strength and high hardness has been reported, but again, processing requires somewhat sophisticated equipment.

To select a suitable electrolyte for producing electroforms, the following must be considered:

(1) physical, mechanical and chemical properties required for each specific application
(2) deposition rates dictated by the shape and design of the part
(3) stability and ease of control of electrolyte
(4) electrodeposited metal costs.

Examples of electrolytes, suitable operating conditions, and some reported mechanical property ranges of the resulting deposits are shown below:

Chromium deposits are often used on electroforms for producing hard, wear-resistant coatings. Electrical conductivity films required on electroforms are obtained by depositing silver, gold and other precious metals on the significant surfaces. (Compositions and operating conditions of these solutions can be found in other sections of the Guidebook.)

CONTROL OF STRESS IN ELECTROFORMS

Nickel:

Two kinds of internal or residual stress may be present in the electrodeposited nickel during electroforming: *tensile* when the deposit tends to contract or pull away from the mandrel at the edges, and *compressive* when the deposit tends to expand or become larger than the mandrel. Stress effects have been studied intensively during recent years, because of their importance in preventing curling and cracking around the edges (tensile stress) or in preventing blistering or buckling (compressive stress) of electroforms. Factors found to affect the level of residual stress include bath composition, temperature, current density, grain size of deposit, addition agents, and impurities such as iron, aluminum, and chromium.

Most electroforms should be prepared in an electrolyte controlled to produce deposits having an internal stress of no more than 1,000 to 10,000 psi tensile. This will minimize the problem of cracking, blistering and distortion of the electroform when removed from the mandrel. Sulfamate baths have the inherent advantage of producing deposits with low tensile stress. The Watts bath, however, requires the use of sulfo-oxygen type addition agents for low internal stress. Because of the sulfur content of deposits made in Watts baths with such additives, it may be necessary to limit the temperatures to which the electroform may be exposed in use to 700°F maximum. At higher temperatures sulfur-containing deposits suffer embrittlement.

Copper:

Copper is normally deposited with low compressive stress values suitable for electroforming. It is possible to control the stress in deposits from the acid copper electrolyte from 400-2,000 psi tensile. The stresses in deposits from fluoborate copper are slightly higher.

Iron:

Iron deposits from the all-chloride electrolyte can be controlled between 15,000 to 40,000 psi tensile. Solutions operated at the higher temperatures specified in the table will produce deposits having the lower stress values. Also, the presence of high ferric ion concentration will produce deposits of high stress and low ductility. Deposits produced from the fluoborate electrolyte will have higher stress values, which limit the number of electroforming applications.

FILTRATION AND PURIFICATION OF PLATING SOLUTIONS

by Jack H. Berg and Konrad Parker

Serfilco, Ltd.
Glenview, Ill.

Prevention of deposit roughness is perhaps the foremost reason for filtering plating solutions. Higher 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 shut-down of the plating line becomes necessary.

Recent EPA regulations severely restrict the amount of suspended solids and dissolved metal impurities in wastewaters discharged to sewers and streams. In order to comply, plating plants may have to resort to some kind of chemical treatment of their effluent to precipitate the metals as hydroxides. The filtration of these hydrated sludges is difficult and requires special separation equipment.

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, which may be:

High Quality Finish—Maximum smoothness and brightness
Optimum Physical Properties—Grain size, corrosion and wear resistance
Maximum Process Efficiency and Control—Covering power, plating rate, purification and clarification.

Then consider the following factors 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 X volume solution necessary to maintain clarity.
3. Frequency of filtration and purification: Batch, intermittent or continuous required to remove dirt and contamination; filter servicing interval desired.

DIRT LOAD

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

A filter with insufficient dirt-holding capacity will require frequent cleaning or servicing. The rapid pressure buildup in the system, as solids are retained, will increase 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 will be 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 of sufficient size to minimize servicing and work interruption.

The amount of drag-in can often be reduced by improving the pretreatment. Vapor degreasing before soak cleaning is desirable on 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, as will be discussed later.

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 will have slimy or flocculent, difficult-to-filter insolubles, while most acid baths contain more gritty solids, which are relatively easy to filter even with 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. It will also indicate the most suitable filter media. 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.

When agitating solutions with air, low pressure blowers are usually employed. This makes it virtually impossible to achieve good filtration of the air, and the plating solution then acts like a fume scrubber. Compressed air is more costly to use, but can be adequately filtered for removal of all oil and solids; therefore, is preferred for agitation purposes, but much more costly.

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

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

Therefore, the filter must have sufficient capacity to hold about 40 lbs. solids per eight hours operation. A horizontal gravity filter would be most cost-efficient for this dirt load (see table).

FLOW RATE

In recent years the flow rate through the filter, or tank turnover as it is referred to, has increased to 2 or 3 per hour for most plating solutions. This means that 1000 gallons require a flow rate of 2000 to 3000 gallons per hour (7.6-11.5 m³/hr). 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.

Recommendations for Filtration and Purification of Plating Solutions

Process	pH	°F Temperature	Filtration	Turnovers* /Hour	Filter Tubes /100 gal.	Fiber/ Core	Micron Porosity
Anodizing	1	60–90	Optional	1	1	U/U	15
" Ni seal	5.5	200	Desirable	2	2	U/S	15
Brass, Bronze	10	100–200	As Required	2	2	U/U	15
Cadmium	12	100	As Required	2	2	U/U	30
Chromium Hexavalent	1	110–130	Optional	1–2	1–2	U/U	15
" Trivalent	2–3.5	75	Continuous	2	3	U/U	1–5
Copper Acid	1	75–120	Continuous	2–3	3	U/U	15
" Cyanide	11–13	70–150	Continuous	2–3	3	U/U	15
" Electroless	14	100–140	Continuous	1–2	2	U/U	3
" Fluoborate	1	70–120	As Required	1	1	U/U	15
" Pyrophosphate	8–9	110–130	Continuous	2–3	2	U/U	10–20
Gold Acid	3–6	80–125	Continuous	2	2	C/U	1–5
" Cyanide	7–12	75	Continuous	2	2	C/U	5
Iron Chloride	1	195	Continuous	2–3	2	U/U	15
Lead Fluoborate	1	100	Continuous	1	1	U/U	15
Nickel Bright	3–5	125–150	Continuous	2–3	2–3	C/U	15–30
" Semibright	2–5	130	Continuous	2–3	2	C/U	15
" Chloride	2	120–150	Continuous	2–3	2	C/U	15
" Electroless	4–11	100–200	Continuous	2–3	2	U/U	15
" Sulfamate	3–5	100–140	Continuous	2–3	2	C/U	15
" Watts	4	120–160	Continuous	2–3	2	C/U	15
Nickel-Iron	3.5–4	135	Continuous	2–3	2–3	C/U	15–30
Rhodium Acid	1	100–120	As Required	1–2	1–2	U/U	5
Silver Cyanide	12	70–120	Continuous	2	2	C/U	5
Tin Acid	0.5	70	As Needed	1	1	U/U	15
" Alk.	12	140–180	As Needed	3	3	C/U	30
Tin-Lead (solder)	0.5	100	Continuous	1	1	U/U	15
Tin-Nickel	2.5	150	Continuous	1–2	2	U/U	15
Zinc Acid Chloride	5–6	70–140	Continuous	2	4	U/U	15
" Alkaline	14	75–100	As Needed	2–3	3	U/U	30–50
" Cyanide	14	75–90	Continuous	2–3	3	C/U	30–100

*Of tank volume with good cleaning cycle. With high dirt load, increase by 50 to 100%
C—Cotton U—Polypropylene S—Stainless Steel
Depending on tank size and space, select appropriate intank or out-of-tank pump with non-metallic solution contact. Either seal-le
or mechanical seal horizontal pumps are most common. For electroless plating solutions, a water flushed double mechanical seal pun

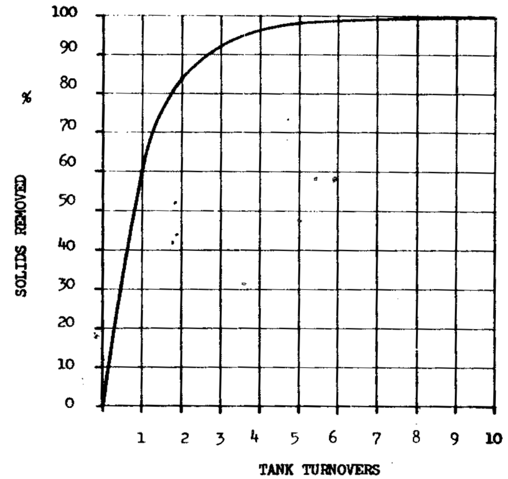


Fig. 1

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 Fig. 1 indicates, four to five complete tank turnovers will 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 will gradually increase with time unless filtration is continued even during non-plating periods.

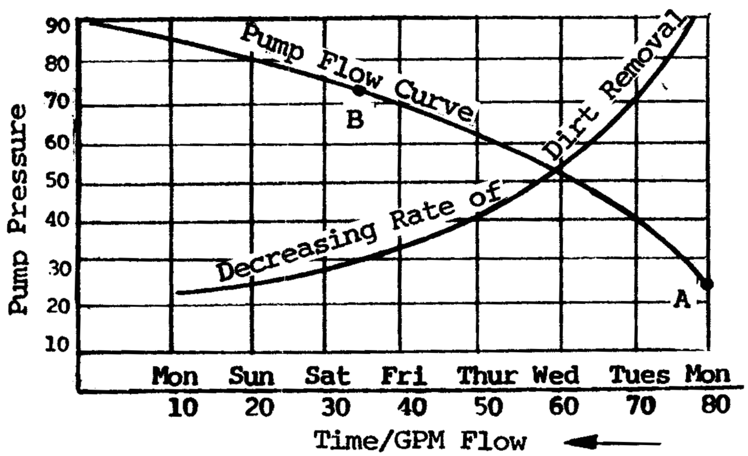


Fig. 2. Clean filter at Point A will flow 4800 gph and dirt removal is maximum. Flow rate has dropped to 2000 gph at Point B. Situation applied to a 2000 gal. tank would represent a reduction in flow from almost 2-½ tank turnover per hour to one tank turnover per hour during a time interval of one work week. If filter continued to operate without servicing, the rate of dirt removed would soon be less than the rate of dirt introduced to the system. The time interval during which the filter is performing effective filtration will be determined by job conditions.

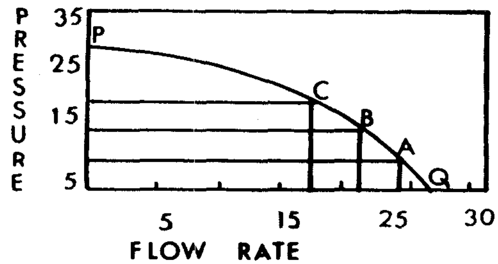


Fig. 3 Typical flow versus pressure curve. Q represents the maximum open pumping against no restriction, while P represents the pressure which the pump can develop at nil flow. A might indicate the pressure drop across a depth type media or a bare support membrane, while points B and C indicate the reduction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

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

Fig. 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 cleaning. 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 which 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 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 anytime after the air is shut off. If carbon and/or 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 over-all 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.

FREQUENCY OF FILTRATION AND PURIFICATION

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 most desirable, there are some plating installations which 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.

Filtration and/or purification during non-productive 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 other soluble solids, such as organic compounds (inorganic salts, wetting agents, oil), 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 ppm of insolubles have increased, it would be an indication that the solution is not being adequately filtered. Therefore, transfer pumping of the solution through the filter is 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 will indicate the need for fresh carbon. Here again, it might 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.

EQUIPMENT SELECTION

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:

Cartridge Filters:

Cartridge filters of the wound type are available in one micron to 100 micron 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 previous 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.

During filtration, the larger particles are retained on the outer layers of the cartridge where the openings are large, while 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 3½ sq. ft. of surface filter area of the same density. Cartridges having a 15 to 30 micron retention will often hold 6 to 8 ounces of dry solids before replacement is necessary, whereas cartridges of 10 microns down to 1 micron will have a dirt holding capacity of perhaps 3 ounces to less than ½ an ounce. The above 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. 4). Using coarser cartridges (>30 micron) on zinc for example, which 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 flow rate

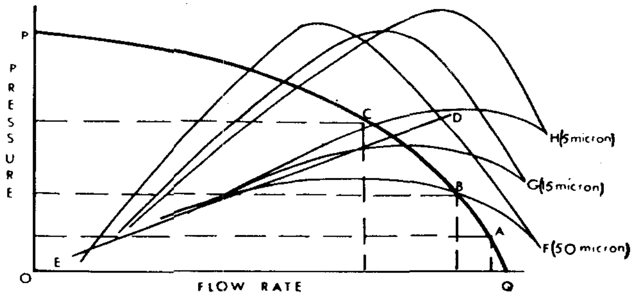


Fig. 4. In comparison with Fig. 3, these curves show the effect on rate of contaminant removal by using a coarser filter medium. Dirt pick-up may increase for a while, due to more effective filtration caused by solid pick-up increasing the filter medium density, after which it decreases as flow-rate is also reduced. A - highest possible flow rate; B - addition of filter aid reduces flow; C - addition of carbon; D - maximum dirt particle removal; E - no flow.

obtainable. This will be accomplished at less cost. Usually two cartridges (3 on zinc, tin, cadmium) are recommended for each 100 gallons of tank capacity.

The pump should provide at least 100 gallons per hour pumping rate (2 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, etc. 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 life span 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 coarser-than-usual non-fibrous 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 2½ " by 10 " long cartridge is used, its outer surface when precoated would be equivalent to about ½ to 2/3 sq. ft. 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, 0.5-2 oz/ft^2 of filter are 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 sq. ft. of filter surface. Lower flow rate indicates finer 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 microns, which is the most significant difference between precoat and depth type cartridges, which offer 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 transferring 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 operate the same as, and have the same functional purpose as ordinary precoat 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 re-precoating. 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 other devices. Iron hydroxide sludges can be dissolved by circulating dilute hydrochloric acid from the slurry tank.

Filtration Chambers:

The size of the chamber depends on the volume of solution, turnover rate and dirt load. From these data, the number of filter tubes or filter surface area required is determined. It has been found from experience that, for 1,000 gallons of "normal" plating solution, 20 filter tubes are needed with a tank turnover of twice per hour. These would have a maximum dirt holding capacity of about 10 pounds (15 micron porosity). With finer filters, high dirt loads or flocculant solids, the chamber size should be increased to accommodate 36 tubes in order to operate without too-frequent cleaning. If a precoat filter is preferred, at least 10 square feet of filter surface area would be necessary for 1,000 gallons.

It has been found that the effective life of cartridges or surface filters may often be tripled by doubling the number of tubes or area. 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. Doubling the size of the chamber can be done with a relatively small increase in cost.

The material or construction will depend on size, solution corrosivity and temperature. Most manufacturers use a variety of plastics or metals compatible with different plating formulations. Steel for alkaline, and rubber or plastic lined steel for acid solutions are the standard for larger filter chambers. New developments are steel chambers with PVC, epoxy and phenolic coatings, capable of withstanding temperatures commonly in use with electroplating solutions. PVC liners are finding increasing use with fiberglass shells (up to 60 cartridges). Small chambers are available in polypropylene, CPVC, acrylic and ABS plastics or Pyrex. In some unusual instances the cost of stainless steel can be justified. With high temperature solutions, CPVC is the best plastic; polypropylene is second choice.

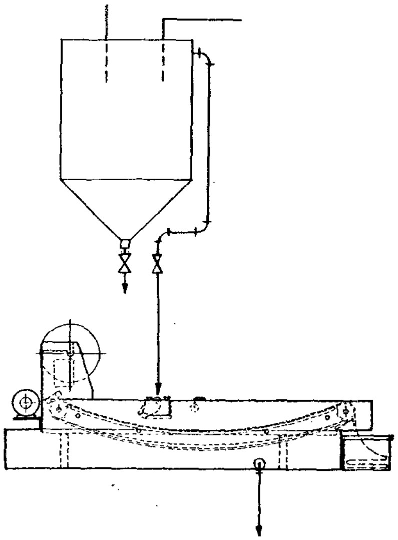


Fig. 5 Automatic disposable fabric filtration system for neutralized waste/precipitated solids/liquids separation.

Horizontal Fabric and Screen Filters:

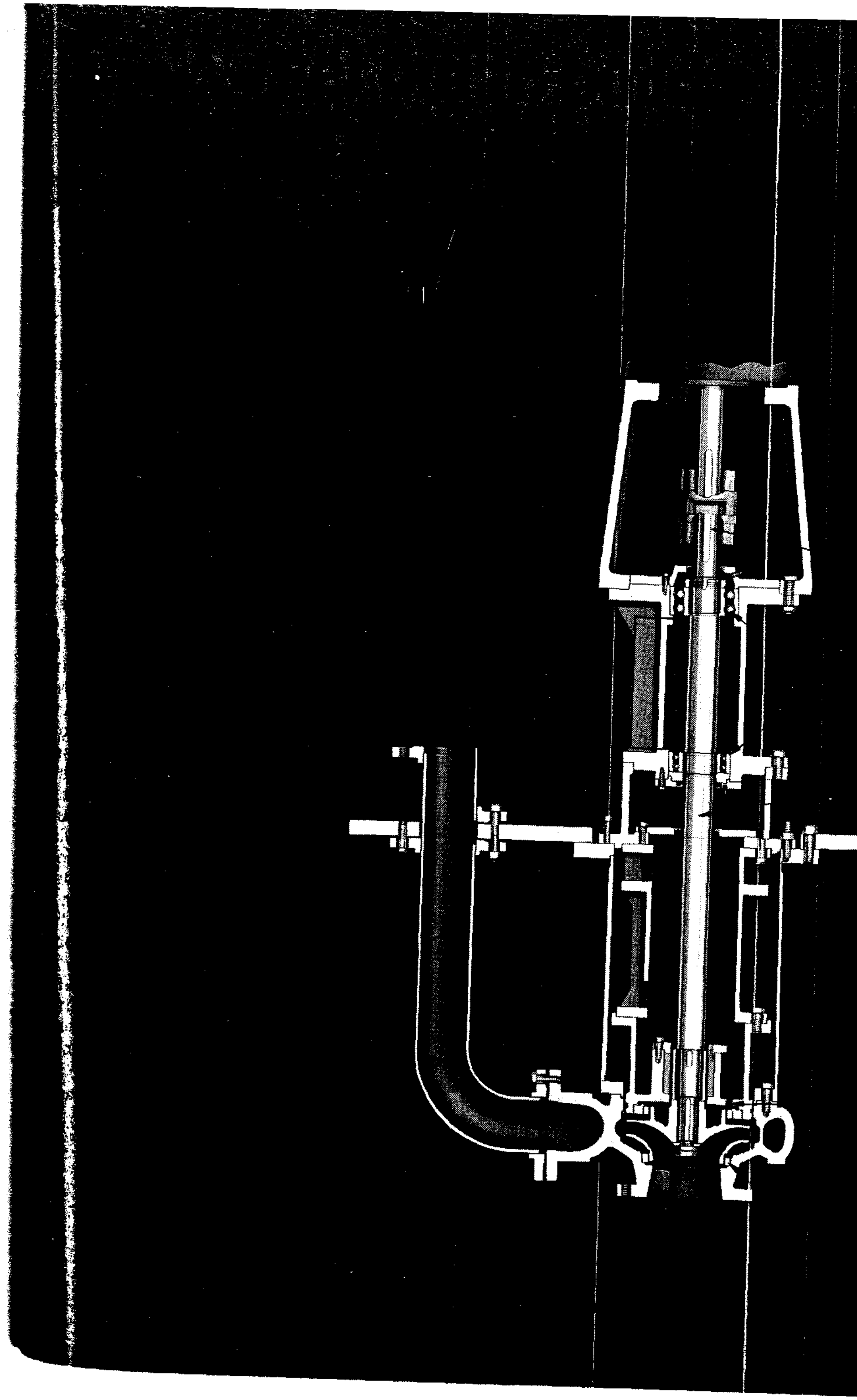
These are especially well suited for the continuous dewatering of hydrated metal sludges resulting from the neutralization of plating wastewater prior to sewer discharge. They are also effective in removing accumulated iron sludge from phosphating tanks.

In one such system (Fig. 5), the 1-3% solids-containing waste 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 stretched over the tank and filtration is resumed. 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 10 to 20% solids, and can be dried by air evaporation or with heat for dry disposal. The filtrate can be discharged to the sewer, if it meets local effluent regulations.

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

ACTIVATED CARBON PURIFICATION

Virtually all plating solutions, at some time or other, may require purification through the adsorption of impurities on activated carbon. Those solutions containing



wetting agents require the most use of carbon since, when oil is introduced into the bath, it is dispersed throughout the solution and clings to the parts, causing peeling or spotty work. Solutions which do not contain wetting agents have a tendency to float oil to one corner, depending on the recirculation set up by the pump.

The choice of purification method will depend on the size of tank and amount of carbon required, and also on other auxiliary equipment which may be available. Generally, carbon cartridges are used on small tanks up to a few hundred gallons, the bulk or canister type for the middle range up to several thousand gallons, and the precoat method 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.

The quality of the carbon is important: special, sulfur-free grades are available. Average dosage is 10 lbs of carbon to treat 500-1000 gallons of warm plating solution by batch treatment, and at least sixty minutes contact time with agitation should be allowed.

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 due to excessive contamination. 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.

Carbon Cartridge:

Ten-inch cartridges (containing about 8 oz of carbon) will fit most standard replaceable filters which 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 filters because of the ease and convenience of quickly replacing a conventional depth tube with the carbon tube when necessary: also, they are most practical for submersible filter systems where precoating with filter aid and carbon is difficult.

Carbon Canister:

Granular carbon is provided in ready-to-use containers holding up to 10 lbs of granular carbon, and placed in line to the tank. A built-in trap filter eliminates migration of the carbon. Prefiltering 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 by-pass valve after the filter.

Bulk Carbon Method:

Granular or chunk-type carbon is poured loosely around standard depth-type cartridge filters or sleeves, or into specific chambers designed for carbon, or is pumped between the plates or discs 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 is desirable, or recirculation on the plating tank prior to plating. 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 cartridges or canisters are easier to handle, if frequent carbon replacement is necessary.

Carbon Precoat:

Powdered or fine granular carbon is deposited on the surface of the support membrane, which may be cloth, paper, or a depth-type cartridge (which becomes a surface medium). A slurry tank or pail may be used to recirculate first the liquid through the filter, then the filter aid, and finally a pre-mixed combination of approximately equal amounts of filter aid and carbon. This purification method may be used continuously or intermittently. It is considered by many to be the quickest way to effect adsorption and yet the messiest. The least amount of carbon is required because of the large surface area offered by the powdered carbon. Any filter may be operated as a depth or surface media and then precoated just prior to the use of carbon addition. This method is also employed for batch treatment. Activated carbon in granular form is also used, but the rate of adsorbency is not as rapid as for powdered carbon although the adsorbency is equal pound for pound.

Batch Treatment:

Complete batch purification in a separate treatment tank is necessary only if day-to-day use of carbon proves inadequate. Here, just as in the case of batch treating for solids removal, the solution is pumped into an auxiliary tank. Carbon is then added in the required amount and agitated for several hours, then an equal amount of filter aid is sprinkled over the top of the solution and agitated slightly, then allowed to settle. After settling, the solution may be decanted by inserting a suction hose near the top of the solution, gradually lowering it as the solution is pumped through a filter which has been precoated with filter aid. Periodic checks of the discharge filtrate should be made to make doubly certain that no carbon gets back to the plating tank.

Summary:

Perhaps the most important consideration when using carbon is the determination whether or not the method of removing solids is adequate. Sufficient flow rate (tank turnover rate) and solids-holding capacity in relation to adequate particle retention must be provided. Any filter surface or depth cartridge will operate longer without cleaning or replacement if carbon is not applied directly but rather used in an auxiliary method such as the bulk, cartridge, or canister type. Carbon in series, handling only a portion of the total flow on a bypass following the filter which is being used for solids removal and also serving as a prefilter, is an extremely effective and desirable method of operation. Thereby, the best method of filtration is combined with a continuous method of carbon treatment.

SELECTION AND CARE OF PUMPS

Since the pump is the heart of the filtration system, it must be large enough to deliver and maintain the desired flow rate and pressure as the dirt builds up on the filter medium. Proper pump and seal selection is critical and requires consideration of:

1. Flow rate required: gph (tank turnovers per hour)
2. Location (in or out-of-tank)
3. Discharge head and distance
4. Filter medium and surface pressure drop
5. Solution corrosivity
6. Solution temperature

All materials of construction must be compatible with the solution to be pumped, taking into consideration the use of materials which may corrode slowly within tolerable limits and, therefore, would be selected if cost-effective for a limited period. Always compare the pump operating cost required for maintenance, down time and replacement of parts, in relation to original cost. Consider the advantages and disadvantages, for a particular application, between self-priming pumps and those which are not self-priming.

Horizontal centrifugal pumps are the most common pumps used in the plating industry. Usually, the only part which wears is the seal. Flow rate is high when the filter is clean and decreases to no flow at all when the filter is loaded. The flow should be restricted initially with a valve on the discharge, since it is possible to overload a motor when the centfigual pump is working against virtually no restriction. Care is usually taken by the manufacturer to supply a sufficient amount of horsepower to prevent this overloading, and also protection is provided in the motor starter. Some users may prefer to use less horsepower in their daily operation and, therefore, must guard against motor cutout by controlling the flow with a valve.

Close-coupled, horizontal pump-motor units are available in all price ranges and sizes, and offer the greatest advantage in always assuring proper alignment between the pump and motor. They are compact and, therefore, require less floor space. Long-coupled pump and motor units, use standard motors and usually require an additional mounting plate to assure proper alignment. Improper alignment will cause vibration of the pump and motor assembly which, in turn, causes failure at the motor and pump bearing; it also has an adverse effect on the pump seal.

Vertical sump pumps are usually of the centrifugal type and, depending upon design, may have no bearings at all, capable of dry operation at high speed, but limited to short lengths; longer pumps require one or more bearings, which may also serve as a seal. Shaft seals in a submersible pump are not necessary since the suction casing is immersed in the solution. Pumps should be specified with suction as short as possible and driven at slow speed (1725 rpm) to reduce the radial load and wear on the bearings. With open impeller they can be operated at elevated temperatures (>160 °F). For longer wear the bearings should be piped for water flushing to provide both cooling and lubrication. With long suction casings and several seals, alignment of pump and motor is critical and should be checked at intervals.

All-CPVC plastic sump pumps are well suited for agitating and mixing all types of solutions by recirculation. Low-cost models have no seal or bearing; their short cantilever shaft requires no support. A double impeller prevents the solution being pumped up the column, even at no flow and maximum head. If mounted inside the tank, they are self-priming. Because of generous clearances in the pump, they are used successfully for hot electroless solutions, and can even be run dry. Pumps of this type are characteristically of the low-head design, and are often preferred for use in small tanks, such as precious metals, and intermediate size tanks to about 1000 gallons. They are also recommended for solutions which do not require the use of filter aid and carbon in the filter chamber, since the low head of the pump will shorten the time interval between servicing of the filter. Generally, submersible pumps are used in solutions where solution loss due to leakage cannot be tolerated and where space limitations dictate in-tank pumping.

Magnetic-coupled pumps are unique because they require no direct mechanical coupling of the motor to the pump shaft and, therefore, no seals are needed, making them truly leakproof. The pump body is generally constructed of plastic, and the impeller magnets are encapsulated in plastic to make them wear-resistant and to eliminate any metal contact with the solution. Those without internal carbon bearings are used for electroless solutions. Magnetic pumps are also available with encapsulated motors, so that the entire unit may be submerged in the liquid. This is an extremely desirable feature for use in precious metal plating, to avoid loss of expensive plating solutions.

If self-priming is desired, this will also affect the pump selection, or a priming chamber can be provided for a centrifugal pump.

In orer to effect a self-priming feature, close tolerances and actual rubbing must occur on both impeller and/or moving parts on the body of the pump. Most noteworthy is the fact that the greatest amount of wear will occur when the pump is developing its greatest amount of pressure, as the filter is approaching maximum reduction of flow due to dirt pick-up. This is why oversizing the filter will reduce the frequency of this occurrence.

The closest to a gear pump for use on plating solutions would be the flexible impeller or liner type, which are both self priming. They develop pressures up to 20 psi, but require relatively frequent impeller or liner replacement when used continuously. Diaphragm pumps are suitable for metering applications.

CENTRIFUGAL PUMP PRIMING

Priming of centrifugal pumps will be made easier if the following precautions are taken. Avoid all sharp bends or crimps in the suction hose. Prevent small parts from entering or restricting flow to the suction hose. Prevent air from getting into the pump by checking for poorly connected hose or flanged fittings which may have vibrated loose. The slightest amount of air coming from an insufficiently tight screw fitting or a loose flanged fitting will prevent successful priming. As the pump packing wears it will also suck air and, depending on usage, must be adjusted as required. (See tips on pump packing and the use of water lubrication to prevent sucking air). If frequent venting of the filter chamber is necessary when the filter is running, it is likely that an air leak has developed some place at the above two locations, and sooner or later, priming will become more difficult. Air in the filter chamber is also an indication that the suction from the tank may be too close to an air outlet being used for solution agitation. Remember, the larger the pump the more velocity is created and the more tendency to pull air into the suction opening. Priming is made easier with a slurry tank or priming chamber above the pump, making it possible to always have a flooded suction. Recirculation through the pump, filter, and slurry tank, and then slowly opening the line to the plating tank will gradually purge the system of air. The suction valve from the plating tank should initially be opened only a crack, so that the pump does not get a slug of air at one time. This air will also collect in the filter chamber, and must be released by venting. In a pre-coated filter, any constant collection and venting of air will soon result in ineffective filtration. As air collects, the cake falls away and is redeposited elsewhere. Subsequent venting returns solution to the unprecoated surface where there is no filtering action, and the contaminated solution passes through.

To prime a centrifugal pump, if hose is used on the suction side of the pump, (without a slurry tank) liquid may be introduced through the hose and pump into the filter chamber. The filter need not be filled completely, but must contain a sufficient volume of liquid so that, as the hose is lowered to approximately the same height as liquid in the chamber, the hose will gradually fill with solution. Shake the hose to make certain any air trapped in the top of the pump, or in other high points, will be expelled completely. When the liquid level completely fills the hose, keep the tip of the hose at the same position but close the valve between the pump and the filter chamber. Now insert the hose in the tank (since the valve is closed, virtually no liquid will run out of the hose if a gloved hand is cupped over the end.) Start the motor and wait until the motor has reached its proper speed, then slowly open the valve to the filter. This is a further precaution which will enable the pump to create enough suction to handle the small amount of air which may still be in the line.

When transfer pumping out a tank, it is advisable to connect a 90° hose barb or a strainer to the suction end of the hose so that it may be lowered as solution level drops. This prevents cavitating the pump, which could occur if the end of the hose rested flat on the bottom or against the side of the tank. If the hose has a tendency to curl, insert a length of straight, corrosion-resistant pipe into the end to accomplish the preceding purpose. Since the most difficult time to prime a pump is after most of the solution has been removed from the tank, operators often dump this remaining heel—a needless waste of solution. Plating tanks with sumps at one end minimize this loss when solution transfer is necessary. Small, self-priming pumps, such as drum pumps, may be used to salvage the heel left in the plating or treatment tank.

PUMP SEALS

The available types of pump seals vary from no seal at all, to lip type, packed stuffing box, and mechanical. Since conventional pumps have an interconnecting shaft between the pump impeller and the motor, a suitable seal is necessary to prevent leakage during the rotation of this shaft. A magnetic-driven impeller is perhaps the only truly sealless pump. Other pumps which use a liner, or section of hose, are sealless but, since these components may fail through usage, fatigue, and abrasive wear, the system, like any other, is subject to eventual leakage. It is always desirable to replace seal components before leakage occurs. Unfortunately, one never knows just how much longer a seal will last before replacement is necessary; they may operate from a few minutes to a more realistic several months or several years.

A lip-type seal consists of a molded, rubber-like material which has a squeegee action in snugging itself around the shaft. A mechanical seal consists of two mirror-like lapped surfaces one rotating on the shaft, the other stationary in the pump, which are held together by a light spring pressure, preventing leakage. A packed stuffing box consists of a suitable cavity, with the rotating shaft in the center, around which a compressible-type material may be inserted in alternating rings and held in place and adjusted by tightening the packing gland. Both the mechanical seal and the stuffing box seal are available with provision for water lubrication, or recirculation of the solution being pumped. Usually water from an external pressure water line is desirable since it assures cooling and lubrication of the seal components. It reduces wear by keeping filter aid and dirt out of the seal area. The water also prevents the solution from crystallizing on the seal faces during shutdown periods. Even while the pump is running, crystals may form as they ooze past the seal faces, or plate-out might occur with electroless solutions.

On double-seal pumps, care must be taken through the use of a check valve, or siphon breaker, so that no solution is pumped into the water system. Also, a regulator should be installed in the water line to control the pressure, since it will vary from low when the plating room is in operation to high during the week-end when no other water is being used. If the water pressure and flow to the seal is not regulated, it is possible to actually draw water through the packing into the plating tank, especially when the filter is clean, since a negative pressure exists at this point. This could cause chemical unbalance and even overflowing of the plating tank. Solutions requiring deionized water for the seal use a double seal arrangement, with an additional small pump recirculating the deionized water in the seal area.

When selecting the type of seal to use, consider the fact that a stuffing box seal or lip-type seal wears slowly, giving warning that replacement will be necessary by gradually increasing leakage. A mechanical seal operates more trouble-free on a day-to-day basis, and yet may fail without warning, causing considerable solution and time lost. (See piping instructions to minimize solution loss).

Certain types of packing are more suitable for acid, and others are more suitable for alkaline solutions. The materials of construction in a mechanical seal will also vary, such as carbon, ceramic, fluorocarbon, plastic, or rubber. Therefore, it is important to give the type of service to the manufacturer to assure suitable materials of construction. However, since some filtration systems are used interchangeably in a number of solutions, some seal wear has to be expected, and periodic replacements of components will be necessary. Whenever replacing the seal or packing, the pump shaft should be inspected. If worn or scored it must be replaced. Otherwise, the new seal or packing will not last long.

TIPS ON FILTER INSTALLATION

Filtration equipment should be installed as close to the plating as possible, and in an area that affords access for servicing. Equipment which is unhandy to service will not be attended to as frequently as required, and the benefits of filtration will then be minimized. Where it is necessary to install the equipment more than 10 to 20 feet away, check the pump suction capabilities and increase the size of the suction piping in order to offset the pressure loss. The suction line should always have a larger diameter than the discharge to avoid starving the pump.

Hoses made of rubber and plastics 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 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 corrosion, impact and temperature resistance are excellent. Iron piping, lined with either rubber or plastics, 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 leakage occur in the system, the siphon action or suction of the pump will be broken when the level reaches the hole. This prevents solution loss that frequently occurs at night or weekends. Whenever automatic equipment is operated unattended, some provision must be made to protect against unforeseeable events which could cause severe losses. This includes some form of barrier or removable strainer to prevent the suction of parts into the pump.

On small systems, where an in-tank type of filter may not be suitable, the entire filtration system may be installed at a position above the solution level, with hoses leading to and from the process tank. The hoses may be removed completely when the solution of filtration system is not in use; however, wherever possible, the filter should be employed continuously to achieve maximum dirt removal.

The addition of a pressure gauge is strongly recommended to determine initial pressure required to force the solution through the filter, and also to determine when the filter media needs to be replaced.

When starting up a new filter system, or after servicing an existing system, it is advisable to completely close the valve on the down-stream side of the filter; in this way, the pump will develop its maximum pressure and one can immediately determine if the system is leak-tight. Sometimes, filtration systems are checked 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, etc., 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.

In conclusion, one can obtain the best results 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.