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Update on the Performance of Open Top Tumblers as Replacements For Conventional Barrels in Batch Plating

By Robert F. Zecher, Tumbleveyor, Inc.

The standard hexagonally shaped, perforated barrel used in batch plating of small parts has two major disadvantages which are overcome by the "open top" tumbler described in this report. These are 1)restricted flow of processing solutions, including rinse water, and 2) excessive dragout on the barrel itself from tank to tank.

The open, stationary tumbler allows practically unrestricted flow of all solutions and does not carry any dragout from tank to tank. Furthermore, it allows much greater flexibility in the application of spray rinses to minimize dragout on the parts themselves and to allow more efficient rinsing in a single tank. There are other environmental protection advantages as well as simplified installation and operation of the plating line.

Greater Solution Exchange

The polyhedral shape of the horizontal perforate barrel evolved in an effort to gain "pumping" action from the rotation of the barrel about its axis. Pumping action is defined as the change in volume as a percent of the contained volume of the barrel and is a function of the rotational speed as well as the geometry of the barrels. Unfortunately the pumping action is greatest at an immersion of only 38.4% of the barrel (diameter) which is not its most favorable plating depth. At typical plating depths of 60 to 90%, this pumping action actually drops off with the resulting exchange of solution nominally less than 1 gal. per gallon per minute.(1)

The turnover rate of the solution inside the barrel can be increased by about 25% by pumping the solution into the barrel under enough pressure to force extra flow out through the perforations and this has resulted in some reduction in plating time.(1)

In the open top tumbler turnover rates several times those in the closed perforate barrel can be achieved. In the accompanying test data a rate of about 3 gal. per gallon per minute was used. Further tests are being made to determine the effect of higher rates as well as limiting maximum turnover rates for the various plating metals and for the effect on plating efficiency and uniformity. See Fig. 2

Lower Voltage Drop

The second factor affecting the plating efficiency of the barrel is the voltage drop through the barrel sides. This is a function of the thickness and the percentage perforation, and is typically in the range of 20% of the total voltage drop. This drop is virtually eliminated in the open top tumbler.

A higher solution turnover rate also allows higher voltages to be used before "burning" occurs.

More Dangler Options

The accessibility to the parts in the open tumbler also allows a variety of dangler options. The danglers can be hung from a bus spanning the entire compartment from above or can be special configurations such as flat strips, bars, etc. The danglers can be changed more frequently to maintain the most efficient contact as well. Fig. 3

Variable Tumbling conditions

The nature of the open top tumbler allows two variables to be exploited to achieve optimum tumbling action for the parts. These are (1) tumbling belt speed, variable from well below to well above nominal barrel rotational speeds, and (2) tumbler angle, also variable from steep to shallow. This means that parts can be processed from a gentle "rollover" to a vigorous "churning". The advantages are better plating thickness control, optimum deposition rate, and/or less damage to fragile or bulky parts.

The option of dividing the tumbler into separate compartments across its width may also offer some advantages in processing smaller loads through the same cycles.

Anode Placement

At its optimum tumbling angle, the open "top" of the compartment is actually facing the front of the tank where the anode bus and baskets or slabs are located. The top surface of the parts is actually at a angle of about 45° to the baskets which can be located all across the front and around the sides of the tank. Fig. 4

Additionally, there is the possibility of placement of more anodes in or around the compartment for special purposes.

No Dragout On Tumbler Itself

Some preliminary tests on dragout of solution on the barrel seem to confirm calculations which show as much as 1/2 gal. of solution being carried out on a 14" x 30" hexahedral barrel.(1) In actual measurement of the solution on a barrel raised from the tank and drained without rotation for about 10 seconds, then moved over a catch pan, over 900 cc's (about 1/4 gallon) of solution was caught. An additional 240 cc's (0.06 gal.) of solution was still on the 80 sq. ft. load of parts and calculations indicate at least another 0.2 gal. on the barrel surfaces for a total of 0.51 gal.
This amounts to a reduction of 90% if all dragout on the barrel itself (not even counting danglers, yoke, ribbing, etc.) is eliminated.

This reduction in dragout has two principal effects: simplified rinsing and solution savings. See fig. 5

Solution Savings

Obviously a reduction in the dragout of solution at a rate even approaching 0.5 gal per cycle can amount to a considerable quantity over a 30 or 40 cycle shift. While many of the basic constituents can be reclaimed from the rinse water usually at great cost, some cannot. The advantage is in not losing these materials in the first place. The sections on rinsing and on ventilation below illustrate how to reduce this solution loss still further.

More Dragout Reduction before Rinsing

The open tumbling compartment allows the tumbler to be equipped with a rinse manifold to remove more solution on the parts before transferring them to the rinse tank. The parts are brought up out of the treatment solution for a short tumbling drain followed by an air blowoff or by a mist or spray rinse. Preliminary tests show reductions of 50% or more of the concentrate on the parts before they are presented to rinse.

The air blowoff adds no additional water to the solution, the mist adds very little, and the spray rinse adds a controlled amount which can be used to make up for some of the evaporation. If the addition of this rinse water builds up excessively, there are a number of ways to maintain equilibrium in the concentration.

Low Water Usage, Single Step Rinsing

Assuming parts passing from the treatment tank to the rinse tank now have 5% or less solution concentration on them, immersion with tumbling action into the rinse water can effect an immediate dilution of concentrate by a significant factor. Using the example of the 80 sq. ft. load, immersing the parts with 0.2 gal of solution on them, which has then been cut by 50% during the rinse or blow off, into 100 gal. of rinse water gives a factor of 1000:1.

One helpful factor here is that the rinsing time can be extended much longer -- up to the plating cycle time, in fact -- because each tank in the line contains a load and barrels do not have to be moved back and forth to coincide with loading or unloading the plating tank. Added to this is the much more vigorous agitation in the tumbler as well as the optional addition of a rinse pump to exchange the water in the tumbler compartment similarly to the treatment tanks.

Finally, after an adequate immersion rinse, the parts can be brought up to an intermediate position and a spray rinse of fresh water applied. The tumbling is maintained during this spray, assuring another significant dilution. This two step rinse is just now being evaluated, along with a small closed loop water purification unit which can effectively reduce water usage to evaporative make up and eliminate waste water discharge altogether.

Ventilation

With no overhead hoist or headroom for passing barrels needed it is then feasible to cover any or all tanks to greatly reduce the air flow required for adequate ventilation. Thus evaporation can also be reduced where advantageous and individual vent ducts can be connected to specific tanks to facilitate scrubbing, reclamation, etc.

Line layouts

Since only the parts are passed from tank to tank it is possible by the use of staging conveyors, right angle chutes, and other bridging means to lay out almost any pattern for the plating line. Since most barrel lines are now designed to return the barrels to the start point, a "U" shaped open tumbler line is probably the most advantageous. The layouts shown in figure 1 show some of the ways to handle either continuous, uniform production of the same or similar parts or random loading of parts differing plating cycles.

Of course, the line layout can be in other shapes such as "L" or "Z" or whatever best suits the work flow through the plating department.

Other possibilities include feeding parts from different prep lines into a common plating tank or feeding from a single plating station into separate post-plating tanks.

Reduced Floor and Overhead Space Requirements

Generally an open tumbler line of similar production capacity to a given barrel line will occupy from 1/4 to 1/3 less floor space. This is due to the elimination of the hoist support system and also to the reduction in the number of rinse, and perhaps other, tanks. At the same time overhead space is eliminated above about 6 feet, which allows for covers on the tanks.

Test Results

Early plating tests on tin and on nickel bear out faster plating cycles and more uniform metal thicknesses. These are shown in comparison with typical barrel results in tables 1 and 2. Additional tests are being carried out on these and other metals just as this paper is being written and there will be handouts at the conference covering as much evaluation as can be accomplished by then.

A few measurements on dragout have already been covered, but much more quantitative testing work is also continuing and results will be included in the handouts.

Conclusions

Two primary advantages to the open top tumbler over conventional barrels as well as several secondary improvements in the overall plating line have been described. So far test results support the plating improvements and the reduction in dragout. Descriptions of mechanical changes in the line point to many secondary advantages such as reductions in line size, in the capacity of reclamation and water purification systems, and in installation and operating costs. Finally, flexiblility in parts handling and in line layout offer many new opportunities for batch plating improvements.

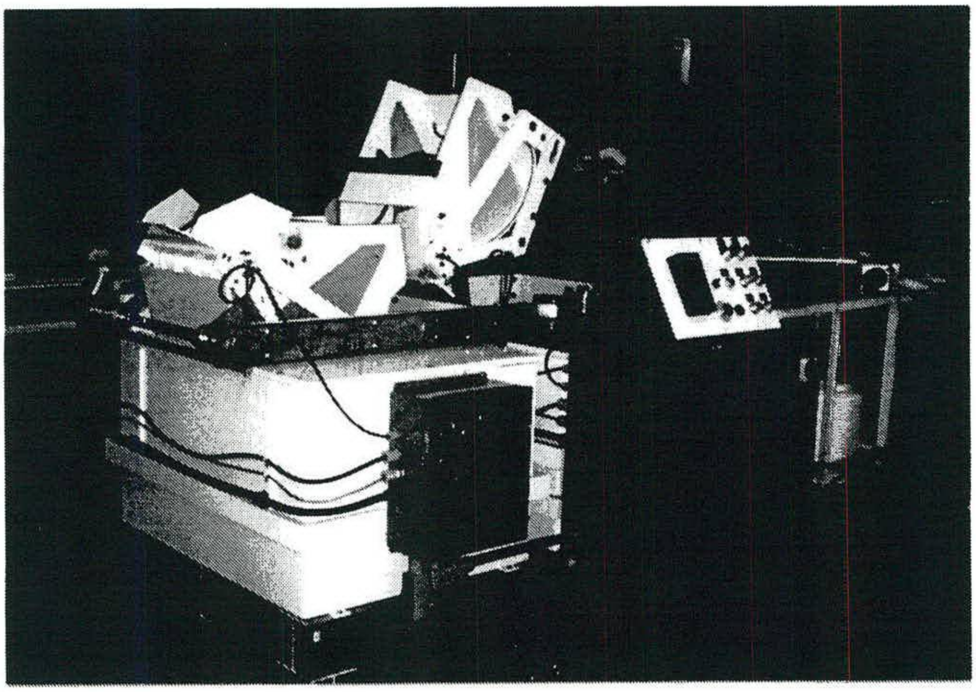

Figure 1. Open top, stationary, pivoting tumblers mounted on plating and rinse tanks showing the plating tumbler discharging parts into the rinse tumbler.

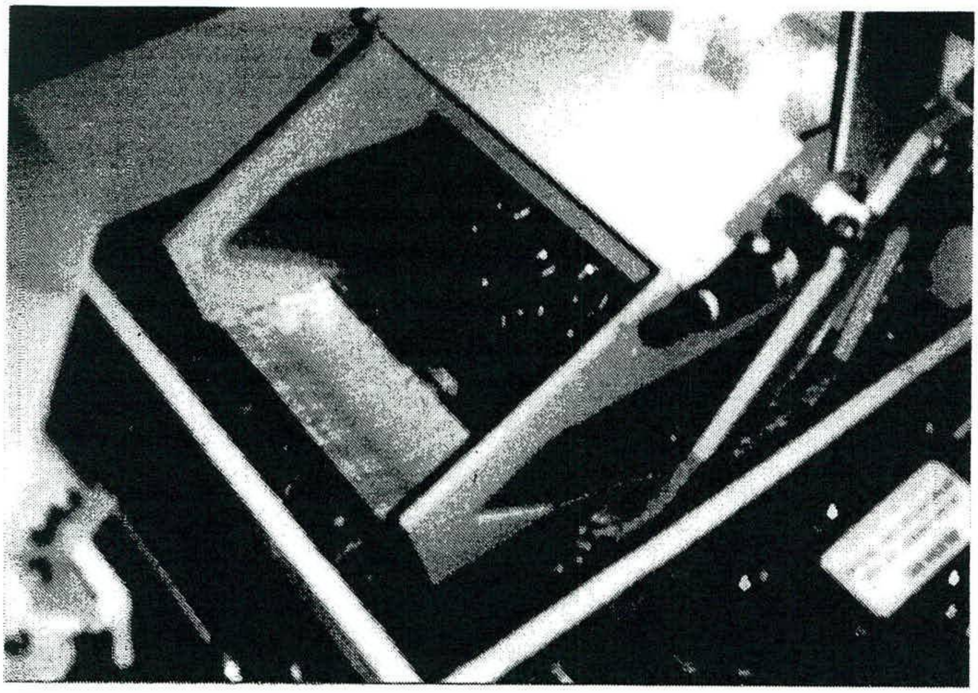

Figure 2. Solution is sparged into the compartment and over the parts from a manifold. Exchanges up to 10 gal. per gal. per min are possible.

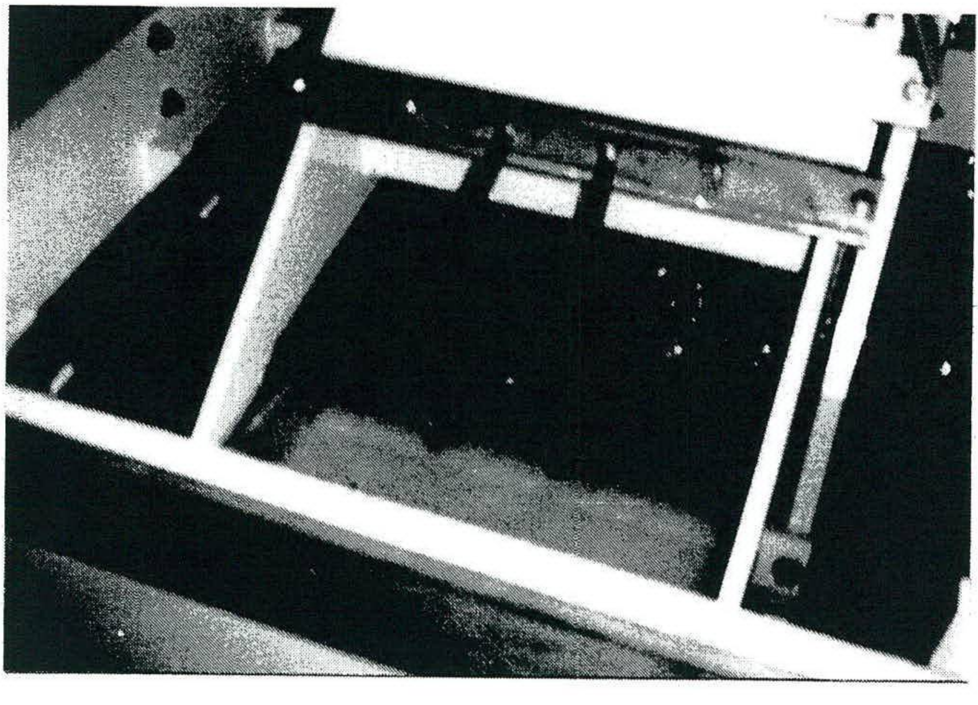

Figure 3. Danglers can be hung in any quantity or configuration from the overhead cathode bus. Other connections for special shapes may also be made.

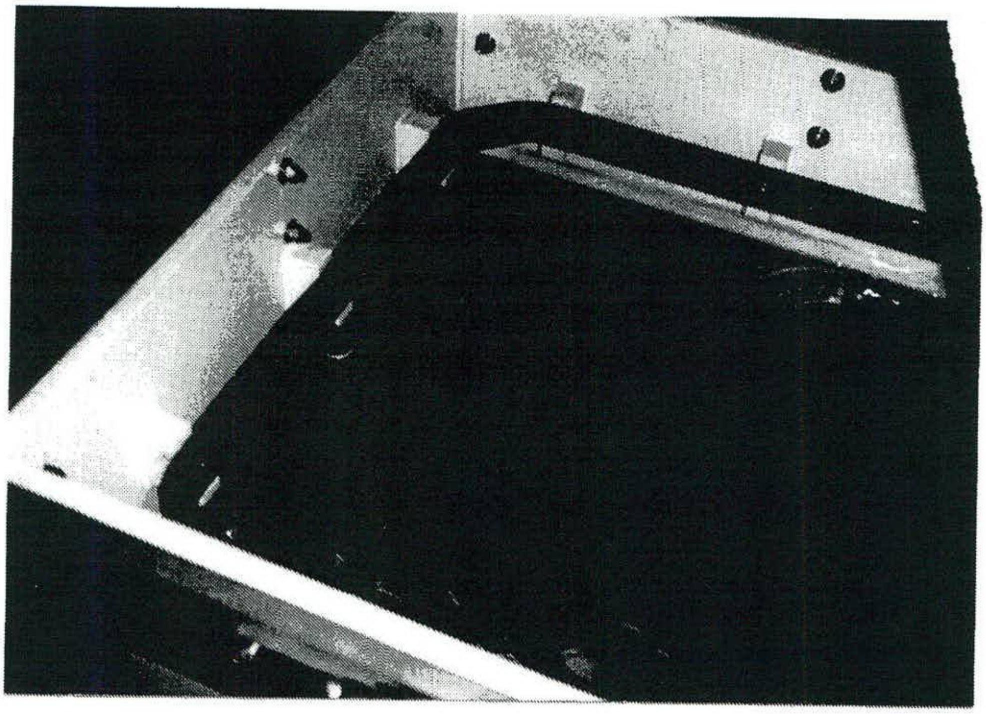

Figure 4. The anode bus extended around the front and sides of the tank allows baskets or slabs to be hung in close proximity to the surface of the batch of parts

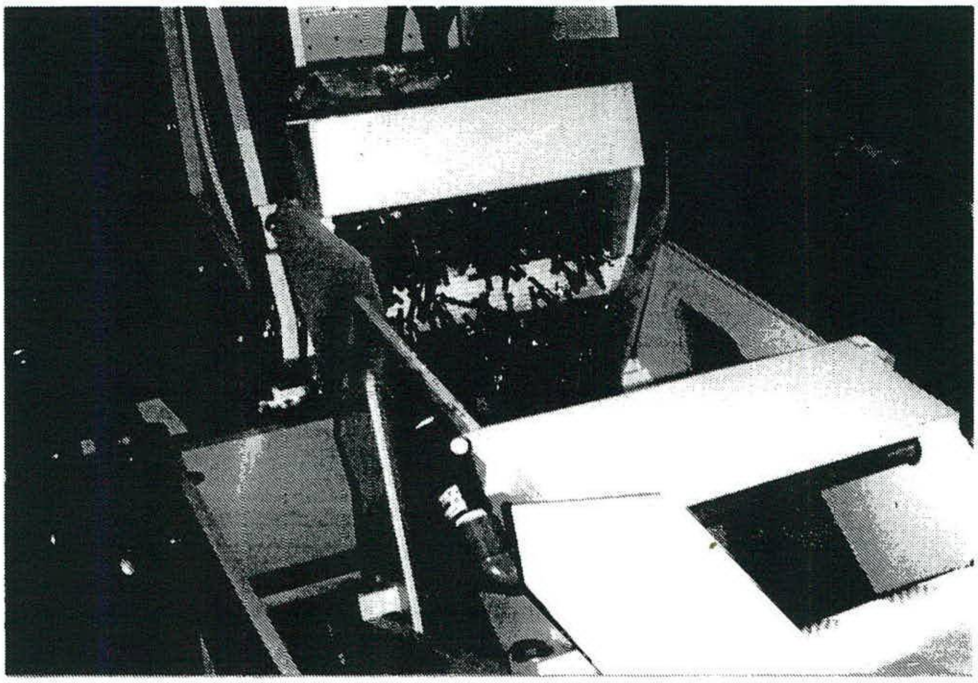

Figure 5. Only the solution on the parts is carried from one tumbler into another. A spray or blowoff before discharge can cut the dragout still further.

	14" X 30 " BARREL	1 CU. FT. TUMBLER
Load size	120 lbs - 125 sq. ft.	80 lbs. - 85 sq. ft.
Voltage	5 volts	7 volts
Amps	350	380
Amps/ sq. ft.	3 - 4	5 - 6
Time to min. Thickness	15 min.	10 min.
Thickness Spread	0.09 - 0.24 mil	0.09 - 0.16 mil
Barrel/ belt speed	6 rpm (17.5 fpm)	15 fpm

Table 1. STANNATE TIN TESTS

Part: Copper reverse loop contact, 2 -5/8" x 7/8"

	14" x 30" Barrel	1/2 cu. ft. Tumbler
Load size	typical 100 lb loads	9 lbs - 10 sq. ft.
Voltage	12 volts	13.5 volts
Amps		130
Amps/ sq. ft.	3 - 4	9 - 10
Thickness at 15 min.		0.1 mil
Thickness at 30 min.	0.1 mil	0.18
Thickness at 45 min.		0.25
Thickness at 60 min.		0.35

TABLE 2. BRIGHT NICKEL TESTS

Parts: Steel caps approx. 1/2 " diam. x 0.400" long

References:
(1) Electroplating Engineering Handbook
4th Ed., Van Nostrand Reinhold, NY

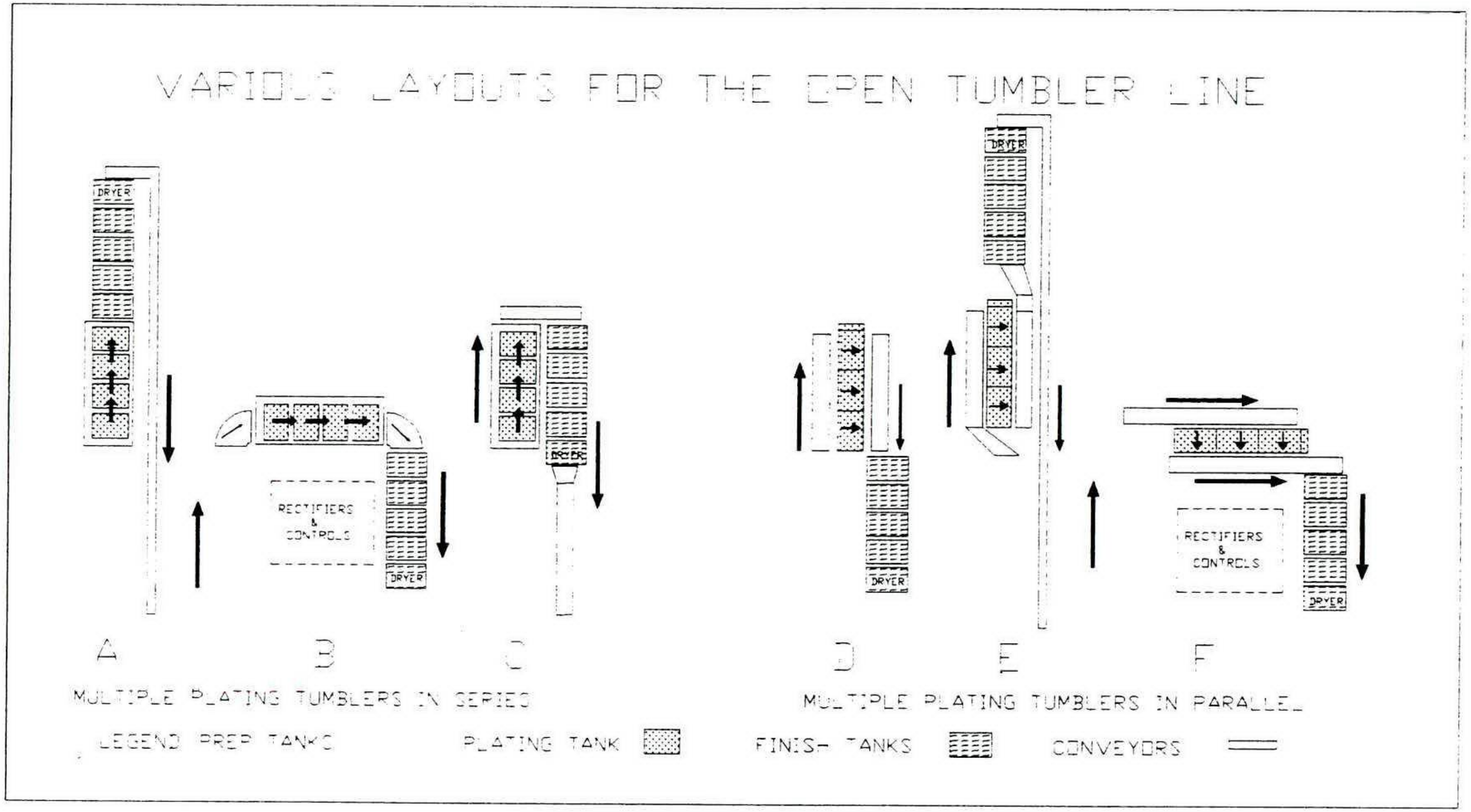
VARIOUS LAYOUTS FOR THE OPEN TUMBLER LINE
DRYER
DRYER
RECTIFIERS & CONTROLS
DRYER
DRYER
DRYER
RECTIFIERS & CONTROLS
DRYER
A
B
C
D
E
F
MULTIPLE PLATING TUMBLERS IN SERIES
MULTIPLE PLATING TUMBLERS IN PARALLEL
LEGEND PREP TANKS
PLATING TANK
FINISH TANKS
CONVEYORS

Figure 6.

Choosing an Appropriate Accelerated Corrosion Test Method

by Cynthia L. Meade, Singleton Corporation

In accelerated corrosion testing, it has become increasingly evident that the traditional method of assessing corrosion resistance by salt spray testing has evolved to include other environments such as elevated temperatures, variable humidity and acidic environments. As a result, researchers, technicians and several industry associations have studied existing corrosion test methods, developed new methods and spent enormous hours and dollars in search of the "right test". As a result, today's finisher may be asked to perform a myriad of test methods. While the selection of the test method may be customer-specified, the purpose of this paper is to aid the finisher in understanding of the various methods and their applications.

Numerous test methods, both static and cyclic are available to evaluate metals, coatings and finished products. The plethora of test methods available provides an opportunity to select an appropriate test method from that wide variety of test methods. Because of this variety, the tester needs to be aware of the risk of selecting and/or performing a test method without knowledge of its usefulness or appropriateness.

The desire is great for a quick and easy solution to the complex effects of corrosion. However, it should be noted that no single test method offers across the board validity because of the complexities of the environmental factors affecting finished products. The widespread adaptation of an inappropriate test method should be avoided.

Selecting a Test Method

Consider the following when choosing or analyzing the results of an accelerated test method:

1. What conditions will the finished product be exposed to? Salt, humidity, temperature fluctuations, gases, for example.
2. Are there geographic considerations? Will so me products end up in coastal environments while others are at dry locations?
3. What demands and expectations are in place for the life of the product? Does the customer or end-user expect the finish to last one year, two years, or five years?
4. What research and testing has already been conducted on this finish and how applicable is it to the finished product?

Salt Spray Test

In spite of the current literature regarding the Salt Spray Test, it remains an effective, efficient and simple inspection tool for manufacturing control such as evaluating different batches of the same product, once a standard level of performance has been established. In a dynamic environment where consumer demands, quality improvement processes and environmental regulations stimulate change, it is important to remember that a "comparison standard" must first be established before a finish can be measured against it.

The Salt Spray Test continues to be useful for the evaluation of finishes used in marine atmospheres due to the high concentration of salt and moisture. Sources in the aluminum industry report that the Salt Spray Test is still a major valid performance indicator.

CASS Test

While the salt spray test is used in numerous industries, particularly metal finishing, another predominant test method for finishers is ASTM B-368, Copper-accelerated Acetic Acid-Salt Spray (Fog) Test - CASS test. It is used primarily for the rapid testing of decorative Copper-Nickel-Chromium or Nickel Chromium plating on steel and zinc die-cast bases. It has also been shown to be effective on anodized, chromated or phosphated aluminum.

The CASS Test is operated at elevated temperatures, 49C (120F), rather than 35C (95F). The standard 5% salt solution is modified by the addition of .25 g/liter of reagent grade copper chloride. Glacial acetic acid is used to adjust the pH of the collected solution to a range of 3.1 to 3.3, compared to 6.5 to 7.2 pH in the ASTM B 117 Salt Spray Test.

Corrodkote Test

The Corrodkote Test, ASTM B 380, was developed for the evaluation of copper-nickel-chromium and nickel chromium coatings on steel, zinc alloys, aluminum alloys, plastics and other substrates. The procedure involves the application of a slurry comprised of .035 g of reagent grade cupric nitrate, .165 g of ACS reagent grade ferric chloride, and 1.0 g of ACS reagent grade ammonium chloride in 50 ml of reagent grade water which meets ASTM D1193 Type IV. Prior to testing, the slurry is applied to the test specimens and allowed to dry The specimens are then placed in a humidity chamber controlled at 38 degrees C ± 2 C and between 80 and 90% relative humidity. One cycle is 20 hours.

Humidity Test

High humidity tests such as ASTM D-2247, Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity, are useful for determining the water resistance of finishes. This test exposes the finish to 100% relative humidity at 38 degrees C (100F). Other humidity tests are available which operate at lower humidities and higher operating temperatures.

Modified Salt Spray Tests

ASTM G 85, Standard Practice for Modified Salt Spray, now includes 5 annexes. These outgrowths of the B 117 Salt Spray Test were developed to provide the tester with alternative corrosion test methods which utilize the existing technology and accumulated data as building blocks for these enhanced test methods. The apparatus and test procedure used closely resemble the ASTM B 117 with variations in the electrolyte solutions and operating conditions.

Acetic Acid

Annex 1, the Acetic Acid Salt Spray Test, formerly ASTM B 287, is useful for testing decorative chromium plating on steel or zinc die-cast. It is a static atmosphere test nearly identical to the ASTM B 117, except that the electrolyte solution is adjusted to a pH of 3.1 to 3.3.

Cyclic Acidified Salt Fog Test

Cyclic Acidified Salt Fog Test, Annex 2, uses a solution with pH of 2.8 to 3.0. The test apparatus is operated at higher temperatures and is cycled as follows: 3/4 hour spray (fog) at 49 degrees C (120 F), 2 hour dry air purge and 3 1/4 hour soak at high relative humidity.

An important part of this test is the dry air purge following the spray cycle. During this step, the corrosion products should dry to a white color. The temperature changes and drying provide thermal stressing and concentration of pollutants on the test specimens.

Acidified Synthetic Sea Water

For production control of exfoliation-resistant heat treatments for the 2000, 5000 and 7000 series aluminum alloys, Annex 3, formerly ASTM G 43, Acidified Synthetic Sea Water (Fog) Testing, is recommended (ASTM footnote). The electrolyte solution is a synthetic sea salt. Similar to the Annex 2, the test apparatus should be cycled between a 30 minute spray (fog) at either 35 or 49 degrees C, followed by a 90 minute soak at 98% relative humidity.

Salt Fog SO_2 Test

Annex 4, Salt/SO_2 is used extensively in the aerospace industry. The solution used could contain either sea salt or sodium chloride. The cycle consists of either of the following: Constant fog at 35 degrees C (95 F) with SO_2 introduced for one hour, four times a day or; 1/2 hour salt spray, 1/2 hour SO_2 and 2 hours soak.

Dilute Electrolyte Cyclic Fog Test

The latest addition to ASTM G 85 is Annex 5. This method was developed by Mebon Paints Ltd. of England and was commonly known as Prohesion^{tm}. It has been used extensively throughout England as an alternative to ASTM B 117 for testing industrial paints on steel. It has not been shown to be useful for automotive paints. Although inclusion in the G 85 Practice would lead one to believe that the test can be performed in a modified salt spray chamber, all manufacturers have developed new test chambers more capable of performing this test.

The test consists of alternate cycles of one (1) hour dry off and one (1) hour fog. A dilute electrolyte solution is prepared from .05% sodium chloride and .35% ammonium sulfate by mass. This solution is similar to the Harrison's solution used during the early stages of the test development. The fog cycle is performed at ambient room temperature, 23 degrees C (74F), while the dry-off is done at 35C (95F). After 3/4 hour of the dry-off cycle, the test specimens must be void of all visible moisture.

Moist SO_2 Tests

Moist SO_2 tests, ASTM G87, commonly known as Kesternich, are frequently used for quick, visible corrosion, similar to that found in industrial environments. This procedure produces an "acid rain" simulation used for testing electrical apparatus, glass, and building materials. When used for testing tin coatings on steel, low concentrations of sulfur dioxide provide a useful means of detecting discontinuities in the coating.

This test procedure is as follows:

1. Fill the chamber with 2L of distilled water which meets ASTM D 1193 Type IV Water.

2. Place the specimens in the chamber prior to heating.

3. Introduce SO_2 into the chamber at .2, 1 or 2L as required by the material specification.

4. Allow the chamber to heat to 40 ± 3 degrees C (104 ± 5.4F) within 1.5 hours.

The cycle may be a continuous 24 hour cycle or may be an 8 hour moist SO_2 exposure followed by an ambient drying atmosphere for 16 hours.

Because the desired test conditions depend upon the reaction of the SO_2 with the water in the chamber to form low concentrations of sulfuric acid , H_2SO_4, it is important to operate the chamber under wet bottom conditions and replace the water every 24 hours.

This test method should always be performed with caution and the equipment installed under a suitable hood and used with proper ventilation.

Other Cyclic Test Methods

The automotive industry has done significant work toward achieving the goal of developing an accelerated corrosion test for paints on sheet steel. Joint efforts between the American Iron and Steel Institute (AISI) and the Society of Automotive Engineers (SAE) Automotive Corrosion and Prevention Committee (ACAP) include the development of an accelerated corrosion test which will compare with long-term vehicle exposure results. This ongoing effort has involved 20 different accelerated test methods. At the present, the committees are evaluating two test methods-9540P, Cycle B and CCT IV and are preparing for a third, CCLT. In previous testing, only 9540P and CCT IV test methods showed acceptable overall performance results.

Due to the incorporation of multiple exposure conditions, the equipment required to perform cyclic tests is more complex.

9540 P Test

The 9540P, Cycle B test is a cyclic test which includes a high humidity cycle, modified salt fog cycle, dry-off period and ambient exposure conditions. For purposes of consistency in control, the test method requires the inclusion of corrosion coupons of 25.4 mm wide and 50.8 mm long AISI 1006-1010 steel. The test requires a salt mist application every 90 minutes for the first eight hours at ambient conditions, followed by 8 hours of high humidity exposure, and finally 8 hours of dry conditions. During the salt mist application, the samples and the coupons must be thoroughly wet and then be visibly dry before the next application.

CCT IV

CCT IV is the other cyclic test method. It includes 10 minutes of salt spray, 155 minutes in the dry mode at 60C, 75 minutes in the wet mode at 60C and 95% or greater relative humidity, after which the following two cycles are repeated 5 times at 60 degrees C--dry for 160 minutes and wet for 80 minutes.

Other similar CCT tests cycle salt fog, drying and humidity modes respectively.

CCLT Test

A preliminary test method, CCLT formerly referred to as the Paper Champion 4, will be studied in Spring '95 via the round robin testing procedure. The test method includes three steps:

1) Humidity - 100% RH at 50 degrees C for 6 hours

2) Immersion in salt solution--.5% NaCl, .1% $CaCL_2$ and .25% $NaHCO_3$

3) Dry - 50% RH and 60 degrees C for 17 hours and 45 minutes

The test cycle is repeated daily. The CCLT test was developed by joint efforts of the AISI and SAE corrosion committees using the "Design of Experiments" testing procedure.

Summary

Through education and experience, the finisher can understand and select an accelerated test method which provides relevant data for their particular application. Any accelerated corrosion test, however, is only useful as part of a total quality control program which includes field testing and data evaluation to established a "comparison standard".

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Surface Treatment of Powder Metallurgical Compacts

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Introduction

Powder metallurgy (P/M) is a rapidly expanding technology for manufacturing of structural parts. The P/M process provides economical as well as technical benefits over conventional processing of wrought material. It is possible to fabricate high quality, complex parts to close tolerances without machining. The energy consumption is low and the material utilisation and productivity high.

The unique ability of P/M to obtain a uniform microstructure and to fabricate alloys and composite materials, which are otherwise difficult to make, increases the interest and research in the field.

Fatigue, wear and corrosion are the three most common failure problems encountered in the industry. Recently, fatigue has been investigated extensively, but wear and corrosion problems of P/M part have been paid only little attention. The application of P/M parts has in many cases been restricted to non corrosive and wear free environments. Solving the wear and corrosion problems of P/M parts, increases the number of potential industrial applications. Surface treatment has been successfully applied to wrought materials to obtain better surface properties, but many of the commercial surface treatments used on wrought materials can not be used directly for the porous P/M parts. For example, electrolyte trapped in the pores during electroplating, could later cause serious corrosion attacks.

The present work has concentrated on improving the corrosion resistance of P/M compacts by electrolytic surface treatment.

Porosity

The porous structure of P/M compacts is a result of the manufacturing process and the initial powder characteristics. The total volume of porosity is important for the mechanical properties, but considering corrosion properties the volume of open porosity is the essential parameter. Open pores means pores in the surface or pores connected to the surface through other pores. It has recently been shown [1] that the volume of open pores decreases with increasing compacting pressure. More interesting is the fact that the porosity of low compact samples consists almost entirely of open porosity, whereas samples with high density contained more insulated than open pores.

In this investigation sintered iron compacts containing 10 % total porosity were used as substrate. The volume of open pores was about 6 %. Such materials are commonly used for industrial applications.

Levelling effect of different plating solutions

P/M compacts without any kind of pore closing pretreatment, are full of open and interconnected pores. When electroplating the P/M compacts, the presence of these pores affect the quality of the electrodeposit. If the coating is cathodic to the substrate the presence of voids in the coating will result in server local corrosion. In order to obtain a pore-free coating it is necessary to control the distribution of the electrodeposit in such a way, that the coating fills up the pores. In order to measure the levelling effect of various treatments, speciments with a V-shaped microroughness profile were manufactured from mild steel. Figure 1 shows schematically a possible distribution on such a profile. Several expressions describing the levelling effect have been presented in the literature (symbols are explained in figure 1):

$$E_1 = (d_2 - d_1)/t \qquad [2,3]$$

$$E_2 = d_2/(t + d_1) \qquad [4]$$

The levelling effect E_1 indicates the degree of the levelling. A positive value indicates that the deposition has a positive levelling effect, and complete levelling leads to $E_1 = 1$. When the deposition is uniform $E_1 = 0$. It has been emphasised that the value of E_1 relates to on the plating time, because the difference between d_2 and d_1 increases with time when plating in a solution with positive levelling effect.

The levelling effect E_2 indicates how thick the deposit is in the pore at a given time, compared with how thick the deposit should have been in the pore to have completed the levelling. The value of E_2 is always positive. A complete levelling corresponds with

$E_2 = 1$. In contrast to E_1 the value of E_2 will not be zero in the case of uniform deposition.

Both E_1 and E_2 are strongly related to the depth of the profile. A comparison of the levelling effect of different solutions must be carried out on the same profile.

A variety of commercial plating solutions were examined. All depositions were carried out at a current density of 2 A/dm². The results are listed in table 1, listed according to the levelling effect.

The results show that acid zinc as well as acid copper have an excellent levelling effect. This supports the conclusion of Meyer [5] that excellent pore filling can be achieved by using acid electrolytes. The cyanide solutions show negative levelling effect. This is in conflict with Saleh et al. [6] who concludes, that complex cyanide solutions give the best pore closure for single layer coatings. This deviative conclusion must be related to the method of measurement (permeability). The coefficient of permeability is not directly related to the levelling effect.

Porosity of copper coatings

Corrosion protection with a coating more precious than the substrate, has the risk of pores in the coating leading to serious localised galvanic corrosion cells. In the following, electrodeposition of pore-free copper coatings on iron based P/M compacts are investigated.

Previous to the plating, samples were immersed 5 minutes in hot distilled water to fill the pores. This was done to limit the entering of the different pretreatment solutions in the pores. The samples were degreased anodically in an alkaline solution, and etched in a solution of $NaHSO_4$ and $NaHF_2$ for 1-2 minutes. A copper strike was plated from a cyanide solution to improve adhesion.

Introductory experiments carried out in acid baths with and without levelling agents showed that levelling agents are very important (figure 2) and that low current density (2 A/dm²) is better than high current density (4 A/dm²).

The influence of increasing coating thickness on the porosity of the chosen substrate, was investigated by depositing various thicknesses of copper coatings from the additive containing solution, using a current density of 2 A/dm². The samples were tested by means of various corrosion test methods, to detect porosity and to evaluate the corrosion protection. Conventional steel samples were produced and used as references.

Test results obtained with the moist SO_2 test are shown in figure 3. The test was carried out according to ASTM Standard G 87-84 [6]. Figure 4 shows the results obtained after 432 hours in a neutral salt spray chamber according to ISO Standard 3768 [8]. Figure 5 shows the results of a modified ferroxyl test according to ASTM Standard B734 [9]. All the corrosion tests show, that a coating thickness of at least 20 μm is necessary to obtain pore-free coatings under the conditions given in this investigation.

Corrosion protection by sacrificial coatings

Coatings of a metal less precious than the steel substrate will, apart from shielding the substrate, also offer cathodic protection in pores by acting as a sacrificial anode. It is therefore relevant to consider this type of protection on P/M compacts, when it is difficult to obtain a perfect pore-free coating.

Four different sacrificial coatings were tested in neutral salt spray test, on both P/M compacts and conventional steel. The results are presented in table 2. It is seen that there is no difference in performance, between deposition on P/M compacts and on conventional steel. The porosity of the substrate has apparently no effect on the corrosion resistance in cathodic protection. The zinc alloy depositions exhibit corrosion protection superior to that of pure zinc in the neutral salt spray test.

Corrosion protection by inhibitors

Corrosion inhibitors are species that increase the overvoltage even when they are present in relatively low concentrations. Also anions such as phosphate and chromate act as powerful corrosion inhibitors by forming insoluble compounds.

Instead of being a disadvantage, the porous structure of P/M compacts could be used to advantage by serving as a reservoir for corrosion inhibitors. For obvious reasons the impregnated corrosion inhibitor is only efficient in the area around the pores. It does not give an overall corrosion protection and should therefore be used in conjunction with additional corrosion protection, e.g. electroplating. The electroplated coating protects against corrosion in general, whereas the inhibitor enhances the protection of the critical areas.

The corrosion protection of two potential inhibitors (270 g/l boric acid and a saturated solution of potassium hydrogen phosphate) were examined in combination with 12 μm electrodeposited copper (2 μm cyanide copper and 10 μm acid copper). These samples and reference samples of copper plated steel were exposed in a moist SO_2 atmosphere for 24 hours and ferroxyl indicator was used to detect iron corrosion products. The P/M compact without inhibitor failed, as expected, the test. Pretreatment in boric acid showed no improvement of the corrosion resistance, but pretreatments with potassium hydrogen phosphate resulted in good corrosion resistance. The corrosion attack was as minor as on the reference samples.

The corrosion protection of potassium hydrogen phosphate, in combination with a zinc coating plated from an acid zinc bath was examined, too. The following samples were plated with 10 μm zinc and tested in a neutral salt spray chamber:

1. P/M compacts with K_2HPO_4
2. P/M compacts without inhibitor
3. Reference samples of conventional steel

Inhibitor containing samples showed an significantly improved corrosion protection, as compared to samples containing no inhibitor. The corrosion resistance was improved to the level of the reference samples.

Conclusion

Among a number of commercial plating solutions, acid zinc and acid copper were found to have an excellent levelling effect on porous P/M parts. A minimum thickness of 20 μm copper plated from the acid copper bath was needed to obtain a pore-free coating. When coatings giving cathodic protection of the P/M substrate were deposited, pores in the coating did not affect the corrosion protection. When potassium hydrogen phosphate was absorbed in the porous structure of the P/M compacts, previous to copper plating, the corrosion resistance was improved to the level of conventional steel substrates electroplated with copper, even when the coating thickness was much less than 20 μm.

It has been shown that good corrosion protection of P/M compacts can be obtained when surface treatment processes are modified to be applied to porous structures.

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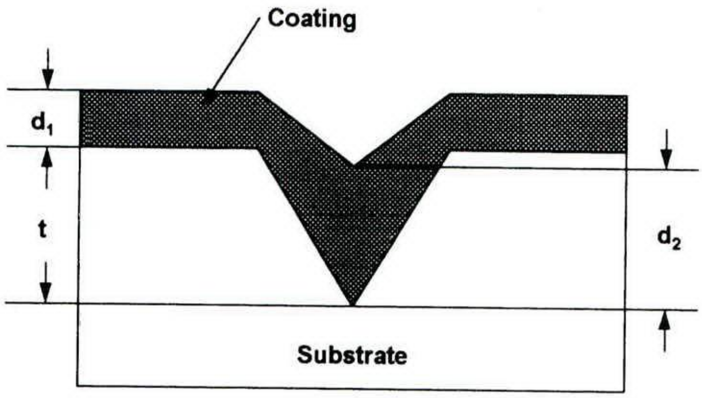

Figure 1: Schematic diagram for deposition on a V-shaped micro-profile.

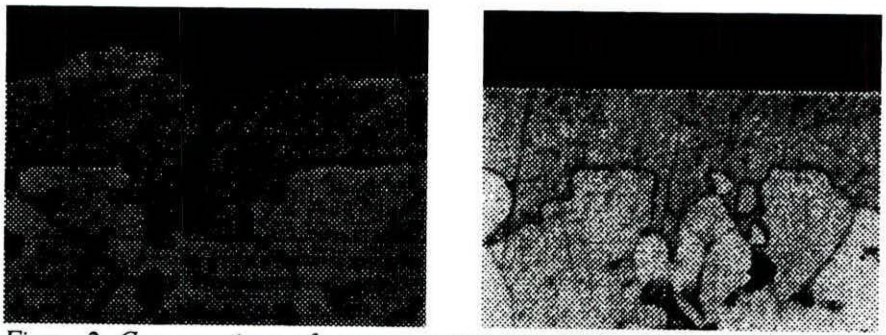

Figure 2: Cross-sections of copper coatings on P/M compacts deposited form solutions without and with levelling agents. Layer thickness approx. 25 µm.

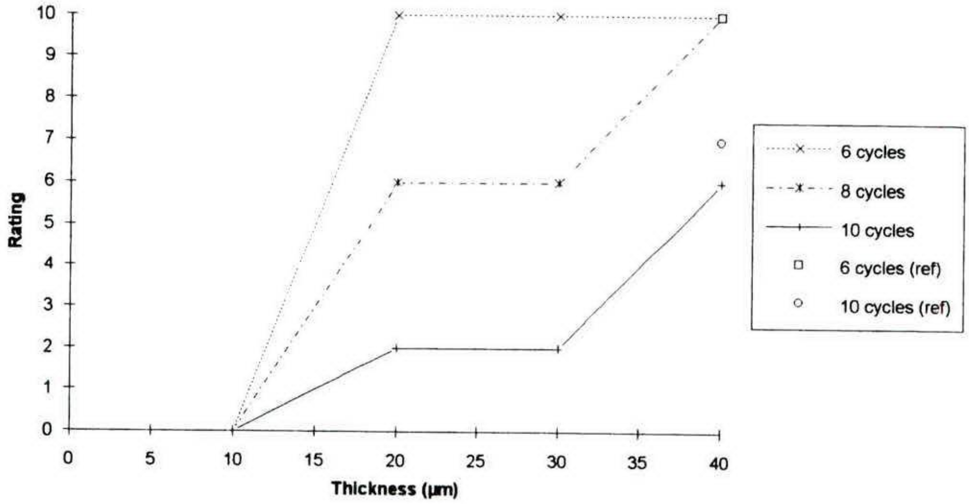

Figure 3: Corrosion rating according to ISO Standard 4540 [7] after exposure to moist SO_2 test.

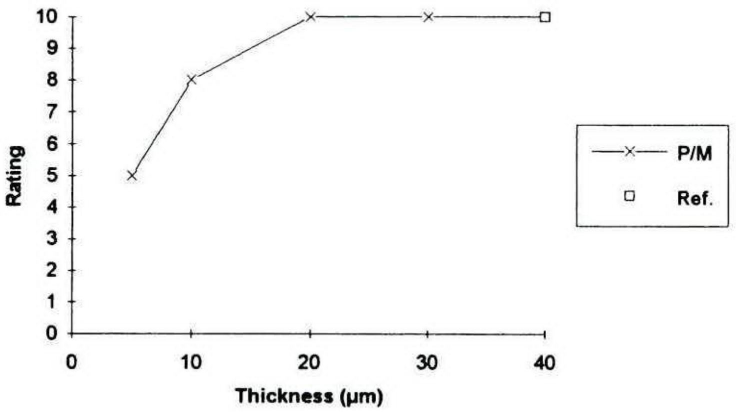

Figure 4: Corrosion rating according to ISO Standard 4540 [7] after 432 hours exposure to neutral salt spray test.

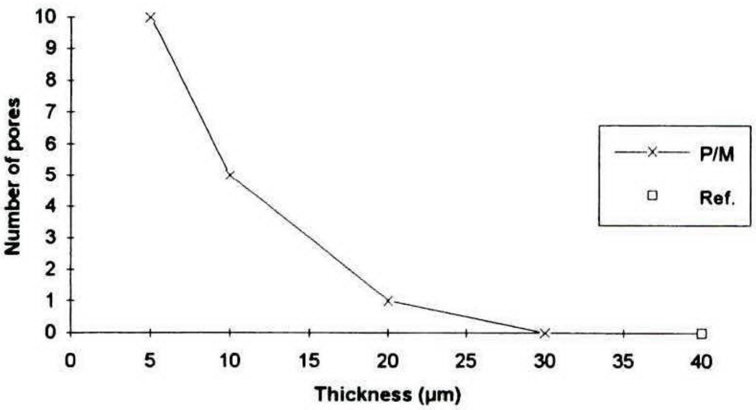

Figure 5: Number of corrosion spots after exposure to modified ferroxyl test.

Solution	d_1 (µm)	d_2 (µm)	E_1	E_2
Acid zinc	16	55	0.78	0.83
Acid copper	14	52	0.76	0.81
Tin/zinc	12	40	0.56	0.65
Bright nickel	12	40	0.56	0.65
Zinc/nickel*	7.8	13.0	0.19	0.37
Zinc/cobalt*	14.7	14.7	0.00	0.35
Pyrophosphate copper	22	22	0.00	0.31
Cyanide zinc	21	9	-0.24	0.13
Cyanide copper	36	12	-0.48	0.14

Table 1: The levelling effect of different plating solutions. Data of the V-shaped profile: 100 µm wide and 50 µm deep (44 µm wide and 27 µm deep).*

Plating solution	Coating thickness	Substrate	Hours to red rust
Acid zinc	11 µm	P/M	288
		Steel	288
Zn/Co	11 µm	P/M	>480
		Steel	>480
Zn/Ni	10 µm	P/M	>480
		Steel	>480
Sn/Zn	11 µm	P/M	>480
		Steel	>480

Table 2: Neutral salt spray test of sacrificial coatings.

Paper Not Available In Time For Publication

Automating a Jobshop—High Production, Multiprocess Lines

Greg Arneson & Troy Brown, Geotronics of North America, Itasca, IL

The evolution of automated metal finishing lines is entering its final phase—automation of the jobshop. Providing the flexibility of a manual line, and approaching the productivity of a fixed timeway, has only recently become possible with advanced scheduling algorithms. This paper discusses two case histories, one a retrofit and the second, a new installation. The major project objectives and subsequent results are presented, along with economic considerations. Special focus will be placed on how the software algorithm and multiple process lines reduce floor space, hoists, and waste treatment.

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FILTRATION AND AGITATION AS TOOLS TO IMPROVE QUALITY IN FINISHING

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Dr. Deming says in one of his 14 points on "Lessons for Management" (therefore, I quote point #3): "Cease dependence on inspection to achieve quality. Eliminate the need for inspection on a mass basis by building quality into the product in the first place."

What is he saying . . . no more salt spray testing?? Perhaps not, but his point is if all the ingredients create a suitable part and all ingredients are monitored to an acceptable standard, then isn't it logical to assume the results will always be the same?

Most recently at trade shows, exhibits, quality seminars and in technical bulletins, we've stressed a review of the plating processes with emphasis on steps to take to prevent contamination of the plating solution; even going so far as to explain that if proper steps are taken, then filtration of the plating solution may not be necessary. Why not??

If we start with the soak cleaner, solids removed from the parts should be separated with a filter; if such solids are present in large quantities, gravity type surface filters can be effective. Filter media is available in different porosities, and is only consumed as necessary when the surface is blinded off due to the collection of solids. Such types of filters are often automatically actuated by a float which activates a motor to drive the spent filter media forward to a dump tank, thus bringing fresh paper into the filter area to repeat the cycle.

Another means of sediment removal is possible with cartridge type cotton filters employing coarse media for maximum solids retention. Of course, cleanable media may also be used, but does require more attention and handling labor.

Since cleaners operate hot, oils removed from the parts are difficult to pick up to extend the life of the cleaner. Therefore, a small auxiliary tank may be used along with a bulkhead fitting, and a few fittings and pipes to overflow the cleaner from the main tank to the auxiliary tank. This smaller tank will allow the cleaner to cool which will let the cleaner separate, and as the oil agglomerates, it will form larger droplets and float.

Now all we need is a pump connected to a skimmer which will pick oil solution off the surface, then pump it through a fine prefilter to pick up any remaining solids before passing the cleaner through a coalescing element where tiny oil droplets are retained on the surface which was previously soaked in water. As the oil is retained, larger droplets are formed which will slowly float to the surface to be vented off. The cleaner can now be returned to the soak tank free of almost all the oil.

Additional similar forms of filtration may be employed in subsequent pretreatment tanks in order to progressively prevent finer and finer particles from getting from tank to tank, keeping in mind the use of skimmers which effectively remove vapors or other contaminants which tend to lay or float on the surface. Thus, when the part is removed from the tank, "surface tension" will not transfer such contaminants from tank to tank.

Perhaps a final purification of the rinse just prior to plating may prevent any remaining oils from getting to the plating tank. Here again, a pump with skimmer should be used to pass the rinse water through a column of granular carbon (prefilter again, if necessary to prevent the carbon bed from becoming plugged with any solids from the water. Such water could have been prefiltered while under city water pressure.)

Perhaps it doesn't seem like much, but I know from experience that we used to pick up 4 to 8 oz. (113-227 grams) of dry solids from highly filtered water in Milwaukee with a 15 micron 10" (25 cm) cartridge.

The question we now want to ask is, what percentage of solids have we prevented from entering the plating tank, and what percentage is left to be dealt with? My guess is that good cleaning can prevent 50-75% of solids, which we previously allowed to enter the solution. Therefore, what is left to do? We already mentioned the water - will it be city water , or water from a dead rinse? In either case, you'll want to filter it before, rather than after, it gets into the plating tank.

This brings us down to one last element of "surprise" contaminants, dust or vapors which could be present in the air used for agitation. While some platers use various types of dry media to filter the air, it is doubtful that the troublesome, tiny particulates which cause the real roughness problems, are retained.

It is also possible that air used for agitation is not as clean (that is, free of insoluble particulates), as the air itself may, in fact, be carrying vapors from other process operations into your plating solution which are absorbed into the solution with the aid of your wetting agents.

Under consideration at this time is a method of agitating the plating solution with a combination of high flow centrifugal pumps which draw solution from the tank and re-deliver it through a sparger system similar to that used for air agitation, but with the addition of eductors strategically placed along the horizontal pipe so as to direct plating solution across the bottom of a tank or up a cylinder or into difficult-to-plate, low current density areas. Each eductor creates, without additional horsepower, up to four times the actual pumped liquid being delivered to its orifice. This means instead of one gallon per minute, you will be circulating four additional, or up to 5 GPM, with the horsepower requirement of only 1 GPM. *(Figure 1)*

We have received reports suggesting the almost universal success of this new method of agitation. Now consider the advantages, as we said:

- . . . Elimination of vapors being introduced into the plating solution
- . . . Elimination of uncontrolled temperature change
- . . . Elimination of air bubbles from entering the suction lines of centrifugal pumps which could cause them to cavitate and lose prime
- . . . Minimizing of brightener breakdown due to oxidation
- . . . Elimination of salt crystal formation in the holes of the dispersion piping

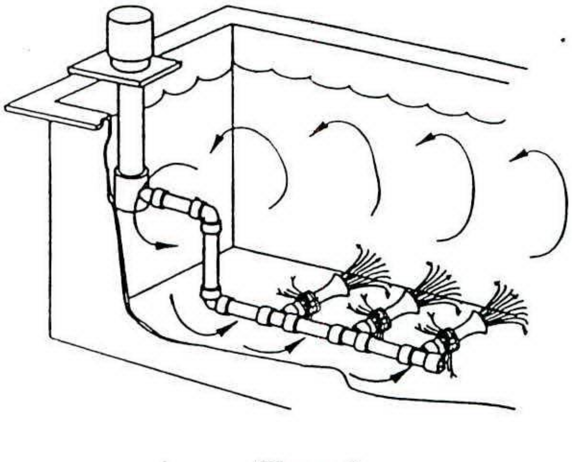

Figure 1
TYPICAL EDUCTOR AGITATION SYSTEM

With pumped / eductor agitation, we are now plating with a solution which is totally self-contained, where a lower amount of solids or vapors is possible and temperature is more easily controlled. It brings us, therefore, one step closer to "Clean Room - Solution - Environment". We now can proceed to filter the solution to remove any particulates which got past your barriers and add the necessary carbon for removal by adsorption of any brightener breakdown, but the amount of carbon will be greatly reduced and, in turn, remove less usable brighteners.

This is why we have been recommending the use of eductors which, when used along with pumps, can create effective agitation of the bath without the problems associated with bringing in outside air. We've also minimized the cooling effect of atmospheric air on the desired temperature of the plating solution, and prevented salts from solidifying and plugging up the holes in a sparger system . . . However minor it might seem, the elimination of air agitation can prevent certain brightener breakdown in the plating solution which, in turn, reduces the amount of carbon needed to maintain the plating solution in its purest form. Needless to say, the steps we used to prevent oil from getting into the plating tank also reduced the amount of carbon needed to maintain purity.

A typical sequence would be to agitate and high flow filter during working hours. At night, without agitation, liquid would pass through filter and optional coalescer at low flow to remove oils. *(See Figure 2, next page.)*

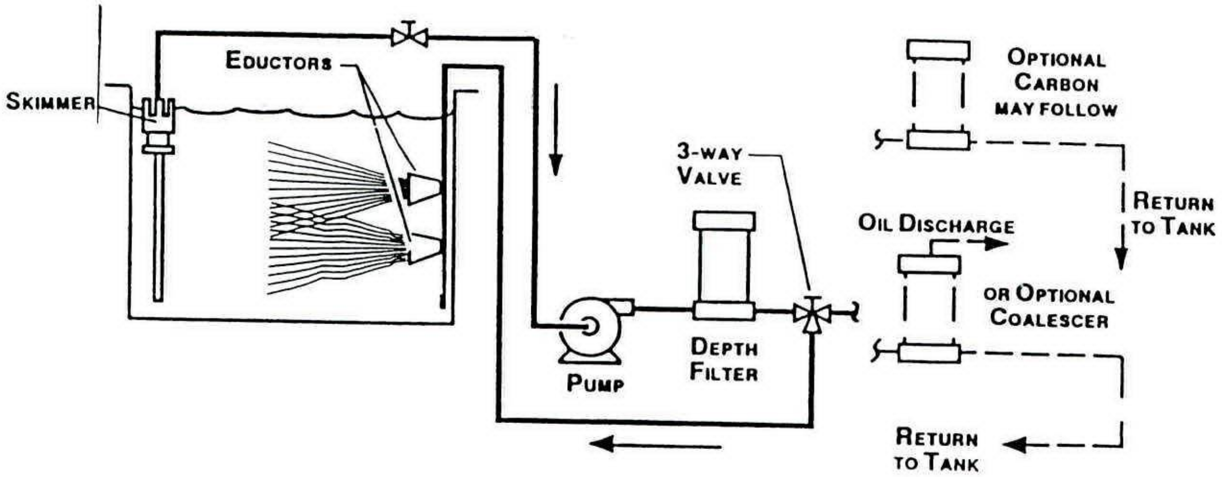

Figure 2

Brightener feeders offer accurate and consistent chemical additions automatically to plating baths, resulting in improved quality.

Solid state, digital totalizing ampere-time (hours or minutes) systems monitor and replenish chemicals depleted during the plating process. Ideal for anodizing, pulse plating, nickel, precious metal and chrome electroplating.

Their unique features include replenishment exactly at the rate of chemical consumption, completely automatic response to varying load size and plating current, and the capability of adding one or two chemicals simultaneously, but in different proportions.

Other papers which we have written have explained the need of filters on the plating solution, stressing the need for adequate solids holding capacity and high turnover rates.

Remember . . . filters can operate for 2 to 4 or 6 months "unattended", meaning no need to clean them or change filter media, provided the amount of solids holding capacity will match the amount of solids which might still get into our plating solution in spite of our most diligent efforts.

We used to say that twenty 15 micron 10" cartridges could maintain a 1,000 gallon bright nickel tank for about six weeks - this meant that we had picked up about 10 pounds (8 oz. per cartridge) of solids from the solution. Obviously, as our pretreatment cleaning has improved along with pump / eduction for agitation, longer periods between filter servicing can be expected.

There is also the possibility of employing two types of filters on a tank; in fact, we commonly recommend doing so to improve the solution clarity on tanks already fitted with some type of filter - or we sometimes suggest the plating filter be moved to one of the pretreatment tanks and a larger, more effective filter be used on the plating tank.

You might ask - why the need for the bigger filter if we have taken all the steps to prevent solution contamination in the pre-treatment?

My answer is simple - referring back to what Dr. Deming is preaching, that the results we expect will be the result of the condition of the plating solution. Therefore, if we can keep our solids below the accepted limit, our desired results can be expected. The same will be true if carbon is used for some form of purification.

Here again, we recommend granular type, employed in canisters for extended contact time without bypass. Such chambers, when installed on the downside of a filter chamber, will receive only clean filtered solution. Therefore, the granular type of carbon will perform almost as effectively as powdered carbon, but without the mess and, more importantly, without impeding the flow or robbing the dirt holding capacity of the media used for filtering.

It stands to reason when all of the above steps are taken, that waste treatment will be reduced and segregated.

The quality of plating will be improved and final inspection could be a thing of the past, as well as salt spray and other testing - perhaps if not completely, at least rejects will definitely be minimized and, in fact, designers will learn to rely on plating surfaces for whatever purpose was intended, whether it be wear resistance, brightness, conductivity or corrosion protection.

Paper Not Available In Time For Publication

Things That Make Life Better in the Lab & Plating Line

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Subjects of practical electroplating.

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Paper Not Available In Time For Publication

Production Line Wastewater, Secondary Containment—RCRA vs. Clean Water Act

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Practical approaches for operational procedures are required when dealing with issues concerning the RCRA Hazardous Waste Rules. There is always a fine line of interpretation when a plating facility is undergoing a hazardous waste inspection. In light of some recent federal and state inspections at plating facilities, an interesting discussion will be presented covering both the legal and operational requirements necessary for maintaining your qualification as a wastewater treatment facility that is subject to regulation under either sections 402 or 307(b) of the Clean Water Act.

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