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III. The Effects of Shields and Baffles on the Distribution of Functional Chromium Electrodeposits

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Editor's Note: Originally published as E.C. Knill, *Plating & Surface Finishing*, 76 (3), 38-45 (1989), this is the third of three papers, all by Mr. Knill, which received the Gold Medal Award for Best Paper published in *Plating & Surface Finishing* in 1989, which was presented at SUR/FIN 1990 in Boston, Massachusetts.

ABSTRACT

Insulating shields and baffles redirect the flow of current and affect the thickness distribution of chromium and other electrodeposits. Many examples of these useful devices for improving the uniformity of chromium deposits are described.

Shields and baffles are terms sometimes used interchangeably in electroplating literature but can and should be defined differently. Shields are nonconductors that direct the flow of current into the shortest path between the anode and cathode or concentrate the flow of metal ions and direct them to a normally low current density area. On the other hand, baffles intercept the flow of metal ions and force them to flow through a longer path to reach the normal high current density region of the cathode.

Advantages

Although the principles of current and thickness distribution control using shields and baffles were established many years ago, these effective control methods have not been adopted as frequently as others described previously in this series of papers,[1,2] even though they have important advantages. Some major advantages of shields and baffles include reusability, reproducibility, reliability and safety. Complex shapes may be plated without the use of fine anode wires that are fragile, consumable and require critical adjustment. Burns or arc marks, resulting from sagging or poorly adjusted anodes, are eliminated. Unlike robbers or thieves, shields and baffles do not require stripping. When shields and baffles are attached to the fixture or permanently mounted in the plating tank, time and costs can be saved. Higher current densities that reduce plating time are often permissible. Fixture design can be more flexible when shields or baffles are combined with either tank or local anodes to achieve improved control of deposit thickness distribution.

Some custom fixtures are costly and time consuming to machine, making them unsuitable for short-run production orders.

Materials

The selection of a suitable material for a shield or baffle is critical. The material must be chemically resistant to chromic acid solutions, dimensionally stable at temperatures up to 150°F (65°C) and stiff enough to support its own weight without sagging or warping. It must not contain conductive pigments or fibers that are subject to surface "treeing."

Polymers used frequently are acrylic resins, chlorinated polyvinyl chloride (CPVC), polyethylene, polypropylene, polyvinyl chloride (PVC) and polyvinylidine chloride. Less common shield and baffle materials include thermosetting laminated resins such as phenolics and melamines that usually require a lacquer coating and are suitable for short production orders. Fluorinated vinyl resins may be justified for applications requiring superior chemical resistance and dimensional stability. One of the most useful but infrequently used materials is plastisol-coated steel) Corrxplex shapes are easily and economically fabricated from steel by bending, welding or machining; the plastisol provides a long-lasting insulating coating.

Acrylic resins and glass are used in laboratories and for limited production because of their clarity and stiffness, but both are slowly attacked by hot, concentrated chromic acid solutions; glass cannot be used with any solution containing fluorides. Fiberglass-reinforced polyester may be justified occasionally for applications requiring light weight, stiffness, formability and good

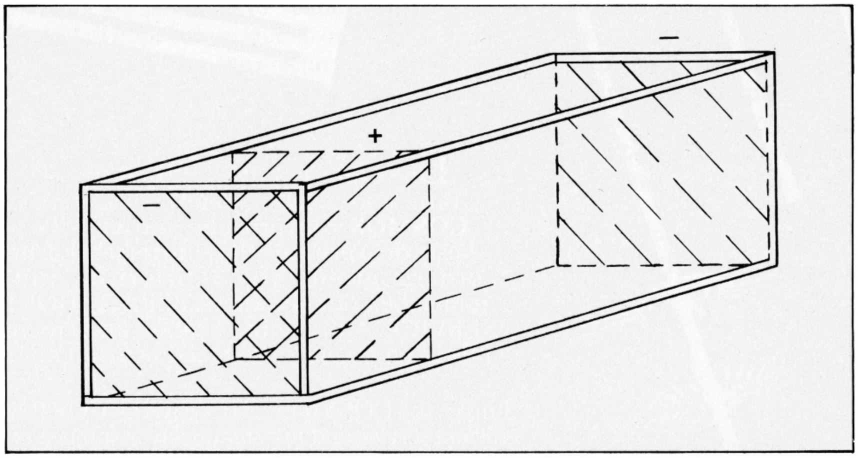

Fig. 1—Haring throwing power cell with walls and bottom that act as shields to control thickness distribution on the cathode.

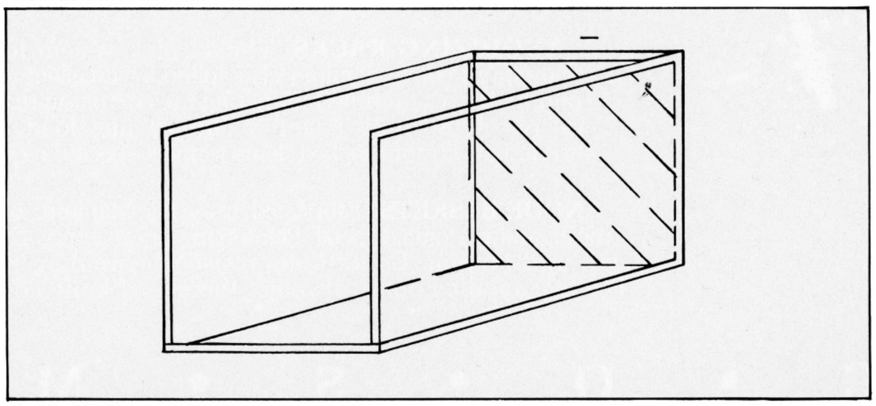

Fig. 2—Half-box cell that can be used with an external anode in the laboratory or production tank to control deposit uniformity.

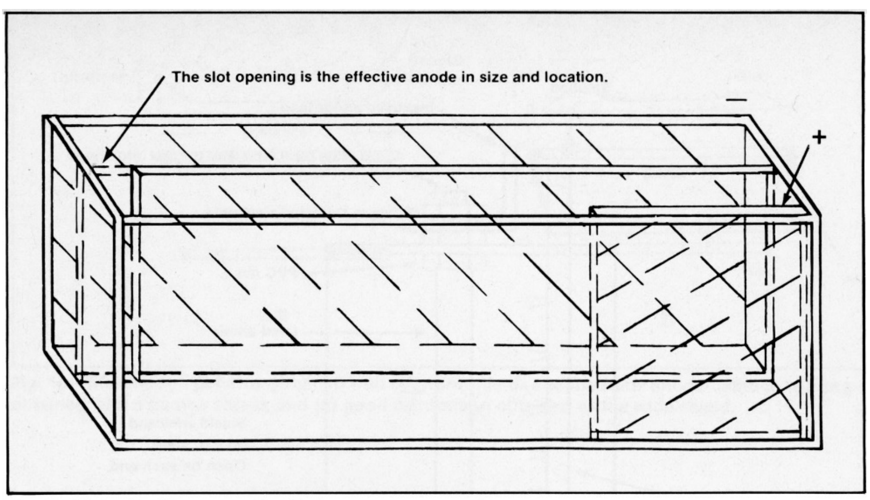

Fig. 3—Slot cell with an opening that serves as an anode.

chemical resistance when coated with 0.4 mm (15 mil) of clear polyester resin. Like plastisol-coated steel, however, it is costly to modify.

Designs

It was a small step from the rectangular box cell[3] (Fig. 1) used in the laboratory for obtaining uniform thickness distribution to the half cell[4] (Fig. 2) used in the plating tank. The slot cells[5,6] establish the effective relocation of the anode(s) to a precise shape and location (Fig. 3). The same principle is useful for introducing current into low current density regions without the risk of short circuits (Fig. 4). Although this slot technique provides the best obtainable distribution of metal in sharp corners, perfect distribution is not possible. The geometry of acute angles makes it impractical to place an effective anode slot close to the corner (Fig. 5). For any interior angle, the distance (D) to the corner is always greater than the distance (X) to an adjacent cathode area. However, satisfactory distribution can be obtained and the current increased to speed up deposition in the angle or recessed area.

Directing the solution flow to introduce fresh solution into recesses will augment this effect. Advantageously, the solution is not overheated when a local anode is combined with a slot design. Even so, helpful fillets may be needed in corners in order to meet full specification thickness.

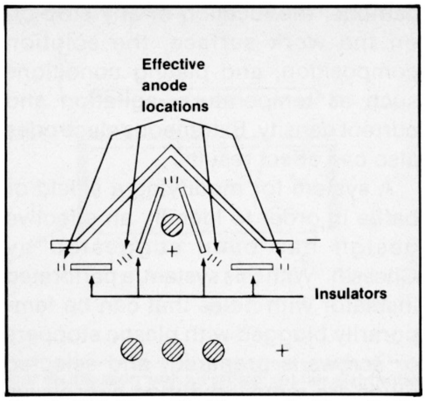

Fig. 4—Shields and baffles used with an inside anode to improve its effectiveness.

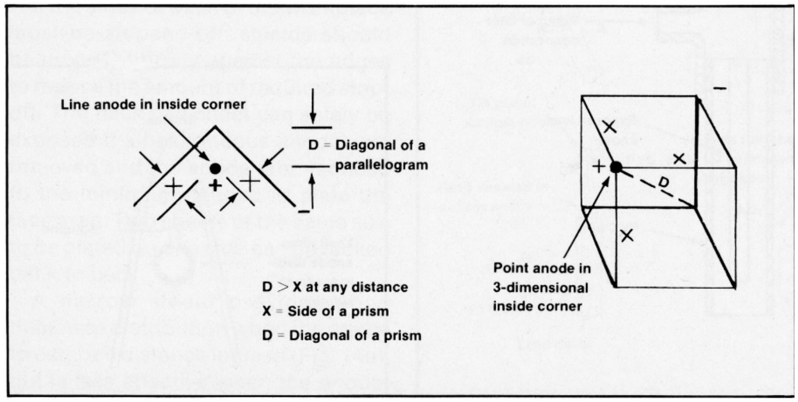

Fig. 5—Comparative distances at inside angles from an inside anode to the cathode areas.

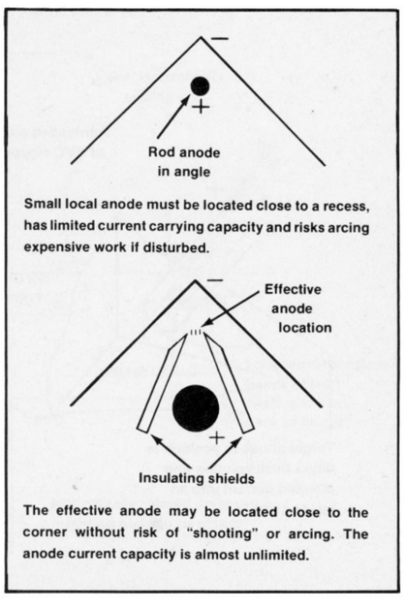

Fig. 6—Insulating shields used between an inside anode and inside angle to improve distribution.

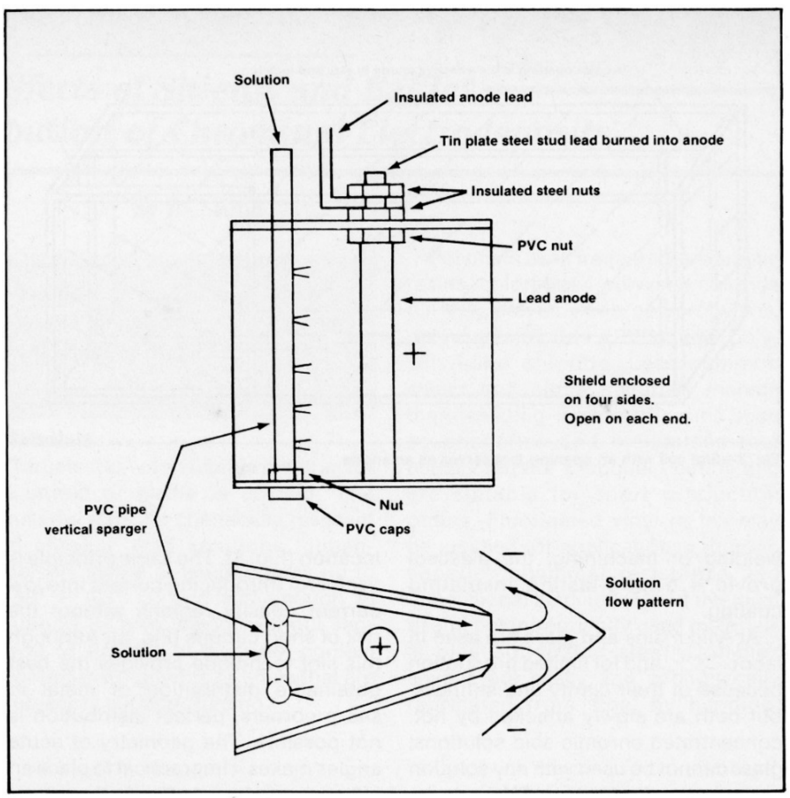

Fig. 7—Slot box and PVC vertical sparger.

Anodes with large area and current-carrying capacity can be used when combined with a slot (Fig. 6). In this case, the current is limited only by the cathode area and its current-carrying capacity. Figure 7 shows how a slot box enclosed on four sides can be shaped and used with forced solution flow to direct current into an acute angle. Another device that can be adopted for building thickness in corners is a polyvinylchloride tube enclosing an anode, as shown in Fig. 8. A lead pipe anode can sometimes be useful for directing solution flow (Fig. 9). Any one of these techniques for increasing agitation may also eliminate pitting caused by particles that other-wise would settle on a significant surface.

The effectiveness of any shield depends on its dimensions and shape, as well as the dimensions of the plated surface and its position relative to the workpiece. Also important are the distance between the anode and cathode, the location of any stop-off

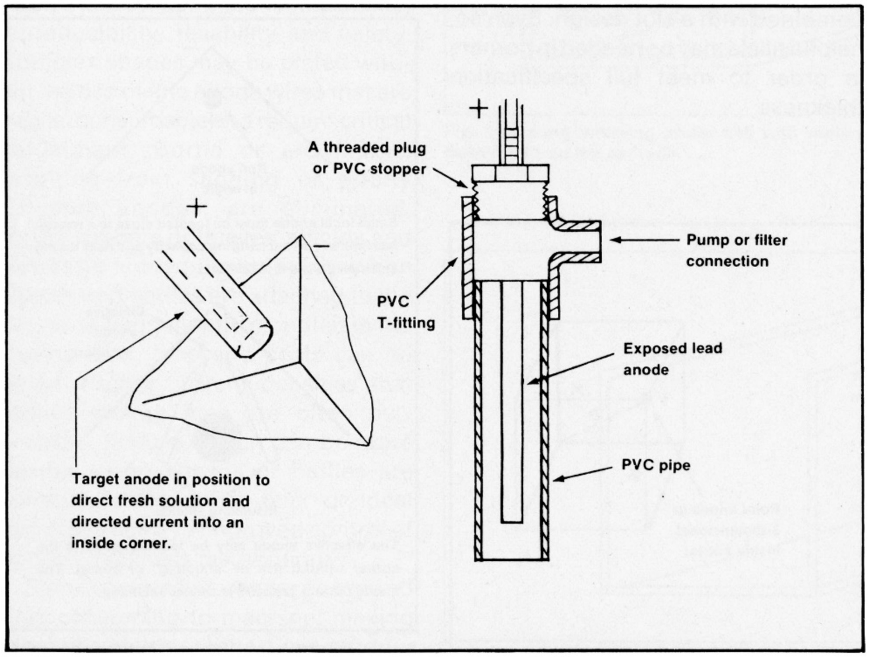

Fig. 8—Target anode in a shield of PVC pipe for plating in an inside corner.

on the work surface, the solution composition, and plating conditions such as temperature, agitation and current density. Extraneous electrodes also can affect results.

A system for modifying a shield or baffle in order to identify an effective design has been suggested by Chessin.[7] With this system, a perforated insulator with holes that can be temporarily plugged with plastic stoppers or screws, is prepared, and selected plugs are removed during successive tests to make adjustments in current distribution. The technique is especially useful to compensate for part design changes that influence current distribution. Of course, new holes can be drilled in strategic locations as the need becomes apparent. Holes with diameters of 3 to 6 mm (1/8 to 1/4 in.) usually are adequate for this purpose. Holes in a cylindrical baffle can be closed by taping the cylinder during a search for the most useful design.

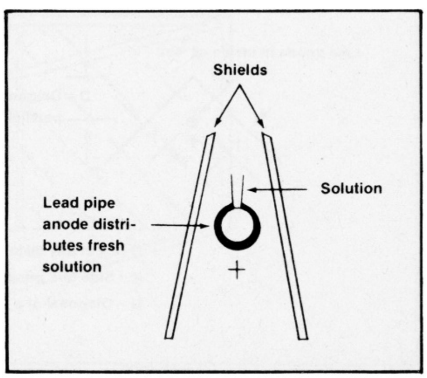

Fig. 9—Lead pipe used as an anode and sparger.

A frame-like shield (Fig. 10) is effective for preventing build-up at the edges of a flat cathode. Edge build-up can be eliminated with a narrow shield ranging from 2 to 5 cm (0.75 to 2 in.) in width and located close to or abutting the cathode surface. However, improvement in thickness uniformity is obtained if the frame width is increased to a dimension approaching the distance between the anode and cathode (Fig. 10b). The shield can be attached to the anode and used as a spacer to establish the anode-cathode distance.

The dual shield and spacer technique has been useful for plating crankshafts (Fig. 11). Shields are split to permit assembly, and surfaces to be joined are lapped to provide a tight seal, using a gasket or compression joint. The spacers also are stop-offs for the side faces of the cranks. The entire crankshaft can be submerged in the plating bath or individual bearings can be enclosed in separate cells supplied with plating solution from a temperature-controlled sump.[8] In either case, the crankshaft should be rotated slowly to provide uniform radial distribution of the deposit and inhibit pitting and particle inclusions. Temperature control within conforming anode enclosures is essential for obtaining uniform distribution on any shape enclosed in two or more cells. Multicell systems with shields attached to the anodes will expedite racking and unracking.

Shields attached to local or spot anodes, sometimes called "sandwich" or "target" anodes, make an especially attractive design (Fig. 12). They are used for plating deep radial grooves or sharp inside corners of horizontally rotated rolls and drums. The shields protect the sides of the grooves while performing their primary function of directing the current flow where needed.

Positioning

When the anode is moderately spaced from the cathode, the distance between the shield and the edge of the plating surface has more influence at the edge than it has on other areas of the cathode, as Fig. 13 shows. Locating the shield close to the edge is customary, but racking and unracking considerations or the location of contacts often limit the proximity of the shield to the edge of the cathode. With an increase in the size of the shield (Fig. 13d), the distance between the shield and the cathode may safely be increased, within limits, with no significant effect on edge build-up. However, a gap exceeding 3/8 in. (1.0 cm) between the shield and workpiece is unusual, even for large cathodes such as press plates and platens.

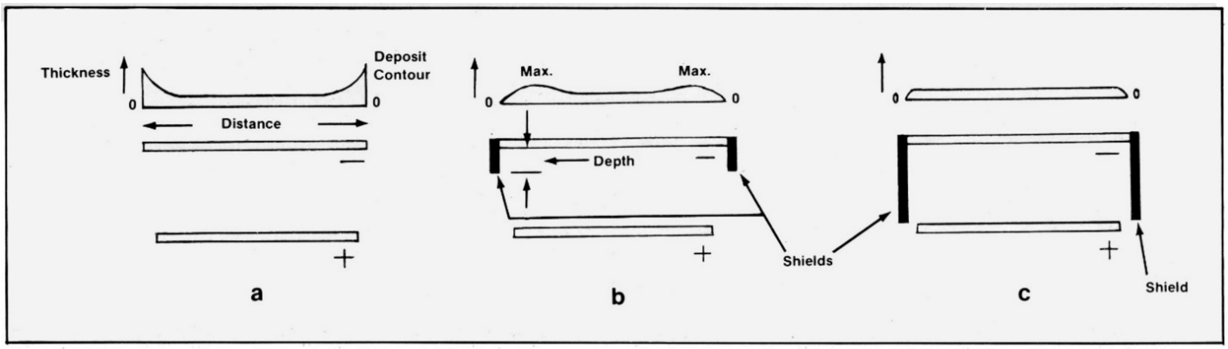

Fig. 10—Distribution patterns obtained with different shields and the same anode-cathode spacing: (a) poor distribution with no shield; (b) fair distribution obtained with a narrow shield; and (c) good distribution obtained with a wide shield.

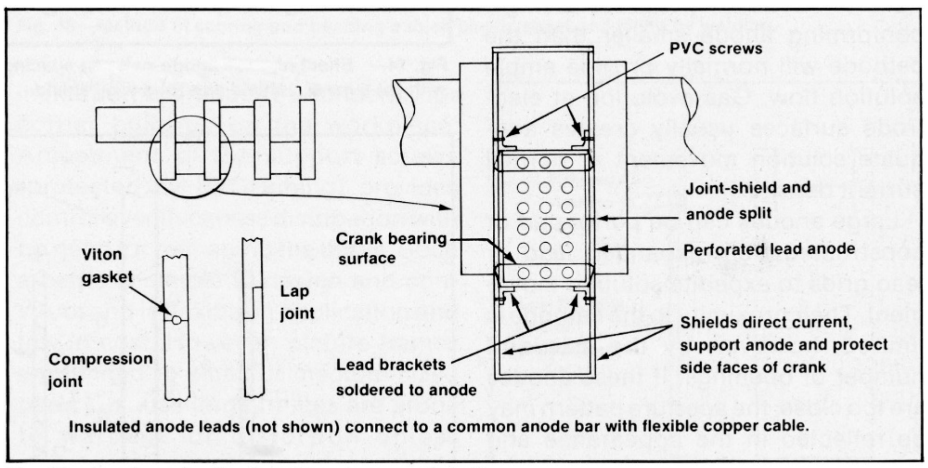

Fig. 11—Anode and cathode system for a crankshaft.

If the sides or back of the workpiece must be stopped-off, shields should be mounted firmly against the edges to reduce the amount of required stop-off. The back of a sheet can safely be exposed if all extraneous anodes are removed and the anode area reduced to the minimum needed to plate the face area. Two sheets of the same size to be plated on one side can be racked back to back.

A narrow shield provides good thickness distribution when the anode to cathode distance is small (Fig. 14a), but is less effective when the anode-cathode gap is large (Fig. 14b). With a wide shield (Fig. 14c), the anode location is less critical, but a relatively close anode-cathode spacing with a narrow shield is usually preferable in order to simplify the construction and handling of the fixture and reduce dragout, weight and costs.

Most production jobs with conforming anodes use a spacing of 3/8 to 2 in. (1 to 5 cm), but those with conventional, close anodes probably have a spacing of 2 to 4 in. (5 to 10 cm). Small plastic molds and metal stamping dies usually use a gap that is no greater than 0.2 to 1.0 in. (0.5 to 2.5 cm). However, there are no rigid rules mandating the anode to cathode distance for all applications. The skill of the fabricator, the design of the fixture and installation limitations often govern the spacing. Nevertheless, the best results usually are obtained by bringing the anode(s) close to the shield without restricting the flow of fresh solution to the cathode. Using a conforming anode smaller than the cathode will normally provide ample solution flow. Gas evolution at electrode surfaces usually creates adequate solution movement at normal current densities.

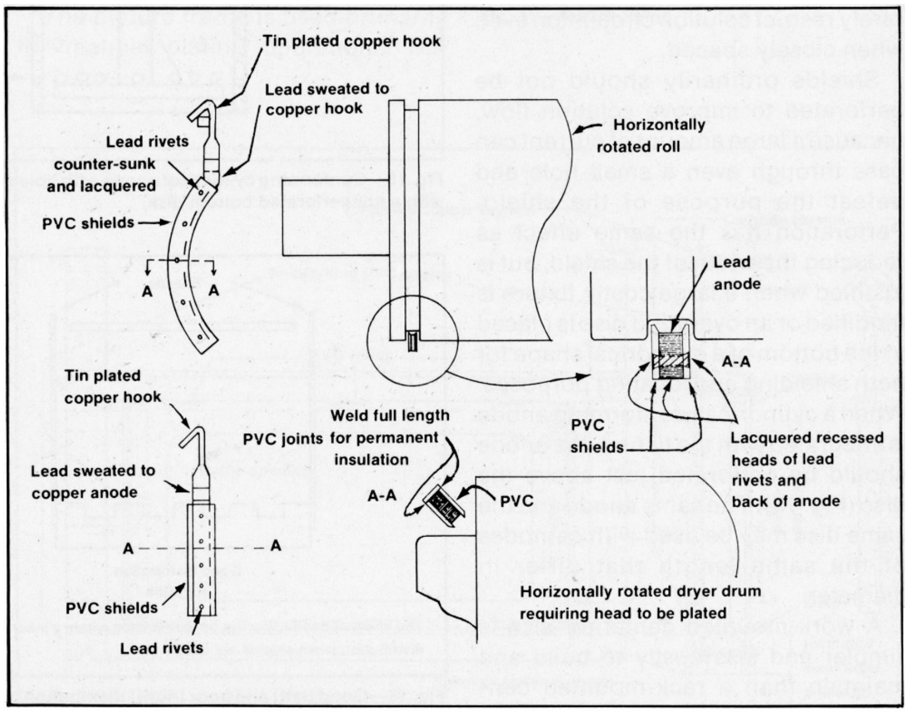

Fig. 12—"Sandwich" anodes.

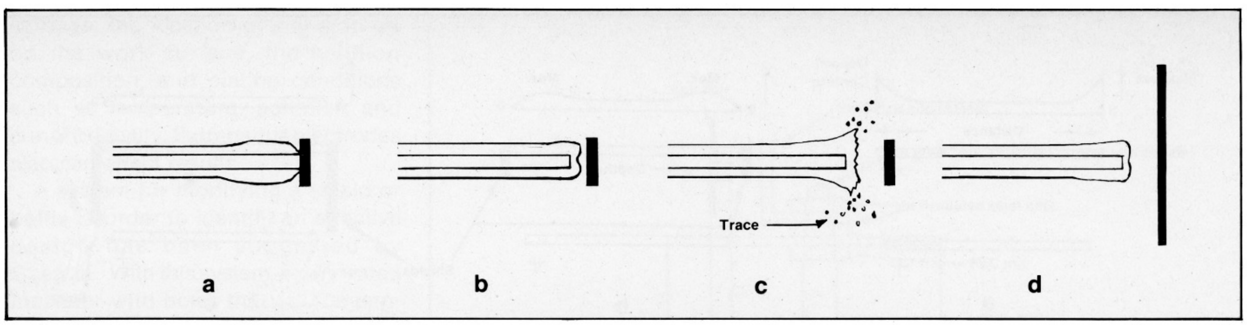

Fig. 13— Effect on thickness distribution of shield spacing and width: (a) a contacting narrow shield; (b) a closely spaced, narrow shield; (c) a narrow shield with a wide gap between the shield and cathode; and (d) a widely spaced, wide shield.

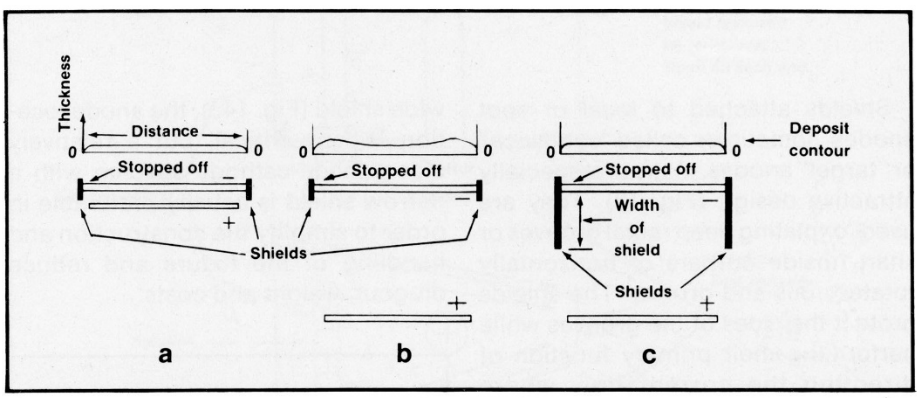

Fig. 14— Effect of close anode-cathode spacing (left) with a narrow shield and wide spacing (right) with (b) a narrow shield and (c) a wide shield.

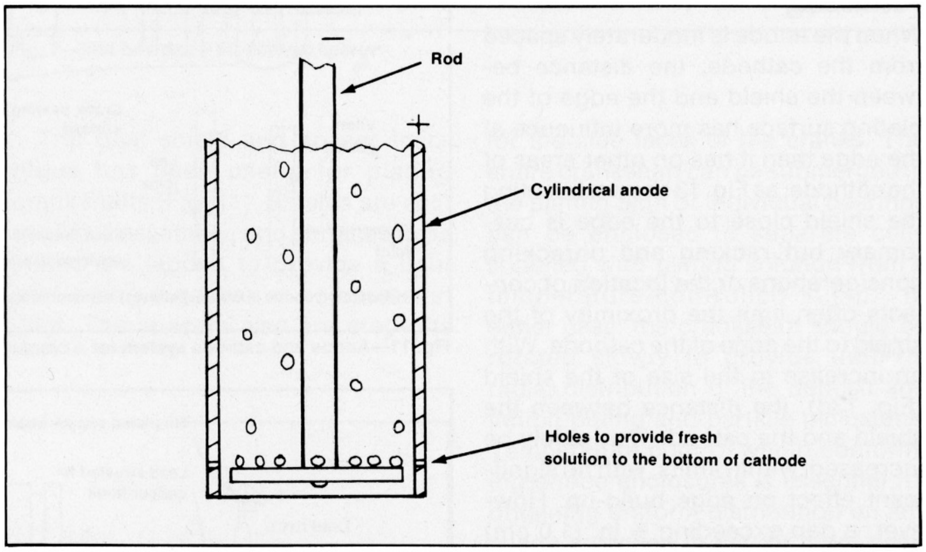

Fig. 15—Conforming cylindrical anode with holes to provide fresh solution at the bottom of a rod plated with a nonperforated bottom disk.

Large anodes can be perforated or constructed from expanded lead or lead grids to expedite solution movement. Their proximity to the cathode is limited, however, by the size and number of openings. If these anodes are too close, the aperture pattern may be reflected in the appearance and thickness distribution of the deposit. Round, conventional tank anodes rarely restrict solution circulation even when closely spaced.

Shields ordinarily should not be perforated to improve solution flow, because a large amount of current can pass through even a small hole and defeat the purpose of the shield. Perforation has the same effect as reducing the width of the shield, but is justified when a large costly fixture is modified or an oversized disc is placed at the bottom of a cylindrical shape for both shielding and locating purposes. When a cylindrical, conforming anode is integrated with the fixture, the anode should be perforated just above the disc (Fig. 15). The same anode and the same disc may be used with cathodes of the same length that differ in diameter.

A work-mounted centering disc is simpler and less costly to build and maintain than a rack-mounted centering cone. The dimensions of the plated surface influence the selection of anode-cathode spacing. Large workpieces usually need wide shields and large gaps, whereas small parts tagged with precision plating specifications must have proportionally narrower shields and closer electrode spacing. Close spacing virtually eliminates the need to change the width of the shield for different cathode areas.

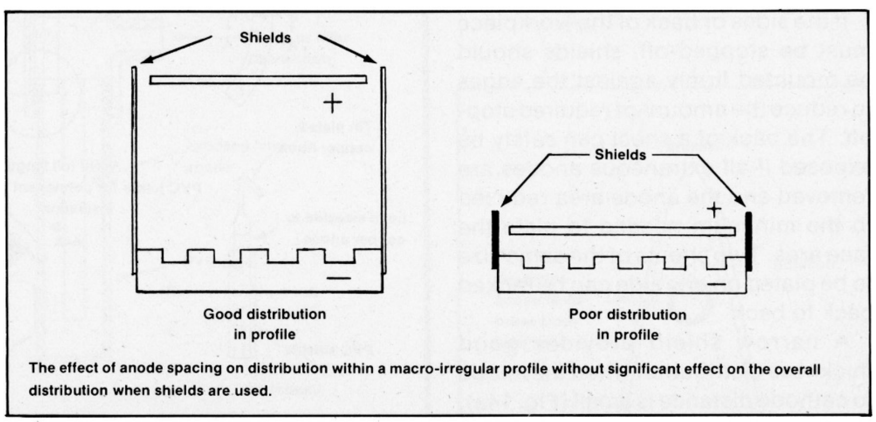

Fig. 16—Good (left) and poor (right) distribution obtained with a wide and a narrow shield, respectively, between the anode and cathode.

A wide shield and an increase in the anode-cathode spacing will improve the thickness distribution in the recesses of surfaces containing holes, grooves or an embossed pattern (Fig. 16). However, any increase in the electrode gap imposes an increase in the voltage and places a maximum limit on this distance. A 9- to 18-V power supply is adequate for almost any chromium plating application.

Use of shields is not limited to plane surfaces with straight borders. Indeed, some important applications involve complex cathode shapes. Cylindrical shields for large parts can be formed by heating and bending plastic sheet. Small cylindrical shields are often made by cutting sections from plastic pipe or machining a plastic slab. Irregular shapes can be fabricated by welding sections of plastic sheet, as required, to enclose the perimeter of the cathode. Such shields may be mounted on the fixture or fabricated in sections to facilitate racking (Fig. 17).

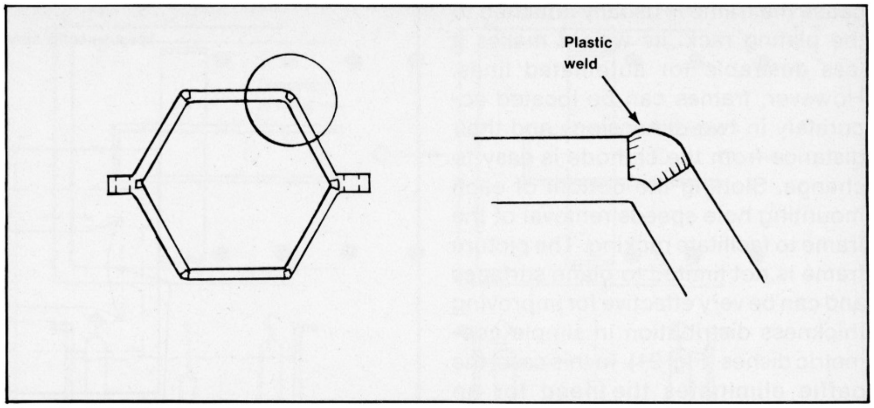

Fig. 17—Shield fabricated in sections to enclose the perimeter of a cathode.

Thermoplastics such as PVC, CPVC, polyethylene, polypropylene and polystyrene can be shaped by bending when heated above their softening point with a hot air gun (or in an oven) and clamped in the desired shape during cooling. The workpiece can be used as a form during cooling or a form can be specially fabricated for the purpose. The thermoforming process usually is limited to thin, 1 to 6 mm (0.04 to 0.25 in.) plastic sheet. However, thicker sections can be readily formed by scoring the back of the sheet where the bend is desired. Scored areas should then be heated before the sheet is bent. The notch helps to facilitate bending with greater precision. The notches are filled by welding to reinforce the fixture after bending (Fig. 18).

Strips and picture frames

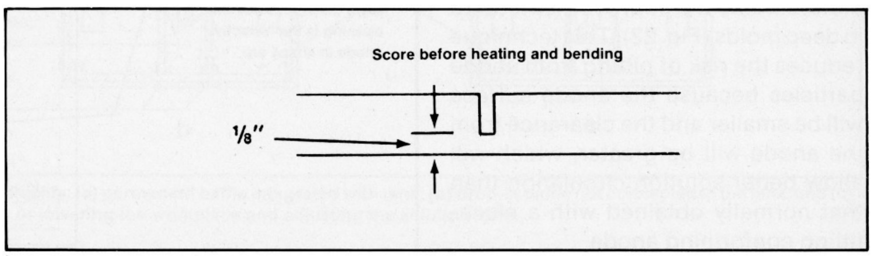

Fig. 18—Method of scoring and bending a thick plastic sheet and filling by welding.

Strip baffles (Fig. 19) and "picture frames" are the most common forms of baffles. The frame of Fig. 20 includes quick-release slots that permit access to clamps and reduce the turnaround time for the rack. The large radii in inside corners reduce the tendency for corner build-up on the workpiece. Adjustment of the support screws (protected by PVC tubing) provides control over thickness distribution with no need for reshaping the baffle. Such a baffle is simple to design and construct and is flexible in application and low in cost. However, picture frames are limited to small or medium-sized parts because large frames are prone to warpage or distortion unless reinforced with structural plastic or insulated steel angles.

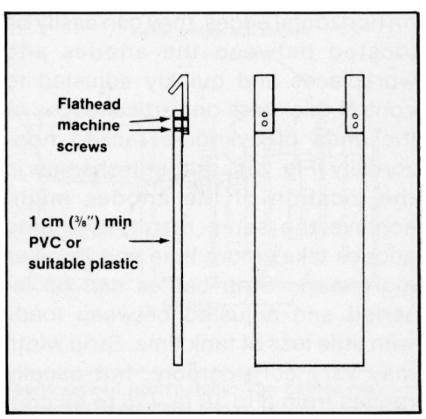

Fig. 19—A strip baffle.

The picture frame is used primarily for manual plating operations. Because the frame is usually attached to the plating rack, its weight makes it less desirable for automated lines. However, frames can be located accurately in two dimensions and their distance from the cathode is easy to change. Slotting the bottom of each mounting hole speeds removal of the frame to facilitate racking. The picture frame is not limited to plane surfaces and can be very effective for improving thickness distribution in simple geometric dishes (Fig.21). In this case, the baffle eliminates the need for an auxiliary or bipolar anode. However, a combination of such an anode and a picture frame will improve distribution in deep molds (Fig. 22). This technique reduces the risk of pitting from anode particles because the anode surface will be smaller and the clearance from the anode will be greater, which will allow better solution circulation than that normally obtained with a close-fitting conforming anode.

Although vertical strips (Fig. 19) are unable to control thickness build-up on horizontal edges, they can easily be located between the anodes and workpieces and quickly adjusted to control thickness on vertical edges or the ends of cylinders racked horizontally (Fig. 23). Although changes in the location of the anodes might achieve the same result, changing anodes takes more time and involves more work. Strip baffles can be inserted and adjusted between loads with little loss of tank time. Strip width may vary considerably, but usually ranges from 6 to 18 in. (15 to 45 cm). They should be a few inches longer than the longest anode in the tank.

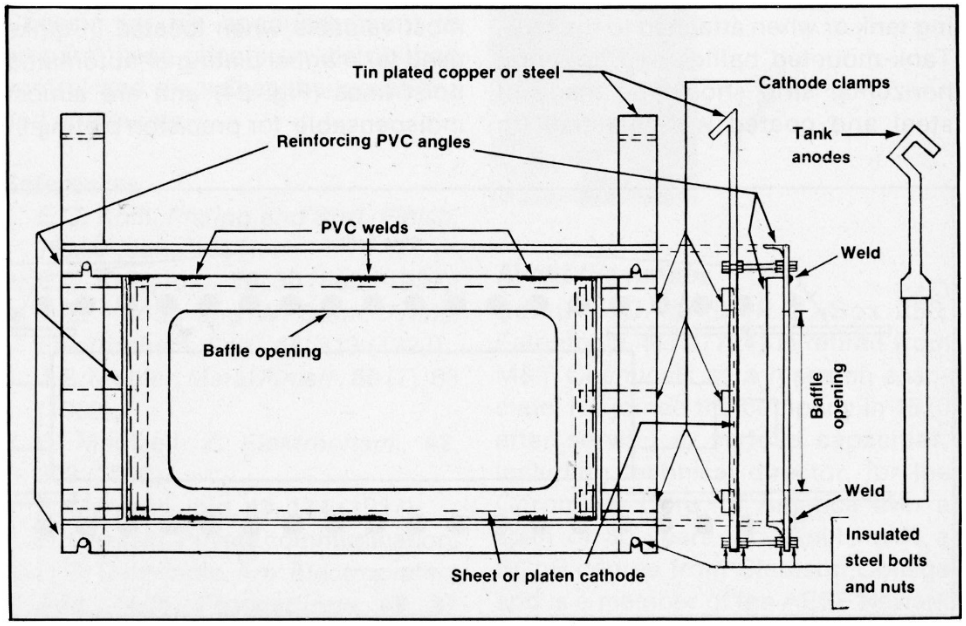

Fig. 20—A picture frame baffle.

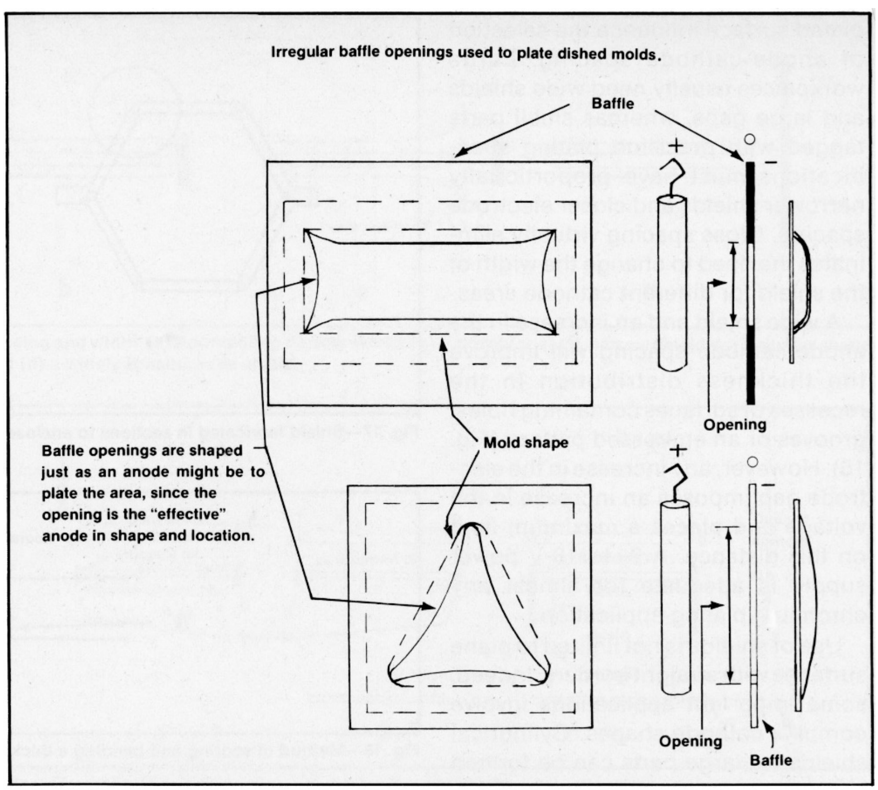

Fig. 21—Baffle with openings designed to plate a shallow dish in a mold.

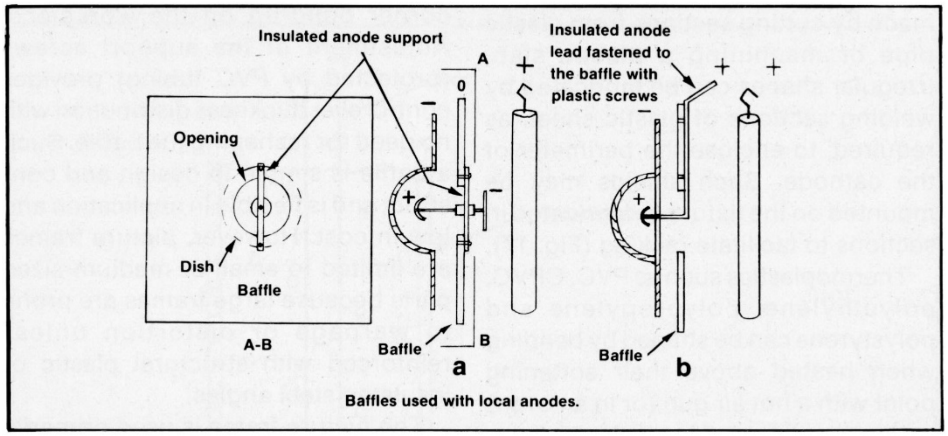

Fig. 22—Baffles assembled with (a) a bipolar anode and (b) an auxiliary anode to plate a deep dish in a mold.

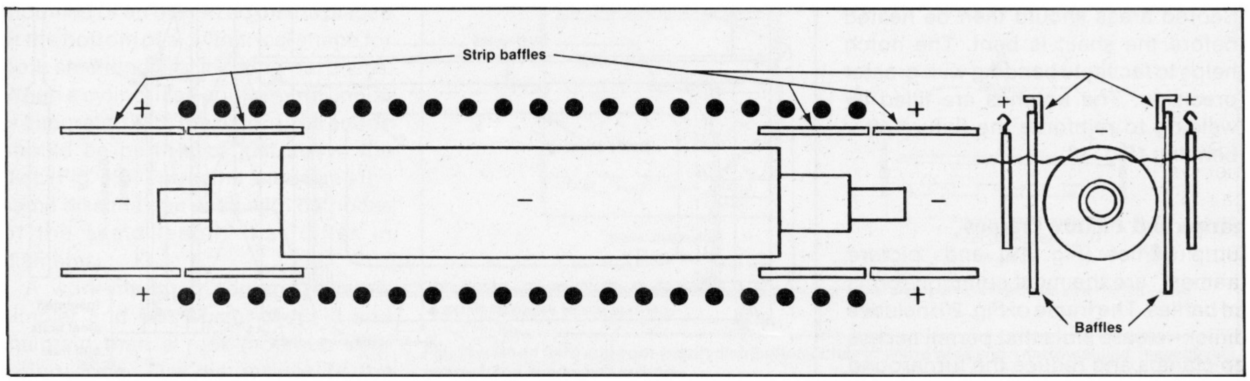

Fig. 23—Strip baffles for plating a cylinder racked horizontally.

Horizontal strip baffles are frequently useful as permanent or semi-permanent fixtures, either in the plating tank or when attached to the rack. Tank-mounted baffles and any long horizontal strip should be made of steel and coated with plastisol to provide rigidity. Horizontal baffles are most valuable when located in tanks used for manual plating or automated hoist lines (Fig. 24) and are almost indispensable for precision plating in fully automatic and finger plating machines. If the baffles are adjustable and suspended from the top of the tank (Fig. 25), workpieces that differ in length and diameter can be accommodated, regardless of the length of the anodes. However, after short workpieces are plated for several days, it is advisable to check the condition of the anodes before long parts are started again. Any scale observed on anode surfaces should be removed chemically. Precision plating demands close attention to the condition of the anodes.

Precautions

No distribution control technique can overcome the effects of poor cleaning or activation. Failure to use clean anodes, make positive electrical contacts or remove unnecessary anodes also can destroy the benefit of even the best-designed distribution system. Stray currents and short circuits can cause disastrous distribution effects. To minimize the risk of these occurrences, all metal components should be eliminated from the tank except the anodes, cathodes and plating fixtures. Temperature sensing and control devices should be insulated or made of plastic. External heat exchangers or Teflon-covered heating elements are suggested.

Benefits of the distribution control methods described in this and previous papers[1,2] depend upon the adoption of good plating practices. High quality functional chromium cannot be obtained if fundamentals are ignored. Of course, the numerical values and dimensions cited herein and in the previous papers are starting points that may be modified as required.

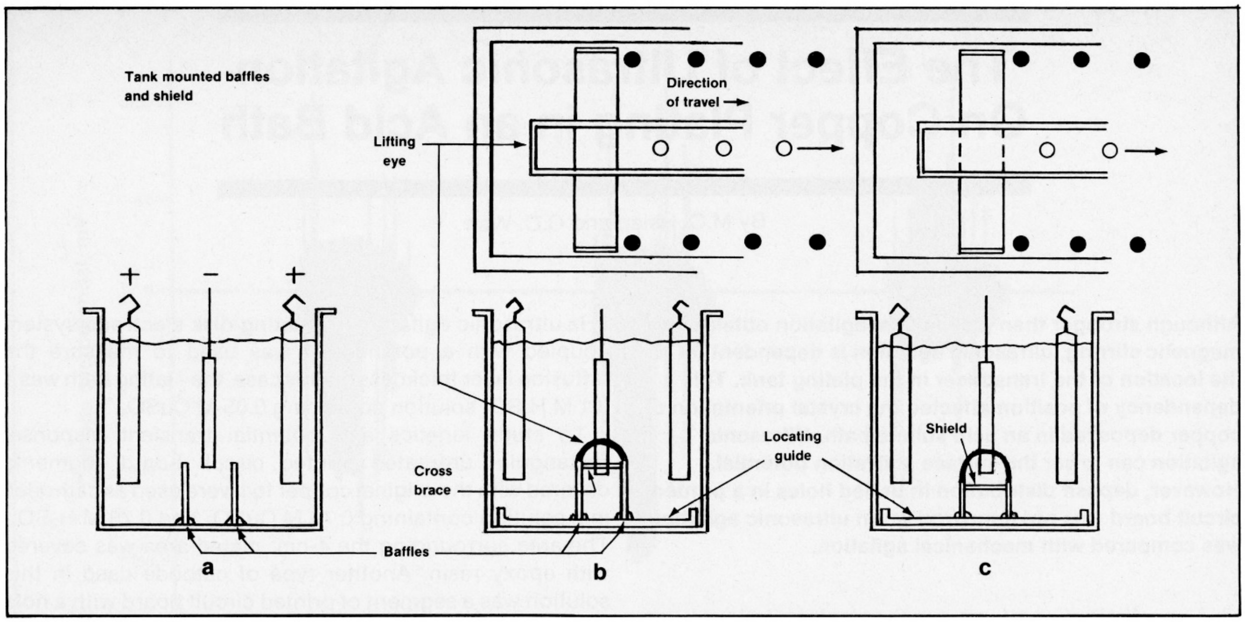

Fig. 24—Permanent and semi-permanent baffles and shields: (a) permanent baffle integrated with tank; (b) drop-in baffle not connected to the tank; and (c) a drop-in shield that can control distribution by raising or lowering the workpiece and adjusting the solution level.

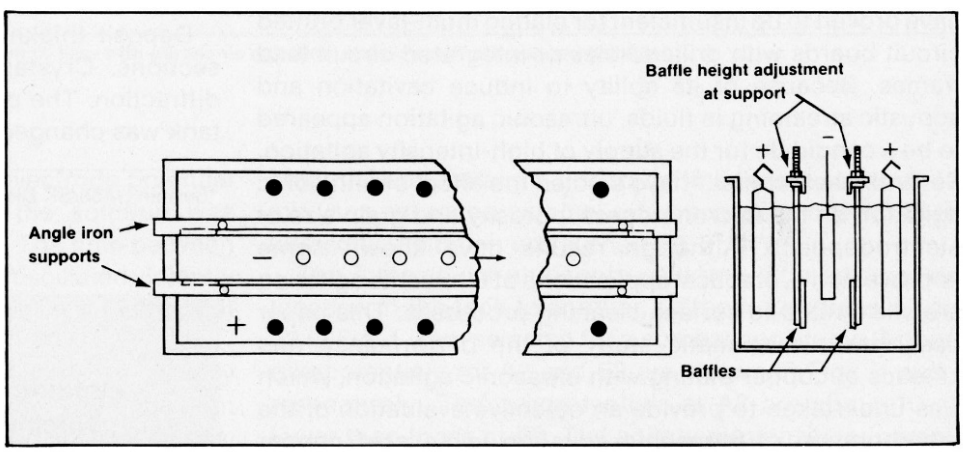

Fig. 25—Horizontal, adjustable baffles are for long parts racked horizontally. The baffles may be continuous in a short tank or divided into shorter units for ease of handling and control in long tanks.

Acknowledgment

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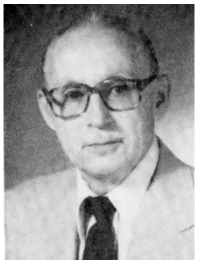
About the Author



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