser-than-usual nonfibrous-type filter aid (to be used where possible). Periodic (daily, if necessary) additions of small quantities of filter aid should be made to lengthen the cycle between servicing. The dirt-holding capacity of this type of filter is usually measured in square feet of filter surface. (If the standard 2.5×10-in. long cartridge is used, its outer surface when precoated would be equivalent to about 0.50 to 0.67 ft^2 of area.)

Flow rate and dirt-holding capacity of the various precoated membranes or cartridges would be about equal.

Before precoating, the operator should know or determine the filtration area to be covered. The amount of filter aid used depends on its type and on the solution being filtered. Generally, 0.5 to 2 oz/ft^2 of filter is sufficient. The manufacturer's recommendations for type and amount of filter aid should be followed if optimum results are to be obtained. A slurry of filter aid and plating solution or water is mixed in a separate container or in a slurry tank, which may be an integral part of the filtration system. The slurry is then caused to flow through the filter media and create a filter cake.

Usual flow rates range from 0.5 to 2 gpm/ft^2 of filter surface. A lower flow rate improves particle retention and smaller particles will be removed. It should be pointed out that, although there may be a wide range in flow rate, the range of selectivity of particles being removed is between 0.5 and 5 μm, which is the most significant difference between precoat and depth-type cartridges and offers a wider choice of porosity.

Buildup of cake should be gradual, and recirculation should continue until the solution runs clear. Cake should be dispersed uniformly across the media before the plating solution is allowed to flow across the filter. A slurry tank piped and valved into the filtration system becomes a convenient and versatile piece of equipment. The slurry may be prepared with plating solution, rather than water, to avoid diluting critical mixtures. Via valving, the solution is drawn into the slurry tank for sampling, preparation of slurry, and chemical additions. Similarly, the solution is returned to the plating tank. This method eliminates the necessity of transfer hoses between tanks, and the subsequent risk of loosening the cake or losing pump prime. The integral slurry tank is also a convenient storage for backwash water.

Precoat Backwash Filters

These filters operate the same as, and have the same functional purpose as, ordinary filters with the further advantage that they can be cleaned quickly by reversing the flow through the filter media. Backwashing the filter aid and dirt away makes the media available for prompt repeat precoating. The basic advantage is that the filter chamber need not be opened each time the filter requires cleaning.

Finer grades of filter aid may be precoated on top of the coarse filter aid when fine powdered carbon is to be used continuously. Here again, periodic (daily, if necessary) additions of small quantities of filter aid should be made to lengthen the cycle between backwashing. The media may be cleaned automatically with sluicing or using other devices. Iron hydroxide sludges can be dissolved by circulating dilute hydrochloric acid from the slurry tank; additional manual cleaning may also be required occasionally.

Some disadvantages of precoat and backwashing are the possible loss of solution, increased waste treatment loading, and the possibility of migration of filter aid and carbon into the plating tank. The use of rinse water for backflushing will reduce waste treatment loading; however, if evaporation is used to control drag-out, this may interfere with evaporator operation and the economies achieved by using this equipment.

Sand Filters

Using sand as the filter media, the pump and filter operate like a precoat surface filter and backwash like a precoat without the need of additional aid to achieve fine particle retention. Performance can be acceptable based on recirculation turnover rates, with the basic disadvantage coming from a smaller surface area, which increases the need for frequent backwashing and resulting solution loss to maintain the desired flow rate (turnover required).

Horizontal Fabric and Screen Filters

These filters are especially well suited for the continuous dewatering of hydrated metal

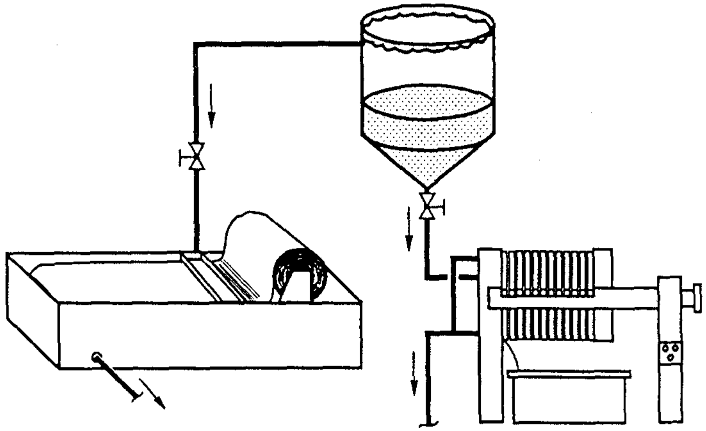

Fig. 6. Automatic disposable fabric filtration system for neutralized solid/liquid waste separation.

sludges resulting from the neutralization of plating wastewater prior to sewer discharge. They are also effective in removing accumulated iron sludge from phosphating tanks.

In one such system (Fig. 6), the waste containing 1 to 3% solids is first allowed to settle in a cone-shaped tank. The supernatant liquid drains into a head box, which directs the flow across the filter medium (paper or plastic) supported by a motor-driven conveyor belt. The liquid passes through the disposable fabric by gravity flow into a receiving tank below. When the pores of the media become clogged, the liquid level rises and a float switch activates the belt drive. Fresh media is fed over the tank and filtration is continuous. The cake on the fabric is allowed to drain before it is dumped into the sludge box. Gravity drain or an immersion pump empties the filtered water from the tank. Cycling and indexing of the filter are automatic. The occasional replacement of the filter fabric roll is the only labor required. The sediment in the bottom of the cone can also be dewatered periodically by filtration on the fabric. Other systems feature pressure or vacuum filtration. The sludge cake contains from 5 to 35% solids, depending upon the equipment and type of cake. Cakes can be further treated by air evaporation or with heat for dry disposal. The filtrate can be discharged to the sewer if it meets local effluent regulations or can be recycled through the system.

The performance of the unit can be improved greatly by the addition of coagulants and flocculating agents, such as polyelectrolytes, which increase the amount of solids, particle size, and settling rate. The flow rate is approximately 1 gpm/ft^2 with 90 to 95% solids retention; with coarse filter media, flow rates increase up to 10 gpm/ft^2. Filter aid can also be precoated to improve retention. The filter media is available in porosities of 1 to 125 μm and rolls 500 yd long. Carbon-impregnated paper is used for purification and removal of organic contaminants. The unit must be sized properly for each application to operate efficiently and with a minimum media cost. Steel, coated, stainless steel, or plastic units are available for corrosive solutions.

BATCH AND CONTINUOUS ACTIVATED-CARBON PURIFICATION

Virtually all plating solutions and some cleaners or rinses at some time will require purification via the adsorption of impurities on activated carbon. Those solutions that contain

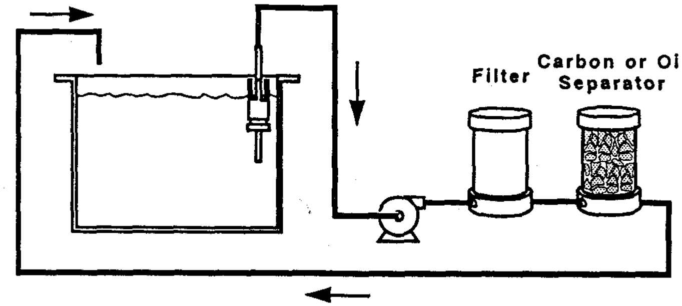

Fig. 7. Skimmer, pump, and prefilter with carbon or free oil separator.

wetting agents require the most carbon; when oil is introduced into the bath, the carbon is dispersed throughout the solution and clings to the parts, causing peeling or spotty work. Solutions that do not contain wetting agents have a tendency to float oil to one corner, depending on the recirculation set up by the pump, and in this case the oil may be removed with a skimmer or coalescer (see Fig. 7).

The choice of purification method depends on the size of tank and amount of carbon required and also on other available auxiliary equipment. Generally, carbon cartridges are used on small tanks (up to a few hundred gallons), and the bulk or canister type or the precoat method is used for the very largest tanks. The canister type is also used on the larger tanks supplemental to surface or depth-type cartridges or on certain automatic filters to supplement the amount of carbon.

Batch Treatment

The quality of the carbon is important and special sulfur-free grades are available. The average dosage is 10 lb of carbon to treat 500 to 1,000 gal of warm plating solution. At least sixty minutes contact time with agitation should be allowed, followed by some settling before transfer clarification can be achieved.

Continuous Purification

A separate purification chamber holding bulk granular carbon, a carbon canister, or cartridges offers the most flexibility in purification treatment. By means of bypass valving, the amount and rate of flow through the carbon can be regulated to achieve optimum adsorption of impurities without complete depletion of wetting agents and brighteners in the plating bath. It provides for uninterrupted production and fewer rejects. When necessary, the carbon can be changed without stopping filtration of the bath. Filtration should always precede carbon treatment, to prevent dirt particles from covering the carbon surfaces.

CONTINUOUS CARBON TREATMENT METHODS

Carbon Cartridges

Cartridges containing up to 8 oz of either powdered or granular carbon for every 10 in. of cartridge length are available and will fit most standard replaceable filters that employ this type of media. They may include an outer layer, which serves as a prefilter, and an inner layer, which serves as a trap filter. These handy cartridges are ideal for small filter chambers because of the ease and convenience of quickly replacing a conventional depth tube with the carbon tube when necessary. They may also be used with submersible filter systems, but in this case the flow rate could be greatly reduced.

Carbon Canister

Granular carbon may be used in ready-to-use chambers, each with a number of canisters holding up to 10 lb of granular carbon, and placed in line to the tank. A built-in trap filter eliminates migration of the carbon. Prefiltration ahead of the purification chamber will prevent solids from coating the surface of the carbon in the canister, assuring maximum adsorbency. The carbon in the canister can be replaced when its adsorption capacity has been reached. This method of separate purification offers the most flexibility. Any portion or all of the filtrate can be treated as needed by means of a bypass valve after the filter.

Bulk Carbon Method

Granular or bulk carbon is poured loosely around standard depth-type cartridge filters or sleeves, is poured into specific chambers designed for carbon, or is pumped between the plates or disks of other surface media. Since no filter aid is used, fines breaking off from the piece of carbon will have to be stopped by the surface media. Therefore, an initial recirculation cycle without entering the plating tank or recirculation on the plating tank prior to plating is desirable. This method does not alter the solids-holding capacity of depth-type cartridges, as most of the carbon will stay on the outer surface layer; however, carbon removal is not easily accomplished.

TIPS ON FILTER INSTALLATION

Filtration equipment should be installed as close to the plating tank as possible in an area that affords access for servicing. Equipment that is not easy to service will not be attended to as frequently as required, and the benefits of filtration will not be maximized. The suction line should always have a larger diameter than the discharge to avoid starving the pump (e.g., 1 in. versus 3/4 in. or 2 in. versus 1.5 in.) Where it is necessary to install the equipment more than 10 to 20 ft away, check the pump suction capabilities and increase the size of the suction piping (1.5 in. instead of 1 in., or 2 in. instead of 1.5 in.) to offset the pressure loss.

Hoses made of rubber or plastic should be checked for compatibility with the different solutions. Strong, hot alkaline and certain acid solutions such as chromium are especially aggressive. The use of chlorinated polyvinyl chloride (CPVC), polypropylene, or other molded plastic piping for permanent installation is becoming more common. Some plastics are available with socket-type fittings, which are joined with solvents. Their chemical inertness and temperature capabilities are excellent. Iron piping, lined with either rubber or plastic, is ideal but usually limited to use on a larger tank capable of justifying the investment. It should be pointed out that whenever permanent piping can be used in and out of the tank a more reliable installation will exist, since there is no shifting to loosen fittings, and collapsing or sharp bending of hoses is eliminated. The suction should be located away from anode bags, to avoid their being drawn into the line and causing cavitation. Strainers on the suction are always advisable.

It is also desirable to drill a small opening into the suction pipe below the normal solution operating level on permanent installations so that, should any damage occur to the system, the siphon action or suction of the pump will be broken when the level reaches the hold (Fig. 8). This provides added safety during unattended operation. Whenever automatic equipment is operated, some provision must be made to protect against unforeseeable events that could cause severe losses. This includes some form of barrier or removable strainer to prevent the suction of parts into the pump. The addition of a pressure gauge is strongly recommended to determine the initial pressure required to force the solution through the filter and also to determine when the filter media needs to be replaced.

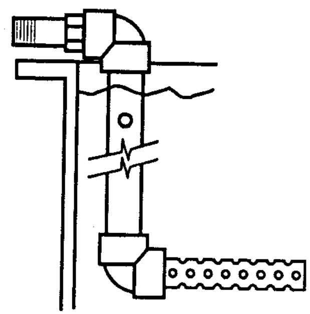

Fig. 8. Suction or dispersion piping system with strainer and siphon breaker. Drill a hole 2 in. below working solution level as a siphon breaker to prevent solution loss due to unforeseen damage to piping, pump, and so on. Chlorinated polyvinyl chloride with screwed connections offers maximum flexibility and ease in installation and may also be used on the return line by eliminating the strainer and replacing it with a longer length of pipe that is open along the full length.

When starting up a new filter system, or after servicing an existing system, it is advisable to completely close the valve on the downstream side of the filter; in this way, the pump will develop its maximum pressure, and one can immediately determine whether the system is secure. Sometimes filtration systems are tested on a cold solution and, in turn, will leak on a hot solution and vice versa. Therefore, a further tightening of cover bolts, flange bolts, and so on may be necessary after the filter has been operating at production temperature and pressure. If pump curves are not available, one may wish to check the flow at different pressure readings to determine a reasonable time for servicing the equipment before the flow rate has dropped too low to accomplish good dirt removal.

The best results are obtained from filtration equipment by following the manufacturer's operating instructions, gaining experience with the filter on the particular solution, and by following recommended plating shop procedures.