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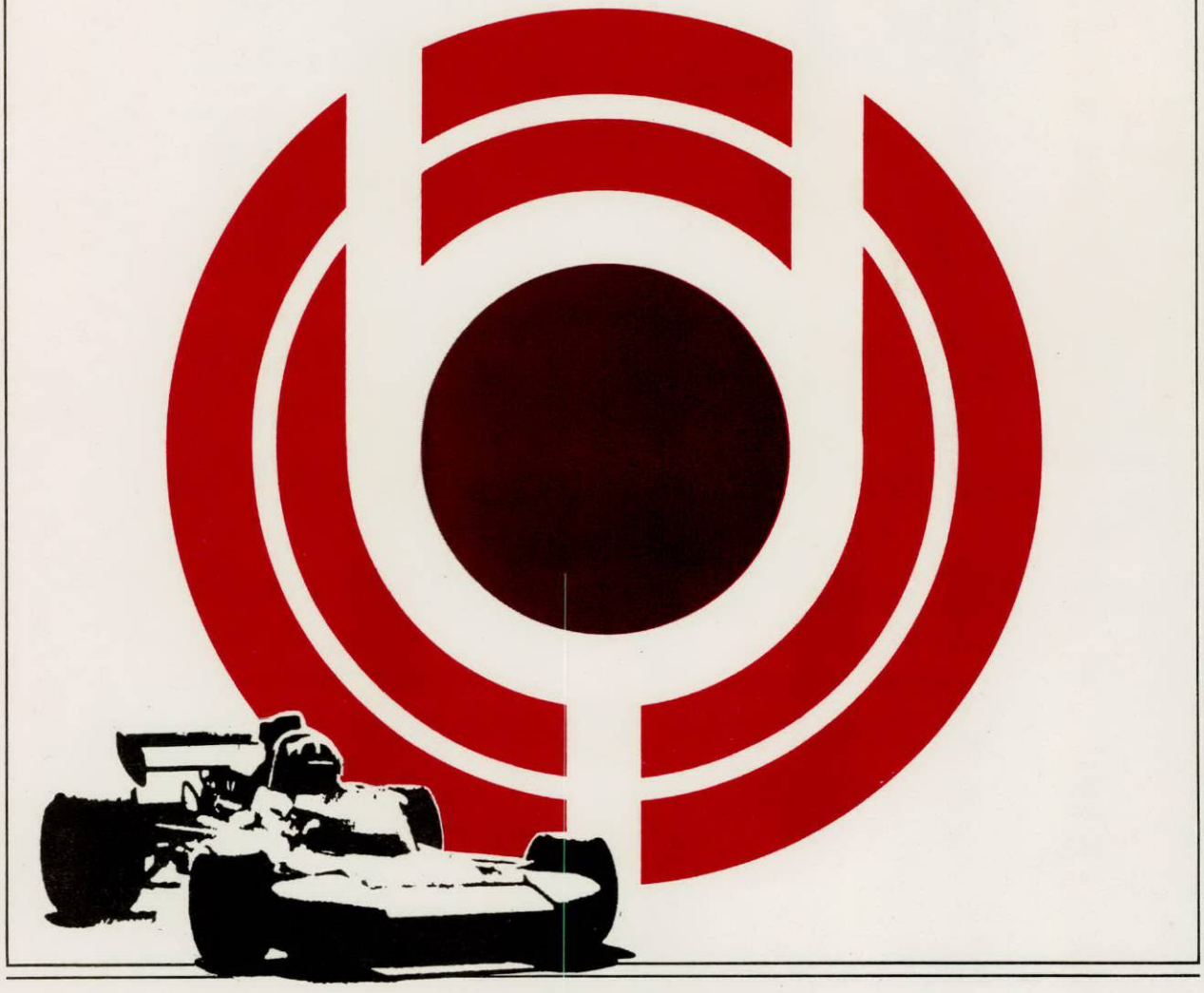

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Indianapolis, IN

## Session G - Organic And Chemical Pretreatment

AMERICAN ELECTROPLATERS' SOCIETY, INC.

70TH ANNUAL TECHNICAL CONFERENCE - INDIANAPOLIS, IN

ORGANIC & CHEMICAL PRETREATMENT

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# Organic & Chemical Pretreatment Session G

## Chemical Pretreatment of Steel for Water-Borne Coatings

Joseph V. Otrhalek, P.E., Dr. S. M. Sokalski and J. J. McGovern
Detrex Chemical Industries, Inc.
Redford, MI

# CHEMICAL PRETREATMENT OF STEEL FOR WATER-BORNE COATINGS

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BY: J. V. Otrhalek, P.E., Director of Research & Development
Dr. S. M. Sokalski, Director of Chemistry
Mr. J. J. McGovern, Automotive Manager

## ABSTRACT

The operations from raw part to finished product comprise an entire system. For water-borne finishes, cleaning and conversion coating is a critical segment. While conventional methods do work, special precautions are required to obtain consistently good work. The ability to recognize the source of problems and take corrective action is an important part of operating a successful pretreatment system.

## INTRODUCTION

During the past 10 years or so, significant advances have been made in understanding the total finishing process for painted goods. Studies of steel surfaces revealed the detrimental effect of carbon on the durability of the total finish. This has resulted in improved mill practice to give steel with a cleaner surface. Other studies using SEM and ESCA as well as a host of other sophisticated tools have led to an understanding and improvement of zinc phosphate conversion coatings. Organic coatings have likewise been studied and improved. As a result of all this work, some very good systems are available that produce excellent tests on panels.

For the manufacturer to benefit from this work, it has to be transferred to the real world of an operating line. To properly make use of the quality processes available, the user must look at his system as a whole-from raw steel to finished product and each step in between. Like the proverbial chain, each link is very important. As we consider the conversion coating part of the system, we must not ignore the other segments of the system. If there is trouble, it may be caused elsewhere. In turn, the conversion coating part should not create problems. When considering conversion coatings, remember that solvent based finishes may cover some mistakes but water-borne coatings are very unforgiving. Where solvent coatings may cover minor amounts of oil or fingerprints, water-borne coatings can leave bare metal. Solvent systems may cover residues but water systems will not. Where solvent systems cover, water-borne systems pull back. In short, a marginal paint preparation line will not work with water based systems.

The usual response to all of this is to blame the pretreatment, to blame the "chemicals". But, these are the same ingredients that helped produce such wonder panels. Experienced supplier service personnel will tell you that time after time over 90% of the problem lies elsewhere. This is not a self-serving statement. The best steel, the best chemicals, the best finishes cannot overcome bad practice on the process line.

## PROCESS

A typical zinc phosphate coating system used to prepare sheet metal for an organic coating consists of several operations or stages. Each stage is separated from the next stage by an inactive area or vestibule. As the part moves along on the conveyor, it will be sprayed with solution for 60 to 120 seconds in each stage. The wet part then passes through the vestibule to the next stage. The stages in sequence are: clean, rinse, zinc phosphate, rinse, acidulated rinse. Some lines may have additional rinse stages. In particular, a deionized rinse is frequently used after the acidulated rinse prior to using a water-borne organic coating. After the pretreatment, the conveyor takes the part to a dry off oven. The part should now be ready for coating. In this process, each stage is important. To get satisfactory preparation, each stage must be working properly. This includes the vestibules and the dry off oven. When the pretreatment is no longer satisfactory, it is time to start looking.

## TROUBLE SHOOTING

All lines have trouble at some time. As an operator of a finishing line, you must be intimate with its innermost workings. So, when there is a problem, you, the operator, are in the best position to apply corrective action. Do not be too hasty in assigning fault. Like Sherlock Holmes, you must not only see but you must observe. Experience will show you that the true solution to a problem is often quite simple if you avoid panic long enough to truly observe. Unfortunately, action is often sought for the sake of action and you miss the time to observe. So, when the finished ware does not meet quality requirements, start observing and start asking questions. First of all, did the line ever really produce suitable quality? Many lines are used for years to produce marginal or poor work. If the problem seems more recent, was the change sudden or did the ware gradually lose quality. What is sometimes noticed suddenly may have been going on for some time. Only the awareness is sudden.

As you trouble shoot the line, start with basics. Here it pays to be a skeptic. Do not necessarily take anyone's word that something is so. Check and recheck. Above all, do not neglect the time honored check of temperature and chemical concentrations in the various stages. Has the line speed been changed? This could significantly shorten dwell time in the various stages. You will find that a significant number of problems are solved right at this point.

The next area of investigation involves the mechanical parts of your system. What is the general condition of your line? One of the most frequent mechanical problems is caused by the slow deterioration of spray nozzles and their pipes. Nozzles become worn, or more frequently, clogged. This is a problem that may not be readily apparent since the operating spray zone in a stage may seem to be full of sprayed material when viewed from an end. One clue to problems with nozzles is patterning on large sheet metal pieces. A more difficult clue involves racks of small parts where some are poorly coated. If they are all in the same area of the rack, this may indicate a few bad nozzles. The most difficult problem is a general deterioration of all nozzles resulting in general poor spray impingement on the parts. This may or may not show up as a slight change in pressure. But who remembers what the pressure should be? Here there is no substitute for the tedious examination of all spray nozzles as well as header lines. It is a difficult maintenance job at best. This is particularly so when a few hundred nozzles are involved. Yet this is an extremely important part of keeping up the performance of the washer.

Another problem, usually easy to detect, is work ruined by drippage. There is nothing more disheartening than a drip mark in the middle of a large, otherwise well prepared, piece of sheet metal. However, drippage may be intermittent and the source hard to detect. Here again, careful observation is important. Are the drip marks really the result of flash drying between stages? Is the drippage coming from above or is fluid from parts dripping on parts racked below? Is the drippage coming from the conveyor chain or the shroud? Is the chain well shielded? Are

misdirected spray nozzles hitting the chain? Sometimes drippage will come from poorly designed exhausts that allow condensation to run back into the equipment. There even have been cases where drippage has come from the outside through holes in the shroud. Is the drippage taking place in the dry off oven? Since the source of drips is so illusive and may occur in several unrelated areas, it is frequently necessary to make a number of corrections in a line.

Correcting this type of problem often ends up in upgrading the quality of the entire conversion coating system, including dry off ovens. Note that another drippage problem may also take place in the paint bake oven when water-borne coatings are used. The water removed from the coating condenses somewhere in the oven and then drips on the parts.

No solution to a conversion coating problem can be complete unless you examine your water supply. It is not only hardness that determines water quality. Total dissolved solids is an important factor. In addition to hardness, this includes chlorides and sulfates. If the total dissolved solids is high, even if hardness does not interfere with the cleaning and conversion coating, procorrosive salt deposits may be left on the work. The salts will be particularly concentrated where the water beads. The drippage discussed previously may also be rich in total solids so that it not only mars the surface but creates a procorrosive condition under the organic coating. Even deionized water can be a problem. If you treat your deionizer as a magic black box, it can cause trouble. When you exceed the capacity of the deionizer and forget to regenerate the unit, you will get total dissolved solids problems. In addition, you can get bacterial or algae problems which will mar the finished work. The deionizer, like any portion of your line, requires care and maintenance on a regular basis. If you take care of your equipment, it will take care of you.

SUMMARY

As you can see, there are many pitfalls in properly preparing work for painting on an industrial scale. However, since many plants do it every day, the task is not impossible. Modern processes do exist that are excellent preparations prior to painting. However, for consistent performance, they and the equipment used to apply them, require attention. It requires that maintenance be performed conscientiously on a regular, scheduled basis. Remember that the cost of doing this is far less than the cost of inferior work or the necessity of reworking or scrapping parts.

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For the manufacturer to benefit from this work, it has to be transferred to the real world of an operating line. To properly make use of the quality processes available, the user must look at his system as a whole-from raw steel to finished product and each step in between. Like the proverbial chain, each link is very important. As we consider the conversion coating part of the system, we must not ignore the other segments of the system. If there is trouble, it may be caused elsewhere. In turn, the conversion coating part should not create problems. When considering conversion coatings, remember that solvent based finishes may cover some mistakes but water-borne coatings are very unforgiving. Where solvent coatings may cover minor amounts of oil or fingerprints, water-borne coatings can leave bare metal. Solvent systems may cover residues but water systems will not. Where solvent systems cover, water-borne systems pull back. In short, a marginal paint preparation line will not work with water based systems.

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# Organic & Chemical Pretreatment Session G

## Ecological/Energy Impact on Phosphate Coatings

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# ECOLOGICAL/ENERGY IMPACT ON PHOSPHATE COATINGS

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The ecological trend involving the replacement of solvent paint systems with water-based paint systems has led to significant changes in the area of zinc phosphate treatments. The use of cathodic or anodic electrodeposited primers affects the zinc phosphate coating characteristics in a manner distinguishable from that of solvent primers. In particular, the phosphate coating characteristics given below are significantly affected by the water-base paint systems, and subsequently play a predominant role in providing adequate corrosion resistance and paint adhesion.

Solubility in Alkaline Environment
Solubility in Acid Environment
Coating Composition
Zinc Phosphate Crystal Structure
Coating Conductivity
Zinc Phosphate Crystal Size
Coverage

The introduction of cathodic electrodeposited primers provided substantial improvement in corrosion resistance over prior primer paint systems; however, new test procedures other than salt spray had to be developed in order to provide results that correlated to actual outdoor exposure testing. At the present time, several testing procedures exist that produce a "scab" type of corrosion in a scribed paint film, in contrast to the standard paint delamination or creepage that is observed after salt spray testing. As a result of the difficulty in assessing the quality of the phosphated coating under paint via cyclic scab testing procedures, it was decided to investigate the corrosion properties of a phosphate coating via electrochemical surface analysis in order to gain a better understanding of the mechanisms governing underfilm corrosion.

The use of electrochemical analysis of zinc phosphate coatings as a means to characterize the coating properties has been previously studied by several investigators.(1)-(4). Since the primary modes of corrosion are the anodic dissolution of the coating (or metal substrate) and the cathodic reduction of oxygen or water, our investigation of zinc phosphate coatings involved both anodic and cathodic polarization techniques; in contrast to prior studies where cathodic polarization was primarily studied. A schematic of our experimental apparatus is shown in Figure 1.(5). Our study involved variation of the potential between a Saturated Calomel Electrode (SCE) and the metal substrate, with concomitant measurement of the resultant current between the metal substrate and counter electrodes. Further, the change in the steady-state potential ($E_{SS}$) of the substrate, when immersed in a dilute solution of an electrolyte, also provided an insight into the corrosive nature of the phosphate coating.

The presence of a zinc phosphate coating, or modification of the phosphating process via final rinse variation, temperature, etc. may affect

both the anodic and cathodic corrosion modes simultaneously or independently. The phosphate coating, however, provided a reduction in the corrosion current in most cases, and thus reflected the "insulating" nature of zinc phosphate coatings. Figure 2 illustrates the results of our cathodic and anodic polarization of phosphated and non-phosphated steel and galvanized steel.(5) From Figure 2, one observes that the steady-state potential of the phosphated steel substrate has shifted to a more negative value, thus reflecting a more passive surface condition. Further, the corrosion current of the phosphated steel sample is less than that of non-phosphated steel. Summarizing, on steel substrates the phosphate coating will "dissolve" first during corrosion, thus providing cathodic protection to the steel substrate. The phosphate coating on galvanized steel provides additional resistance to corrosion, but with a different mechanism from that of steel. Again, the corrosion current on the galvanized steel is less with the phosphated coating; however, the resultant steady-state potential has shifted toward a more positive value. The shift of the steady-state potential in the positive direction implies that the phosphate coating has increased the corrosivity of the galvanized steel; however, the corrosion current of the phosphated galvanized steel has decreased. In summary, a phosphate coating on galvanized steel protects the galvanized substrate by inhibiting the dissolution of the galvanized substrate during corrosion, even though the phosphate coating does not provide cathodic protection to the galvanized steel substrate (i.e., dissolve first during the corrosion process). One may conclude that the phosphate coating acts as a physical barrier in its protection of the galvanized steel substrate.

The zinc phosphate treatment of aluminum is complicated by the existence of several aluminum alloys, each of which has specific characteristics that affect the zinc phosphate/aluminum interaction. Further, the electrochemical analysis of zinc phosphated aluminum substrates is also complicated by the rapid formation of the protective aluminum oxide film, whose solubility is pH dependent. Since cathodic polarization affects the pH of the electrolytic solution used in the electrochemical surface analysis, the analysis of the zinc phosphated aluminum substrate was performed at several pH values, as shown in Figure 3.(5) From Figure 3, one may note that the pH of the electrolytic solution substantially affects the anodic polarization behavior, and the corrosivity of the phosphated aluminum surface decreases as the pH of the electrolytic solution decreases. Therefore, one may conclude that the main factors contributing to the resultant corrosion reistance of a phosphated and painted aluminum substrate will depend upon the solubility (or stability) of the aluminum oxide film and/or the zinc phosphate coating at the pH which results from the corrosion process at the paint defect. Since the zinc phosphate coating solubility is also pH dependent, it cannot be stated precisely whether or not the phosphate coating provides anodic or cathodic protection to the aluminum substrate.

In the majority of cases where aluminum will be treated with a zinc phosphate coating, steel and galvanized steel are also being processed simultaneously. In the processing of these substrates, special attention must be directed at the cleaning of these substrates prior to phosphating. The cleaner must be sufficiently alkaline to remove the oils, smut, dirt,

etc, from the steel and galvanized steel substrates, without excessively attacking the aluminum substrate. Further, the phosphating bath would require the addition of fluoride compounds to prevent the build-up of soluble aluminum in the zinc phosphate bath, which would inhibit the coating formation on steel. The electrochemical analysis of the effect of fluoride concentration in a zinc phosphate bath upon the coating formation on an aluminum substrate is given in Table I. The current produced from both cathodic and anodic polarization of the phosphated aluminum substrate within 50 millivolts of the steady-state potential was measured and averaged. As one may note, as the fluoride concentration in the phosphating bath increased, the coating weights increased with a simultaneous decrease in the crystal size and polarization current.

A major ecological improvement associated with zinc phosphate processing would be the elimination of a chrome-based final rinse. The electrochemical behavior of an iron phosphated surface was found to be affected by the chemical nature of the final rinse. Further, through experimentation, it was discovered that certain final rinse solutions rendered the surface activity, as measured via the Polarization Current, comparable to that caused by a chrome-based final rinse. In continuing our experimentation, it was determined that the Polarization Current can be correlated to subsequent salt spray performance of the painted substrate (solvent type paint), as shown in Figure 4. In addition, the Polarization Current was also correlated to subsequent Cyclic Scab Test (see Appendix A) results using a paint system comprising a water-base cationic electrodeposited primer (Figure 5). Testing of the non-chrome final rinse solutions under production conditions is proceeding at this time.

As is well known, savings in energy costs can be obtained through the use of "low" temperature processes, where "low" temperature usually refers to processes that operate at temperatures below 110°F. Several "low" temperature iron phosphate processes are available in the Fabricated Metals Industry, where the requirement for paint adhesion may exceed that of corrosion resistance (e.g., office furniture). In those industries where optimum corrosion resistance of the painted substrate is mandatory (i.e., Automotive Industry), a zinc phosphate or calcium/zinc phosphate coating would be necessary to meet this demand. Although "low" temperature zinc phosphate solutions have been developed in the past, these systems were inadequate to provide the necessary corrosion resistance with the water-base electrodeposited primer paint systems that are being utilized today. Past "low" temperature zinc phosphate coatings usually contained manganese, produced heavy coating weights (i.e., 250-300 $mg/ft^2$) on low carbon steel, and exhibited a tendency to be "powdery". Further, processing difficulties were usually encountered, such as excessive sludge formation and erratic coating behavior. Through experimentation it was determined that the following parameters substantially affected the resultant quality of a "low" temperature zinc phosphate process:

- Cleaner Composition
- Crystal Refinement Stage
- Bath Composition
- Coating Composition
- Temperature Fluctuations

As a result of the decrease in operating temperature (from 125 to 95°F), the rate of acid attack at the metal surface is reduced, which in turn minimizes the resultant pH change at the metal surface/bath solution interface. Since the pH change at the interface is minimized, the deposition of the zinc phosphate coating is also reduced unless adjustments are made in the processing parameters. One primary adjustment in the processing parameters would be the incorporation of an "activating" rinse prior to phosphating. The presence of an "activated" metal surface via the use of Jernstedt salts provides compensation for the minimal acid attack at the metal surface. The activation of the metal surface may also be provided by the cleaner as long as the degreasing capability of the cleaner stage is not substantially reduced.

It was determined in our investigation that substantial modification of the constituents in the zinc phosphate bath was required in order to produce a zinc phosphate coating that provided the quality with cathodic electrodeposited paint systems that was comparable to the "iron-enriched" zinc phosphate coatings which are being employed in the Automotive Industry currently. Further, it was also determined in our investigation that the incorporation of manganese into the zinc phosphate bath was not required to provide adequate coating formation at 90 to 95°F or to improve the performance. The effect of bath acidity upon coating formation on steel is shown in Figure 6, where "R" refers to the ratio of Total Acidity to Free Acidity (see Appendix B). As one may note, as "R" increases, the rate of coating formation increases.

Finally, the characteristics of our low temperature zinc phosphate coating on galvanized steel was determined using Auger Depth Profile Analysis, as shown in Figure 7 (6). The coating studied in Figure 7 was applied to the galvanized steel surface via immersion. As one may note in Figure 7, a substantial amount of nickel was found throughout the coating, which we believe represents a major factor in providing optimum corrosion resistance and paint adhesion on galvanized steel. Additional surface analysis of our low temperature zinc phosphate coating on steel (spray application) has also shown the presence of nickel in significant amounts. In summary, the presence of nickel in a zinc phosphate coating plays an important role in providing the optimum adhesion and corrosion resistance of a painted and galvanized steel substrate.

In conclusion, the continuing ecological and energy restrictions in the coatings industry will significantly affect zinc phosphate coating technology. As quality requirements continue to increase, so does the need for a better understanding of the complete function that a zinc phosphate coating performs under paint in helping to prevent the loss of paint adhesion and subsequent corrosion of the base metal.

## APPENDIX A

## CYCLIC SCAB TEST PROCEDURE

a). 15 Minute Immersion - 5% NaCl

b). 1 Hour, 15 Minutes drain in Ambient Atmosphere

c). 22 Hours, 30 Minutes at 85% R.H., 120°F

(a) + (b) + (c): 1 Cycle
5 Cycles per week
Test Duration: 20 Cycles

## APPENDIX B

Total Acid Titration: Sample Size 10 milliliter

Sample titrated with 0.1 Normal NaOH to Phenolphthalein Endpoint

Free Acid Titration: Sample Size 10 milliliter

Sample titrated with 0.1 Normal to Brom Phenol Endpoint

TABLE I

FLUORIDE EFFECT ON ZINC PHOSPHATE COATINGS ON ALUMINUM

| Fluoride Concentration | Crystal Size (microns) | Ct.Wts(Avg) $mg/ft^2$ | Polarization Current* (microamps/$cm^2$ |
|---|---|---|---|
| 30-40 ppm | 50-60 | 40 | 24 |
| 150-200 ppm | 20-30 | 90 | 16 |
| Over 350 ppm | 5-10 | 180 | 4 |

*Measurements performed at a pH of 7.5

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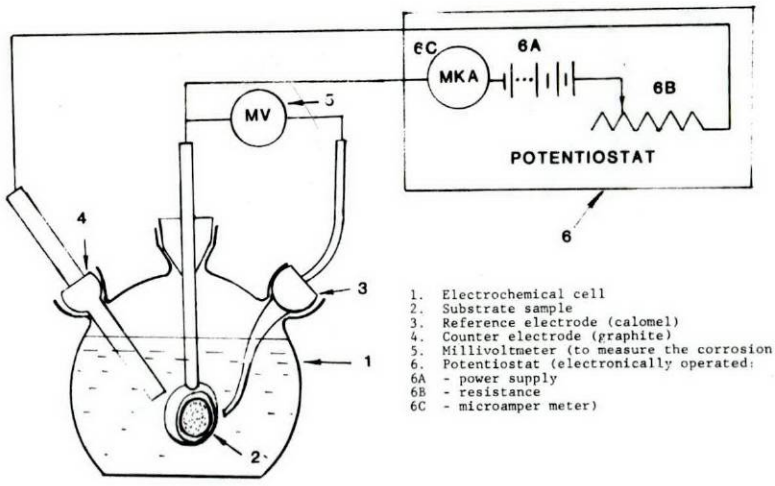
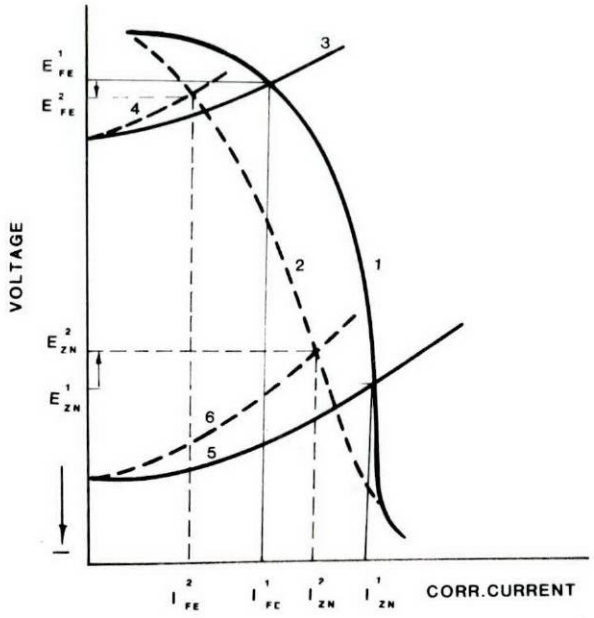
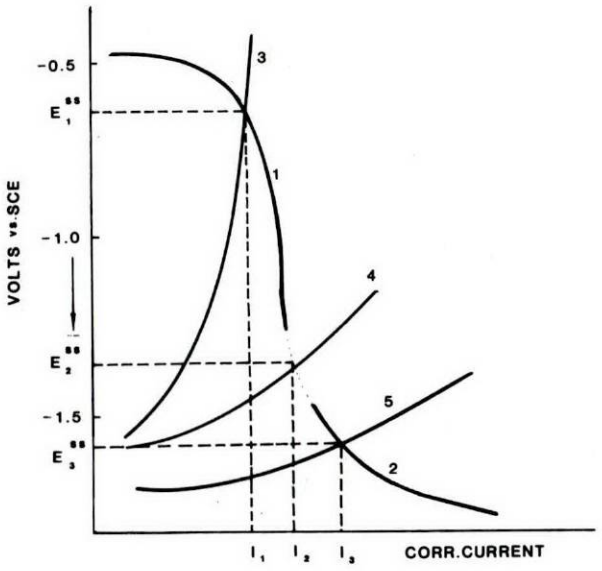



Figure 1. Electrochemical Measurement Apparatus.




1. Oxygen reduction on non-phosphated metal
2. Oxygen reduction on phosphated metal
3. Anodic dissolution of non-phosphated steel
4. Anodic dissolution of phosphated steel
5. Anodic dissolution of non-phosphated galvanized steel
6. Anodic dissolution of phosphated galvanized steel

Figure 2. Formation of Steady-State Potentials on Steel and Galvanized Steel Substrates.




1. Oxygen reduction
2. Hydrogen evolution
3. Dissolution of aluminum at pH from 3 to 5
4. Dissolution of aluminum at pH from 7 to 9
5. Dissolution of aluminum at pH = 10 and more.

Figure 3. Formation of Steady-State Potential on Aluminum.

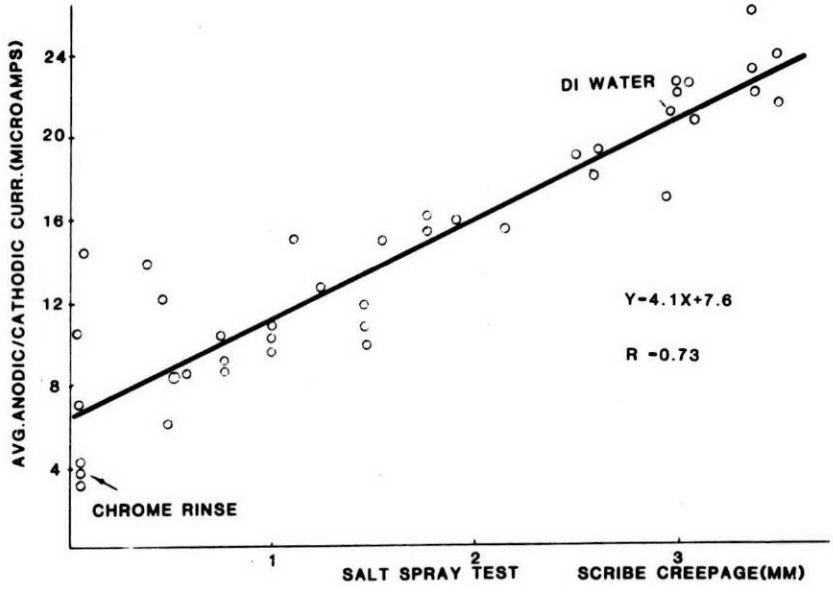



Figure 4. Linear Diagram of Potentiodynamic and Salt Spray Tests.

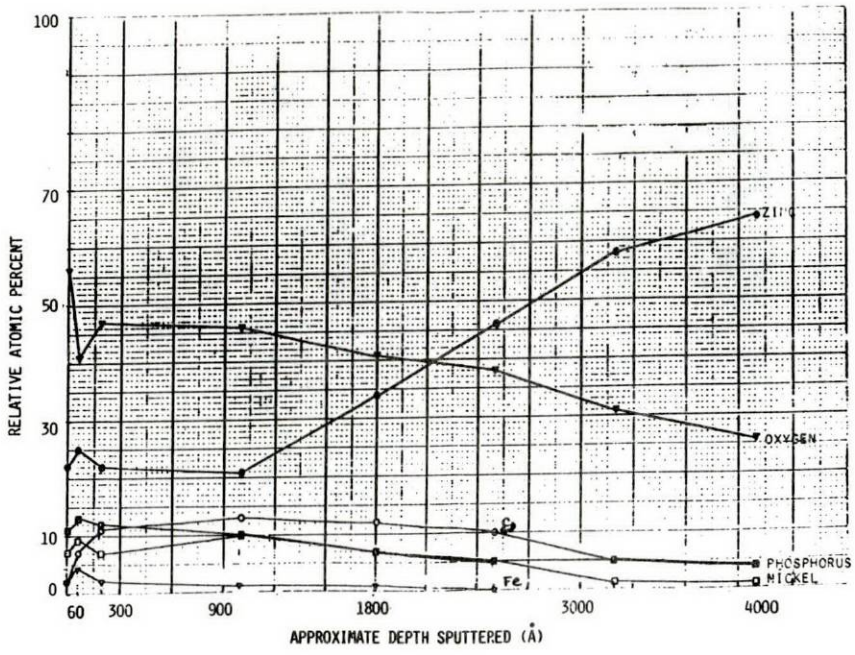



Figure 7. Auger Depth Profile of Phosphate Coating on Galvanized Steel.

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# Organic & Chemical Pretreatment Session G

## Compliance with Solvent Emission Regulations Without Change in Resins, Pigments or Basic Equipment

Dr. George E. F. Brewer
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## Compliance Solvents

A unique opportunity for complying with governmental paint-solvent emission regulations was introduced on July 8, 1977 through a U.S. Environmental Protection Agency notice in the Federal Register (2): "...volatile organic compounds of negligible photochemical resistance that should be exempt from regulation under State Implementation Plans...(are)... Methane, Ethane, 1,1,1-Trichloroethane, Freon 1,1,3..." This notice was later confirmed and reconfirmed 4 more times during the next three years (3) and expanded to include several more solvents, of which methylene chloride is of interest to the paint and finishing industries.

The exempt chlorinated hydrocarbons are now called Compliance Solvents. Their use has virtually changed the description of allowable paints from "not exceeding certain specified weights of VOC per volume of paint minus water" to "paint minus water or compliance solvents" (lb VOC/gal [VOC+NV]). Since 1979 the majority of states, including California, have exempted 1,1,1-trichloroethane and methylene chloride from emission restrictions.

## Compliance Paints

Compliance paints may be looked upon as High Solids paints thinned with 1,1,1- and/or methylene chloride to the low viscosity of conventional materials. Indeed, some paint manufacturers sell a paint concentrate, which the customer reduces with compliance solvents.

Another way to look at compliance paints is to state that they are conventional paints in which a certain amount of solvents (like xylene, VM&P, butanol, etc.) have been replaced by compliance solvents.

In either case, compliance paints are solvent borne materials of conventional viscosities, and can be formulated while retaining the resins and pigments currently used by a customer.

A rapidly increasing number of U.S. resin and paint manufacturers supply materials formulated by use of compliance solvents.

## Toxicity and Carcinogenity Tests

1,1,1-trichloroethane and methylene chloride have been subjected to many tests involving thousands of animals. Some of these tests have been reported in a U.S. Environmental Protection Agency Report (4, page 174); "...interim results of carcinogenic tests... of methylene chloride...were negative...", and (4, page 207); "...a National Cancer Institute bioassay of 1,1,1-trichloroethane found no correlation...(with)...any cancers..." Several studies gave 1,1,1- and methylene chloride a clean bill of health (see 5,6, and 7).

The Occupational Safety and Health Act (OSHA) allows equal or larger Time Weighted Average exposure of workers to 1,1,1- and methylene chloride ($CH_2Cl_2$) than for other commonly used solvents. The toxicity Threshold Limit Values for compliance solvents are higher or equal to most other

solvents, as shown in Table 1. Thus, the wastes and sludges of all currently used paints are considered toxic, and are subject to all applicable waste disposal regulations.

Table 1

OSHA EXPOSURE[a] and TOXICITY[b] STANDARDS

| SOLVENT | 3[h] TWA ppm | TLV ppm |
|---|---|---|
| 1,1,1- | 350 | 350 |
| $CH_2Cl_2$ | 500 | 200 |
| Toluene | 200 | 100 |
| MEK | 200 | 200 |

a Fed. Register 39-23540, 6-27-74
b Am. Conf. Gov'mt. Hygienists 1976

Archer and Stevens (8) conclude from these and many other data: "...although chlorinated solvents do not differ dramatically from hydrocarbons under OSHA regulations covering worker exposure, they offer safer working conditions when flamability hazards are of concern..."

## Availability

A number of U.S. manufacturers produce 1,1,1-trichloroethane and methylene chloride. Their combined production capacity is estimated as 1,250 million lbs 1,1,1- and 900 million lbs methylene chloride annually. The 1980 sales were estimated as 570, and 530 million lbs respectively.

In as much as the metal finishing industry is concerned, much of these two chlorocarbons are used for metal preparation, either directly or in combination with phosphates.

Methylene chloride is also used as a paint stripper.

These solvents are stabilized as needed for the above mentioned applications. However, to date, only the Dow Chemical Company has developed grades of 1,1,1-trichlorethane and methylene chloride specifically stabilized for coating purposes. It is a reasonable assumption that - if successful - plenty of motivation will be provided for the utilization of existing production capacity of other chlorcarbon manufacturers.

## Solvent Emission Regulations

One of the most environment-conscious states is California which exempts the use of 1,1,1- and methylene chloride from regulations. The current law, in form of Rule 1107 has been summarized as follows (9): "...beginning in January 1983 all users of coatings which are applied to miscellaneous metal parts and products, must limit the amount of VOC in the baking finishes they use (baked at temperatures in excess of 194°F) to 360 g/L as applied (3.0 lb/gal) paint minus water or compliance solvents. For air drying coatings, or coatings that are force dried at temperatures below 194°F, you will

be limited to 420 g VOC/L (3.5 lb/gal) of coating as applied. However, by January 1984, in the Los Angeles basin, you must reduce these Volatile Organic Compounds to 275 g/l (2.3 lb/gal) of baking enamel as applied, and to 340 g/L (2.8 lb/gal) for air dried paint as applied..."

The unit 340 g VOC per liter paint minus water or compliance solvent (2.8 lb/gal) does not lend itself directly to translation into lb VOC emitted while coating a given size of production. The unit most directly related to a metal finishing operation is "lb VOC per gallon of Non Volatiles." The conversion of lb VOC per gallon of paint minus water or compliance solvents to lb VOC/gal NV is facilitated by Equation 2 see Appendix or see (10, page 21) .

California Rule 1107 imposes not only 340 g VOC/liter (2.8 lbs) but also demands a transfer efficiency of 65%, in other words, electrostatically aided handspray. Equation 3 see Appendix or see (10, page 37) is helpful for the computation of the VOC emitted, as shown in Example A of Appendix. For instance, when 1604 $ft^2$ are painted 1 mil thick at 65% t.e. by use of a paint of 2.8 lb VOC/gal (VOC+NV), assuming $d_{VOC}$ as 7.0 lb/gal, 7.23 lb (3.28 kg) VOC are emitted. In other words, in California, according to Rule 1107, 7.23 lb VOC are allowed.

A paint of 2.8 lb VOC/gal (VOC+NV) contains approximately 60 vol%NV ($d_{VOC}$ = 7.0) according to Equation 1 and also according to Figures 1 and 2c.

If the transfer efficiency is increased to 95% by use of centrigugal electrostatic atomization, two important advantages are gained:

a) The cost of paint is reduced by about 1/3.
b) Since the allowable emission remains unchanged, paints of lower vol%NV can be used according to the Equivalence Concept (11). These, less concentrated paints, are easier to atomize.

Again, using the equations of the Appendix, the following data are obtained: At 95% transfer efficiency a paint of 3.5 lb VOC/gal (VOC+NV) and at 40% t.e. a paint of 2.0 lb VOC/gal (VOC+NV) are equivalent to the 2.8 lb VOC paint, in other words, in all 3 cases, not more than the allowable 7.2 lb VOC are emitted per gallon of NV applied. However, 95% transfer efficiency means automatic centrifugal electrostatic atomization, requiring considerable investment of capital. 40% t.e. requires an approximately 70 vol% NV paint, very difficult to handle with paint heaters and centrifugal guns. Yet, such a 70 vol% NV paint with proper composition of its 30 vol% VOC, can be reduced by use of 1,1,1-trichloroethane to any desired viscosity, to allow easy handling.

Of particular interest is reduction to a 30 vol% NV concentration dissolved in VOC plus 1,1,1-trichloroethane because such paints are of the viscosity for which conventional air atomizing guns are designed. Figure 3 shows that low viscosity compliance paints are available for any type of atomizing. equipment.

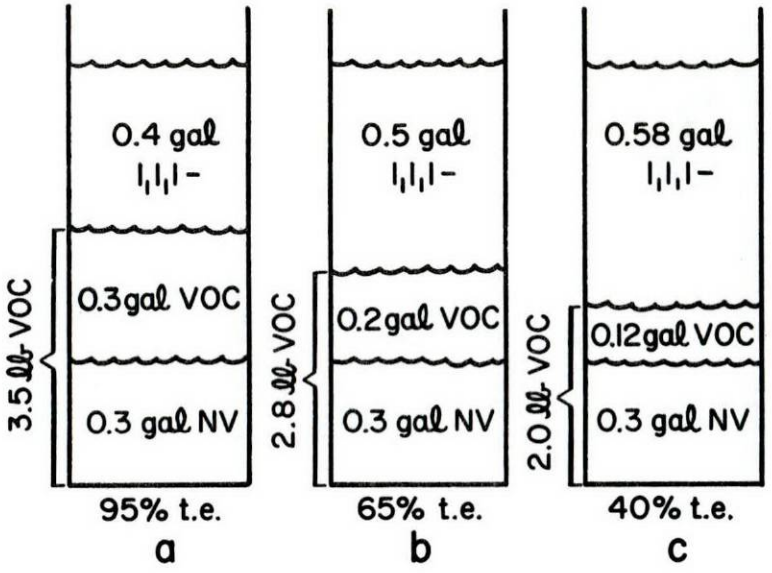


FIGURE 3

Equivalence Principle.
Adjustment of paint to conventional viscosity
and VOC Emission for various %t.e.

Continued Use of Existing Equipment

Governmental Regulations are concerned with the quantity of environmentally objectionable VOC associated with the volume of NV. Figure 1 shows the gradual increase of NV caused by stricter regulations. Hand in hand with increased NV goes higher and higher viscosity, demanding higher fluid pressures and heating devices. A break-through occurred when it was realized that paint viscosity can be lowered through the use of environmentally inoffensive diluents, called compliance solvents, such as 1,1,1-trichloroethane.

These paints can be formulated at, for instance, 30 vol%NV with varying quantities of VOC. At this constant volume of NV, their viscosity varies very little. The relative quantities of VOC and 1,1,1- can be changed, to comply with the individual requirements of the user.

Large companies may find cost advantages in investing in automatic booths, using centrifugal electrostatic atomization which results in up to 95% t.e. (Figure 3a)

Small companies, which currently use air atomizing hand guns, can continue to use these with minor changes in equipment, usually ranging from no cost

to several thousand dollars only. A paint which emits into the air not more than the allowable 7.2 lb VOC at 40% t.e. is schematically presented in Figure 3a. The viscosity of this and other compliance paints is approximately 60 centipoises (25 seconds #4 Ford cup or 27 seconds #2 Zahn cup), and there is little doubt that the large number of manufacturers who operate today by use of air atomized hand spray will welcome the opportunity to continue the use of this technique through incorporation of 1,1,1- into their paints.

Equipment Changes

Essentially one change has to be made for both air drying and baked compliance paints:

> The contact between paint and aluminum has to be avoided (12). This demand is not confined to appliance paints only. In fact a literature study revealed that the earliest notice about the danger of paint components in contact with aluminum appeared in 1934, when it was pointed out that alcohols react with aluminum under liberation of explosive hydrogen gas (13).

The other change applies only when direct fired ovens are currently used:

> The contact between compliance solvent vapor and direct flame has to be avoided to prevent the formation of hydrochloric acid vapors. The necessary change consists in using fresh air to supply the flame (9, page 6).

A good number of cases are on record where the necessary changes have been accomplished at expenditures of less than $5,000.

Revival of Air Drying Paints

Particularly in times of high cost and shortage of energy, air drying materials are of great interest. Also, the quality of air drying materials has improved over the years. Yet, ambient temperature of forced cure (up to 195°F) is not too widely used. The reason is that air drying materials have required large amounts of VOC. Most State Implementation Plans allow more VOC for air drying paints, usually between 3.5 and 4.5 lb VOC/gal (VOC+NV). Even this large allowance does not produce typical air drying lacquers of sufficiently low viscosity. The addition of 1,1,1-trichloroethane, however, results in easy to handle paints, in compliance with Solvent Emission Regulations.

These air drying compliance paints are now being re-accepted by industry and reports begin to appear in the literature (14).

Summary

1,1,1-trichloroethane and methylene chloride, sometimes called "Compliance Solvents", are exempt from Governmental Regulations in the majority of

states, including such key areas as California, Connecticut, Indiana, New York, Ohio, etc.

The definition of allowable paints can be understood as limiting the "lb Volatile Organic Compounds per gallon of paint minus water or Compliance Solvents." lb VOC/gal (VOC+NV) .

Compliance paints contain exempt chlorinated solvents, replacing part of their VOC, or may be looked upon as High Solids materials thinned with Compliance Solvents to conventional viscosity.

The use of Compliance Solvents brings the opportunity of retaining a currently used system of resin and pigments while accomplishing compliance with such strict emission regulations as California Rule 1107 for 1982 and 1984.

The changes in the formulation of compliance paints are restricted to changes in the solvent balance only.

The cost of converting from conventional paints to compliance paints is much less than the cost of converting to other allowable paints.

Air drying lacquers, complying with Emission Regulations, are beginning to be re-accepted by industry.

## Appendix

### Equation 1

Computation of vol%NV from lb VOC per gallon paint minus water.

$$\text{vol\%NV} = \left(1 - \frac{\text{lb VOC}}{d_{VOC}} \times 100\right)$$

where:

vol (VOC + NV) = 1 gal

$d_{VOC}$ = density in lb/gal

### Equation 2

Conversion from $\frac{\text{wt. VOC}}{\text{vol (VOC + NV)}}$ to $\frac{\text{wt. VOC}}{\text{vol NV}}$

$$\text{vol VOC} + \text{vol NV} = 1$$

$$\text{vol NV} = 1 - \text{vol VOC} = 1 - \frac{\text{wt. VOC}}{d_{VOC}}$$

$$\frac{\text{wt. VOC emitted}}{\text{gal NV applied}} = \text{wt VOC} \; / \; \left(1 - \frac{\text{wt VOC}}{d_{VOC}}\right)$$

Equation 3

Computation of wt. VOC emitted.

$$\text{wt VOC emitted} = \frac{100}{\%\text{t.e.}} \times \frac{Ap}{K} \times t \times \frac{\text{wt VOC}}{\text{gal NV}}$$

where:

%t.e. = % transfer efficiency

Ap = area painted ($ft^2$ or $m^2$)

t = film thickness (mil or $\mu$)

K = 1604 $ft^2$mil/gal or 1,000 $m^2\mu$/L

$\frac{\text{wt VOC}}{\text{gal NV}}$ = wt VOC associated with 1 gal NV

Example A

How many lb VOC are emitted when 1604 $ft^2$ are painted 1 mil thick by use of a paint of 2.8 lb VOC/gal (VOC+NV) at 65% t.e. as the California 1107 mandates? Assume $d_{VOC}$ = 7.0 lb/gal.

Equation 2:

$$\frac{\text{lb VOC emitted}}{\text{gal NV applied}} = 2.8/\left(1 - \frac{2.8}{7.0}\right) = 4.67$$

Equation 3:

$$\text{lb VOC emitted} = \frac{100}{65\%} \times \frac{1604\ ft^2}{1604\ ft^2\ \text{mil/gal}} \times 1\ \text{mil} \times 4.67\ \frac{\text{lb VOC}}{\text{gal NV}} =$$

$$= 7.2\ \text{lb VOC emitted} = 3.3\text{kg}$$

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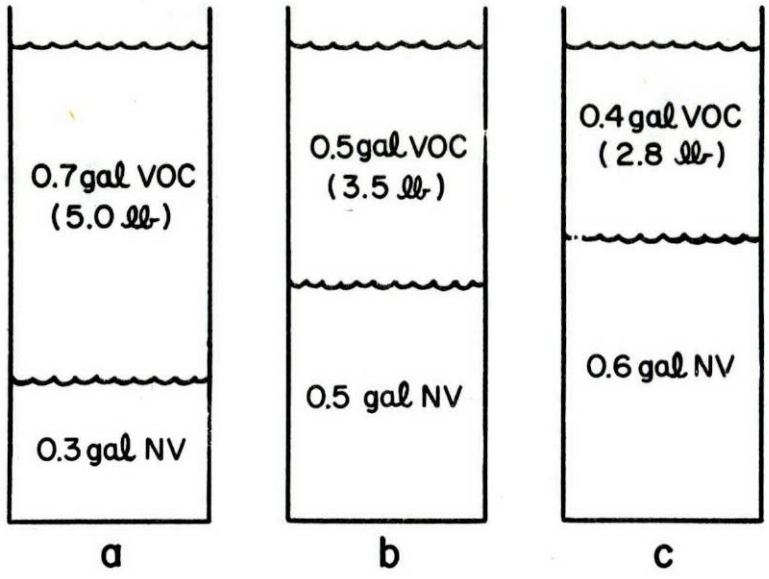


FIGURE 2

Volume fraction of VOC
and
lb VOC/gal(VOC+NV)

Most State Implementation Plans mandate the use of paints of not more than 2.8 lb VOC and up to 3.5 lb VOC for General Metal Finishing, in other words, approximately 45 to 60 vol%NV (see Figure 2b). Paints of these solid contents are of higher viscosity than conventional materials, which, in many cases necessitates considerable capital expenditure for new spray painting equipment.

Conventional hand spray guns result in very low transfer efficiency, probably not higher than 30% for general merchandise and not more than 40% for such large objects as automobile and truck bodies (1).

Many State Implementation Plans require transfer efficiencies of 50% t.e., and some states require 65% t.e., which, for these high viscosity paints, can be achieved only by use of electrostatic centrifugal atomization.

The large expenditures for new equipment can in many cases be avoided by the use of a recently developed class of paint solvents, which has lifted conventional handspray equipment from obsolescence into renewed interest.

# G-4

# Organic & Chemical Pretreatment Session G

## Considerations When Converting to Water-Borne Coatings for Dip, Flowcoat and Spray Application

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# CONSIDERATIONS WHEN CONVERTING TO WATER-BORNE COATINGS FOR DIP, FLOWCOAT, AND SPRAY APPLICATION

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## Abstract

The strengths and weaknesses of water-borne coatings will be compared to solvent base coatings for application and physical properties.

Recommendations will be presented on how to initiate an efficient water-borne trial run program and to economically convert an existing solvent system to a water-borne system.

## Introduction

Some of you are familiar with water-borne coatings, either having tried to introduce them into your production and were not successful, then reverted back to a solvent system or have been able to adapt a water-borne system to your application line and are now enjoying the benefits.

Problem areas encountered when converting to a water-borne coating may have always been present but the solvent coatings were just more tolerent of these conditions.

Water-borne coatings are replacing solvent coatings which have been in use for many years and have been modified through those years to obtain the accepted application properties and appearance.

## Physical and Application Properties of Water-Borne Coatings

Water-borne coatings are more susceptible to contamination and have poorer surface wetting properties than solvent coatings. The presence of oil, dirt or grease on poorly cleaned parts may result in cratering and crawling. Even though the water-borne coating may coat over a contaminated surface and have an acceptable appearance, a loss of adhesion may be seen. Good maintenance of the pretreatment is required to minimize or eliminate this problem.

Water systems are also prone toward pull-away from sharp edges and wash out under holes. This can be eliminated again by good maintenance of the pretreat, mechanically by exhaust in the flash off area and the formulation using additives. The most troublesome of water-borne properties is that of popping and blistering at higher film thicknesses. The use of high boiling

solvents, two zone ovens, and preheating the coated parts are several ways of eliminating the popping and blistering. Viscosity control is more critical since higher viscosities yield higher film thickness which lead back to the blistering and popping problem.

Water-borne coatings are more prone to bubbling and foaming than solvent systems, but with proper formulation, the bubbling and foaming can virtually be eliminated and not cause any application problems.

Water based coatings are more sensitive to temperature and humidity than solvent coatings but this can be controlled by viscosity adjustment, small amounts of co-solvent, in-line heaters and chillers and adequate exhausing of the application area. Even though the application and physical properties of water-borne coatings are more sensitive than solvent coatings, they can be no cause for concern if handled properly.

Now that the weaknesses of water-borne coatings have been brought to your attention, we can discuss the numerous strengths of water-based coatings when compared to solvent coatings.

After the conversion from solvent to water has been made, many installations have experienced improved mileage and lower application costs. Since the coating is water soluble, it is possible to eliminate the dry off oven for dip and flow coat applications and, in some instances, spray.

Systems to recover the paint in the dip and flow coat vapor tunnels have become common place. This material is used as a reducer, further lowering the application cost of water-borne systems. It is also possible to formulate lower cure coatings for customers and decreasing oven temperatures by as much as 75 degrees. Where the same color is being applied by spray and dip or flow coat, it is feasible to use the same material, thereby reducing material inventory.

The water-borne coatings can also be formulated to a low solvent level and to a high flash point to meet various EPA and fire regulations.

## Application of Water-Borne Coatings

When a dip coating is compared to flow coat, there are strengths and weaknesses to be considered for both types of application. Dip coatings will tend to have less film variance on a part than will flow coat. There are less rejects with dip than flow coat which are caused by plugged or misdirected nozzles. Color change, where required, is easier and less expensive with a dip system. Several tanks on rails can be

rolled into place beneath the conveyor, but to change colors for flow coat requires pumping out of the material and flushing before the new color can be introduced to the system. Water-borne coatings are prone to bubbling and foaming in flow coat applications and at times it can be very difficult to control. The dip tank, on the other hand, has less agitation and consequently less bubbling. Dip tanks require a larger volume of paint than flow coaters which makes for a longer time to turn the material over. This requires a closer monitoring of the paint for amine and co-solvent.

As previously mentioned, water-borne coatings are more susceptible to contamination, and there is the possibility of dumping a dip tank if the cause cannot be found and corrected. On the other hand, if the flow coater were to become contaminated, the tank could be recharged with a minimum of production time and at less cost.

Water-borne coatings are being applied successfully by air and airless guns with and without electrostatic and by all types of high speed rotational electrostatic equipment. There are installations using the lower speed 3600 RPM disc with satisfactory results.

When compared to solvent coatings, water-borne coatings applied by electrostatic spray have given improved wrap and penetration. With some lines, this has eliminated the need for touch-up or reinforce. Better atomization, due in part to the high speed rotational electrostatic equipment, yields improved hiding at a lower film thickness.

The prime disadvantage of applying water-borne in various installations is the requirement of making application equipment changes and the isolation of the electrostatic applicators. Color change may pose a problem for high volume lines where limited floor space and color change time are factors. It is more difficult to obtain high film builds with water-borne coatings as they are more susceptible to humidity and temperature changes. This condition can be controlled by varying the RPM's of the rotational applicator, gun air pressures, voltage, and distances to the ware. As with dip and flow coat systems the application properties of spray coatings can be controlled by small amounts of co-solvent, viscosity adjustments, paint temperature, and ambient temperature and humidity control.

## Planning a Water-Borne Program

Once it is been decided that a water-borne program is to be initiated, the initial preparations are for a trial run. First contact your pretreat and paint suppliers so that the specifications can be reviewed and paint samples requested.

When the water-borne paint has been approved to your paint specifications, the next step is to have the supplier make a line survey. After the line survey is completed, the supplier should submit his recommendations and modifications necessary for his product to be successfully applied. Usually, the addition or changes needed for a trial run involve a minimum of expense. Dip tanks and flow coaters will require little, if any, modifications. One or more air mixers may be needed for agitation as water-borne coatings are more prone to settling. The addition of in-line filters is recommended since the changing from solvent to water and back to solvent will generate some dirt. The water-borne coating will loosen the solvent coating no matter how much scraping and flushing is done. Spray systems will require some sort of isolations and possibly a change in application equipment.

The paint supplier should also furnish a procedure for clean-up. This would include the steps necessary to prepare the dip, a flow coater, or spray system for loading with the water coating and also the steps for converting the system back to solvent after the trial is over.

The length of trial will be dependent on the time allocated, type of application, and the objectives of the trial. Spray trial runs offer the most flexibility and can be as short as a five hook run and are easily taken in and out of the system. Flow coat trials are more time consuming as they involve more clean-up before and after the trial. These are normally started and terminated on a weekend. Dip tanks with their larger volume of paint are normally loaded on weekends and if acceptable will continue to run.

After the short trials, the extended run of 15 to 30 days is usually undertaken. This allows for an observation of paint stability, mileage, and application with temperature and humidity changes.

## Conversion from Solvent to Water-Borne

After having made several trial runs there will be an indication of what modifications will be needed to convert the solvent system to a water-borne system.

Dip tanks need few, if any, modifications for use with water-borne coatings.A weir and headers may be the only additions. As previously mentioned, air mixers and in-line filters are recommended as is DI water for reducing the coatings. Hangers may need to be redesigned to change the flow pattern if blistering and popping were a problem that could not be resolved.

During the initial flow coat trial runs, it may become evident

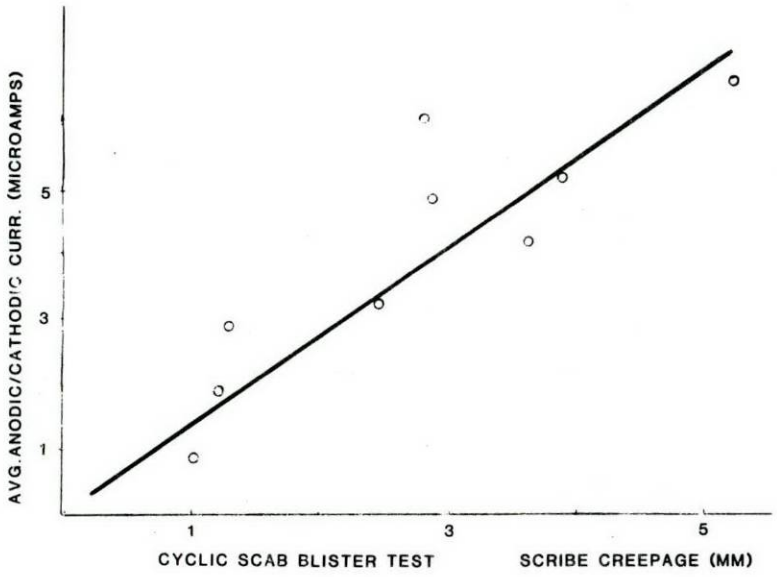


Figure 5. Linear Diagram of Potentiodynamic and Cyclic Scab Blister Test.

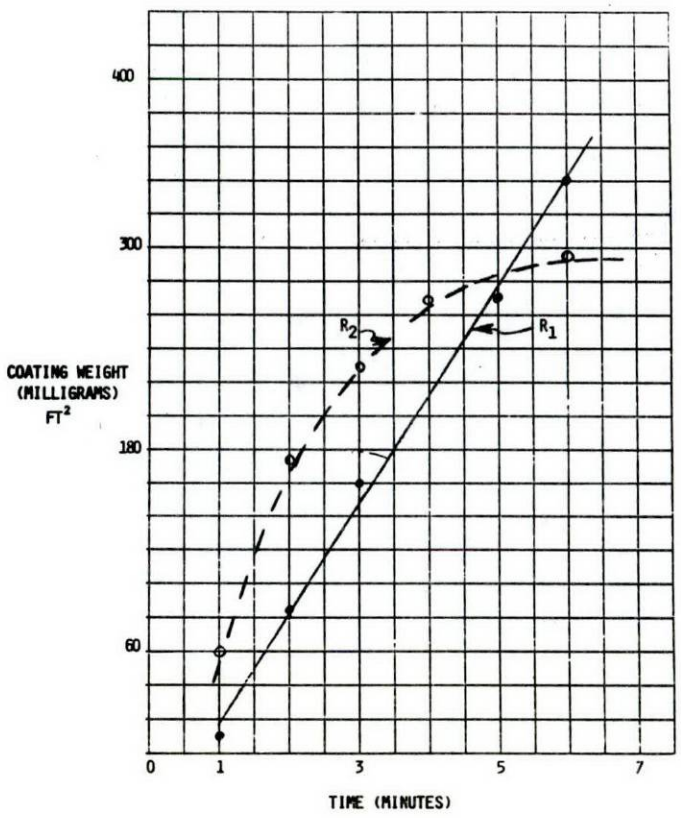


Figure 6. Bath Acidity Effect Upon Coating Formation at 93°F.

that the coverage and penetration are not satisfactory. Flow coaters normally require more risers and the addition of nozzles if only copper tubing is being used since water-borne coatings are generally applied at higher viscosities and have less tendency to break up and provide good coverage. If a large number of risers and nozzles are added, then it may be necessary to obtain a larger pump. The vapor tunnel may require modification to control the temperature and humidity. As mentioned for dip tanks, a hanger redesign may be required to eliminate heavy film build areas. Electrostatic Spray application of water-borne coatings require the isolation of the paint supply and the supply lines to the applicator.

If disc application is being used, it may require a hanger redesign of change in the loop to meet the distance to ware requirements when changing from a large diameter, lower-speed disc, to a smaller diameter, high-speed disc.

## Conclusion

Because of the different parameters involved, i.e., type ovens, line speed, flash time, hanger design, type product, and product specifications, nearly every customer has a water-borne coating tailor made to his requirements.

One may observe a water-borne line in operation to obtain an idea of the application properties but the only positive way to determine if a water-borne system will meet your requirements is to have an extended trial run on the production line.

G-5

# Organic & Chemical Pretreatment Session G

## An Evaluation of Autodeposition

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# AN EVALUATION OF AUTODEPOSITION

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## Abstract

The results of an investigation of autodeposition as a corrosion protective coating are presented. The chemistry and interesting features of the process, along with particulars of its stages, are covered. Autodeposition is evaluated against criteria desirable for a coating and an application process. Then, the results of a process parameter investigation through specific case salt spray testing are summarized.

## Introduction

Autodeposition was investigated as a means of improving the corrosion protection for certain sheet metal parts. Based on the conclusions of this investigation, it was recommended that an autodeposition paint system be installed to coat these parts.

The decision to thoroughly study autodeposition was made following very good salt spray results and the realization that this type of system could be less expensive than the previously considered cathodic electrodeposition system. Input from a company which has operated an autodeposition paint system since 1976 increased interest in this type of coating system. It was learned that relatively little test data was available for this coating, thus an extensive evaluation and test program, including a process parameter investigation for the less costly and less known autodeposition system was planned.

## Description of Autodeposition

This waterborne process, which depends on chemical reactions to achieve coating deposition, has been in commercial use since 1973. Since that time approximately one billion square feet of surface area have been treated. There are two installations in the United States at which sheet metal headlamp housings and car frames are coated.

The autodeposition coating bath consists of a latex emulsion resin, hydrofluoric acid, hydrogen peroxide (oxidizing agent), and deionized water. Theoretically, the percent solids in the bath may vary widely, but for commercial applications it generally ranges from 5 to 12 percent. The bath viscosity is close to that of water. No organic solvents are present in the

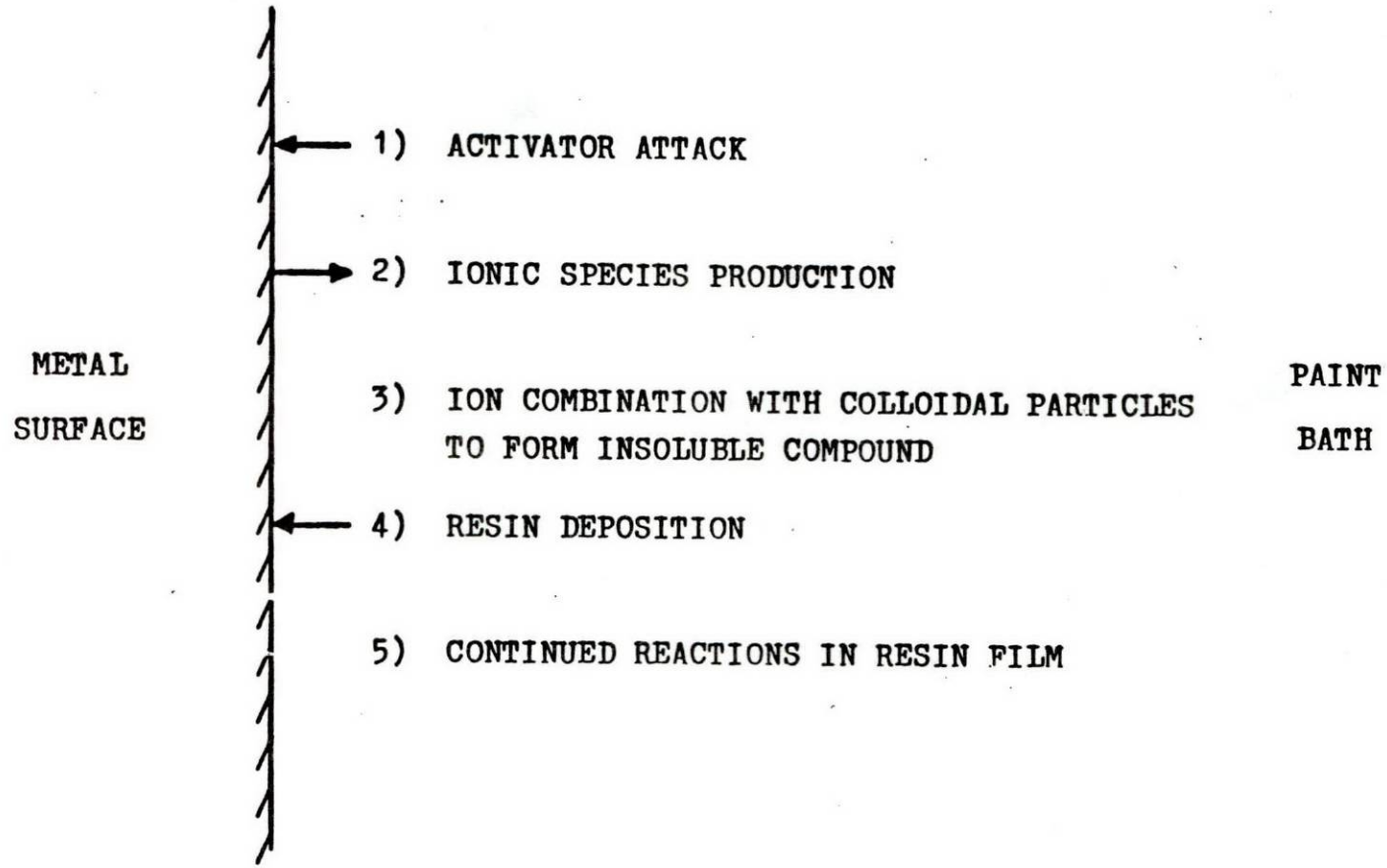
coating bath; however, in certain systems a small amount of low vapor pressure coalescent may be present. Another feature of the bath is its acidic nature; the pH is typically between 2.6 and 3.5.

The chemical reactions in the coating which effect deposition proceed by the mechanism shown in figure 1. Proton attack etches the steel surface and metallic iron is oxidized to the ferrous ion ($Fe^{+2}$). Hydrogen peroxide oxidizes the ferrous ion, producing the ferric ion ($Fe^{+3}$). The ferric ion acts as a destabilizing agent for the colloidal latex particles in the bath, causing their deposition onto the metal surface. The newly deposited coating is adherent yet porous, and so chemical activators can rapidly permeate it to reach the surface of the metal.

The thickness of the autodeposition film is time rate dependent. The coating continues to grow as long as ionic species are produced at the coating metal interface. As shown in figure 2, the rate of film growth is initially very rapid, but the deposition rate slows as deposited particles begin to interfere with the diffusion of the activators to the metal surface. The film thickness will continue to grow as long as a part is in the coating bath, although after long immersion this growth becomes negligible. Different patterns of growth result from such factors as the particular latex involved and the resin solids content.

Another interesting feature of autodeposition is the uniform thickness of the deposited coating, even on commercial metal surfaces with varying degrees of chemical activity. In an autodeposition bath, local anodes (sites of high chemical activity found at sheared edges, cut threads, deformed areas, etc.) are coated first since this is where ionic species are generated most rapidly. Once these active sites are coated, the local cell polarity is reversed, and they become cathodic in relation to the surrounding uncoated areas. The polarity continues to reverse during coating and the result is further deposition where the coating is thinnest, since this is where activator diffusion occurs most readily. Thus, for autodeposition the film build is continuously balanced and consequently the deposited coating has uniform thickness.

The coating deposited by autodeposition displays an unusual characteristic for a latex paint. Coated parts can be water rinsed shortly after removal from the paint bath with very little material loss. On leaving the paint bath, the coating consists of two layers. One of these is a very cohesive, reacted layer, while the other is composed of undeposited excess colloid and activator from the paint bath. The chemicals in this second layer continue to react, which results in deposition of the drag-out resin and increased film thickness. Figure 3 indicates that resin lost in the water rinse following coating

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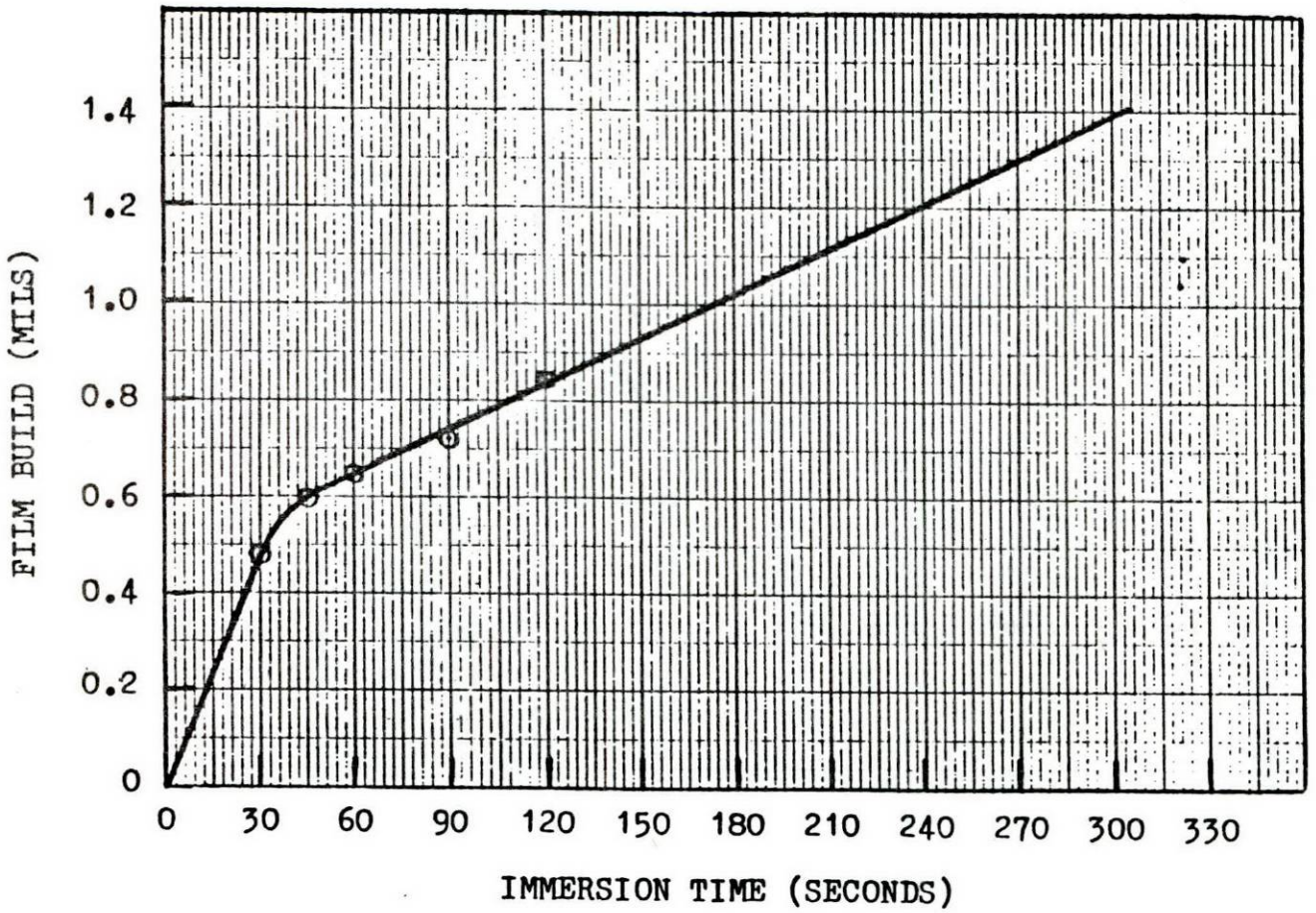
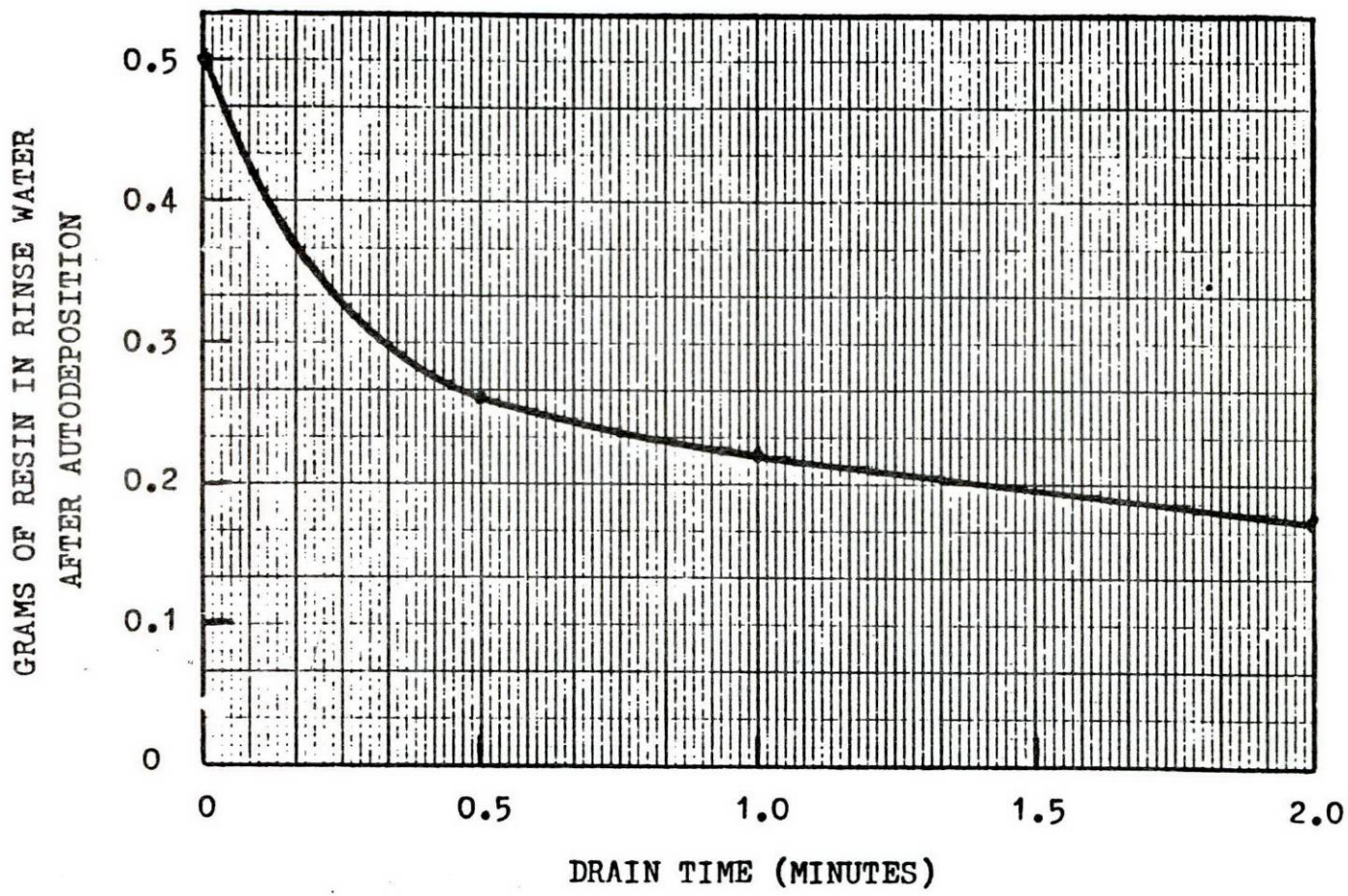
PROPOSED REACTIONS AT METAL SURFACE
AND PAINT BATH INTERFACE

FIGURE 1




FILM BUILD WITH TIME FOR AUTODEPOSITION COATING (6% SOLIDS)

FIGURE 2

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RESIN LOSS WITH DRAIN TIME

FIGURE 3

decreases with the exposure to air time prior to rinsing. This feature of autodeposition minimizes the loss of resin due to drag-out and results in both a favorable coating efficiency and low demand on a waste treatment facility.

A final characteristic of autodeposition, one of the most important, is that it does not require a separate metal conversion coating, such as a phosphate. This is possible since the adhesion of the deposited coating is extremely good due to strong interactions between the metal and the organic film. This elimination of a phosphate stage leads to savings in floor space and operating costs.

An autodeposition system consists of the following major stages: 1) Clean, 2) Rinse, 3) Coat, 4) Rinse, 5) Chrome Rinse and 6) Cure. Descriptions of each of these stages provide a better understanding of the process and its requirements.

A cleaning stage is typical of all metal finishing processes. Oils and shop dirt must be removed from parts prior to coating. This is especially true for autodeposition, because any contamination may inhibit activator diffusion and prevent deposition. Also, this system contains no organic solvents to help dissolve oils. Therefore, it is recommended that both spray and dip cleaner stages be employed to insure the thorough cleaning necessary for good coating adhesion. Impingement of the spray cleaner dislodges the majority of the soil, while the more concentrated dip cleaner removes any soil which may remain, particularly in recessed areas.

The cleaning stage is followed by multiple rinses to prevent alkali contamination of the coating bath. The conductivity of the drippings from the parts should be reduced to well below values attainable with plant water. Thus, a short deionized water rinse is required just prior to the coating bath to prevent build-up of ionic contaminants.

The coating stage is next. The chemical makeup of this bath has already been covered, but other aspects of the stage are worth mentioning. First, the temperature of the bath should be maintained at a relatively constant 20°C (68°F). This requires a heat exchanger, even though the autodeposition reaction is not exothermic. Control of the bath temperature aids in determining the etch rate of the ionic species, which in turn affects the deposition rate. Maintaining the bath at the specified temperature helps stabilize film build and insures high quality. Secondly, the coating bath requires agitation to hold the resin and pigment in suspension. To accomplish this, variable speed mixers with propellers are mounted along the sides of the coating tank. The paint tank should be sized for an average material turnover rate of approximately once per month. Another

suggestion is that a sludge removal system be employed to prevent buildup. Figure 4 shows one possible system, along with other coating tank features. This system incorporates a lance for cleaning the bottom of the tank, a weir in which to accumulate sludge, and a tank bottom that slopes to a collection trough. Sludge is pumped from this trough and the bottom of the weir to drums for disposal. The tanks should also be dragged occasionally to remove fallen parts.

An immersion tap water rinse follows the coating stage. A dip rinse is preferred since the freshly deposited film is fairly soft (about 30 to 40 percent solids) and could be damaged by spray impingement. Unreacted paint bath material on the parts and racks is removed in the rinse. This minimizes resin contamination of the next stage, the acidic chrome rinse, and in turn reduces replenishment and treatment costs. Removal of the unreacted material from the parts also decreases the possibility of streaks or other patterns which may appear if this material is allowed to dry.

The last stage before curing is an acidic chrome rinse. This proprietary solution containing hexavalent chromium serves basically as an inhibitor. It is baked into the resin film and improves both coating adhesion and corrosion resistance.

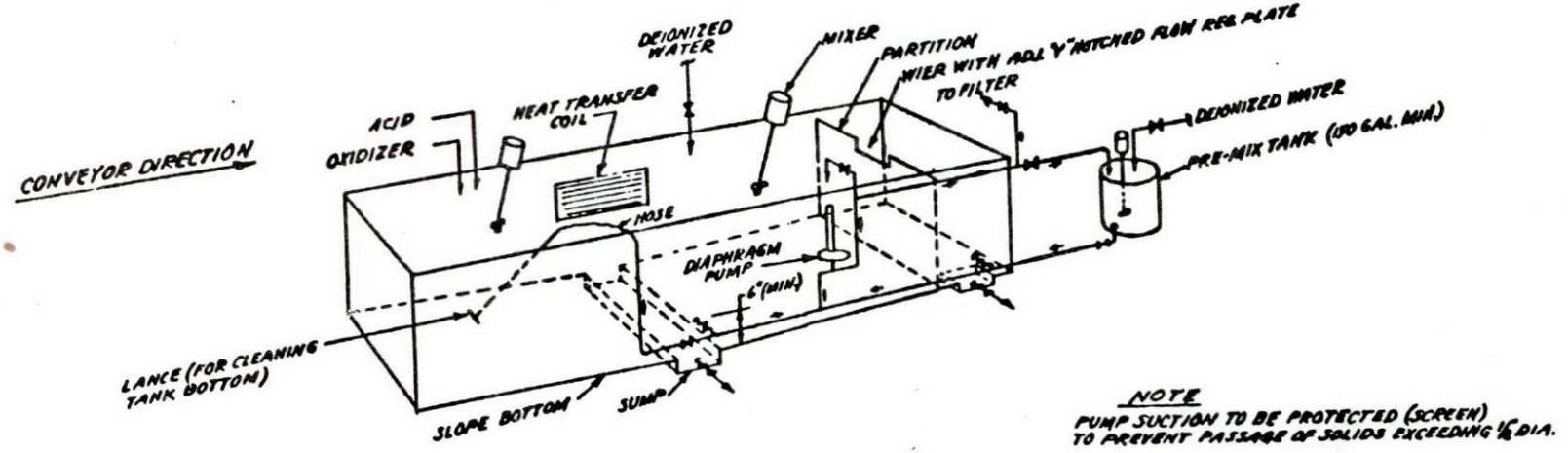
The coating is cured in a two zone oven. Parts are in the first zone 10 to 15 minutes at 110° - 120°C (230° - 248°F) to evaporate water from the wet coating. Full curing occurs during the 10 to 20 minutes the parts are in the second zone, which is held at about 140° - 180°C (284° - 356°F). The objective is to reach a peak metal temperature of approximately 174°C for about eight minutes to obtain optimum cure. The exact cure cycle depends on the part geometry and on the desired corrosion resistance.

## Evaluation of Autodeposition

In an attempt to determine the production reliability of autodeposition, a company which has operated this type of paint system for over five years was contacted regarding their experience. Below is a short description of that system and a summary of their response.

The system applies a 0.7 - 0.9 mil coating to sheet metal housings using three parallel monorail conveyor systems. The parts average 0.86 square feet in surface area. The line runs two shifts per day, five days a week. It is capable of coating approximately 12,000 parts per hour.

There has been almost no system downtime due to the autodeposition process itself. Normally, process problems due to




Provided by Amchem Products, Inc.

SCHEMATIC OF AN AUTODEPOSITION COATING TANK

FIGURE 4

deviation from the established paint bath conditions have had the effect of reducing the appearance quality, usually by streaks or reduced coating gloss, but very rarely have they resulted in unacceptable corrosion resistance. A small number of racks are stripped each month, resulting in each rack being stripped on the average of once every three years. Although it is recommended that the coating tank be drained and cleaned, and about one third of the bath be replenished each year, the system was once operated for almost two years before the maintenance procedure was required. The quality of the coating did not drop until the end of the two year period. The experience with this autodeposition system was described as a good one. This information led to the conclusion that the autodeposition process is sound and dependable.

The criteria for a corrosion protective coating and its application process against which autodeposition was evaluated were: basic test requirements for an underhood class finish, product requirements and production requirements. The performance of the coating is reported in the form of brief test results.

Coated parts were evaluated by conducting the following tests:

1) Tape adhesion test
2) Humidity test and tape adhesion test
3) Neutral salt spray test
4) Chip resistance (gravelometer) test

The coating easily passed both tape adhesion tests with no peel back occurring in either case. It received a rating of very good to excellent for the salt spray test, with less than one percent red rust. Chip resistance test specimens were given a 5B rating and so the coating handily passed this test also.

Coated parts were installed on vehicles for durability tests in which they received two years of simulated corrosion. The coating was in very good condition on all parts tested with no significant red rust. The requirement for this test was that the coated parts receive a rating of eight or better on a corrosion rating from scale of zero to ten where ten signifies no red rust. The coating easily met this requirement since the returned parts were assigned a rating of nine.

The coating was further evaluated in the following product requirement areas:

1) Coating thickness
2) Brittleness
3) Bend effect

4) Brake fluid resistance

5) Gasoline resistance

6) Corrosion resistance

7) Corrosion creepback

The coating thickness was specified to be no less than 0.3 mil. Numerous thickness checks on well over 100 parts coated to a nominal film build of 0.7 to 0.8 mil revealed that the coating thickness never dropped below 0.5 mil. For the brittleness test, a furrow was scribed to the base metal on a coated part using a dime. The coating met the requirement that it not flake beyond the width of the furrow. Sample coupons coated by autodeposition were subjected to the bend test over a 0.25 inch mandrel. Results of the test were excellent at the required bend angle of 5°, and so the bend angle was gradually increased up to 350°. Results were excellent even at this angle, with no noticeable changes in the coating. A piece of a coated part was immersed in brake fluid and another in unleaded gasoline at room temperature for 30 minutes. In both cases no rub-off of paint onto a soft cloth occurred. Thus, the coating passed both solvent resistance tests. Furthermore the tested parts were required to show no more than five percent red rust after a 96 hour salt spray test. In anticipation of an increase in the salt spray exposure time, coated parts were also tested to 168 and 240 hours; results showed 1 to 2 percent and 1 to 3 percent red rust, respectively. This data indicated that the autodeposition coating could meet the 96 hour test, and it would continue to meet corrosion resistance requirements if the salt spray exposure time were increased to 240 hours. Coated parts were also vertically scribed, subjected to salt spray for 240 hours (96 hours required) and then immediately blown dry. The failure distance, measured from the scribe line was not to exceed 3.0 millimeters. It ranged from 0 to 0.5 millimeters.

The coating satisfactorily met these four remaining product requirements:

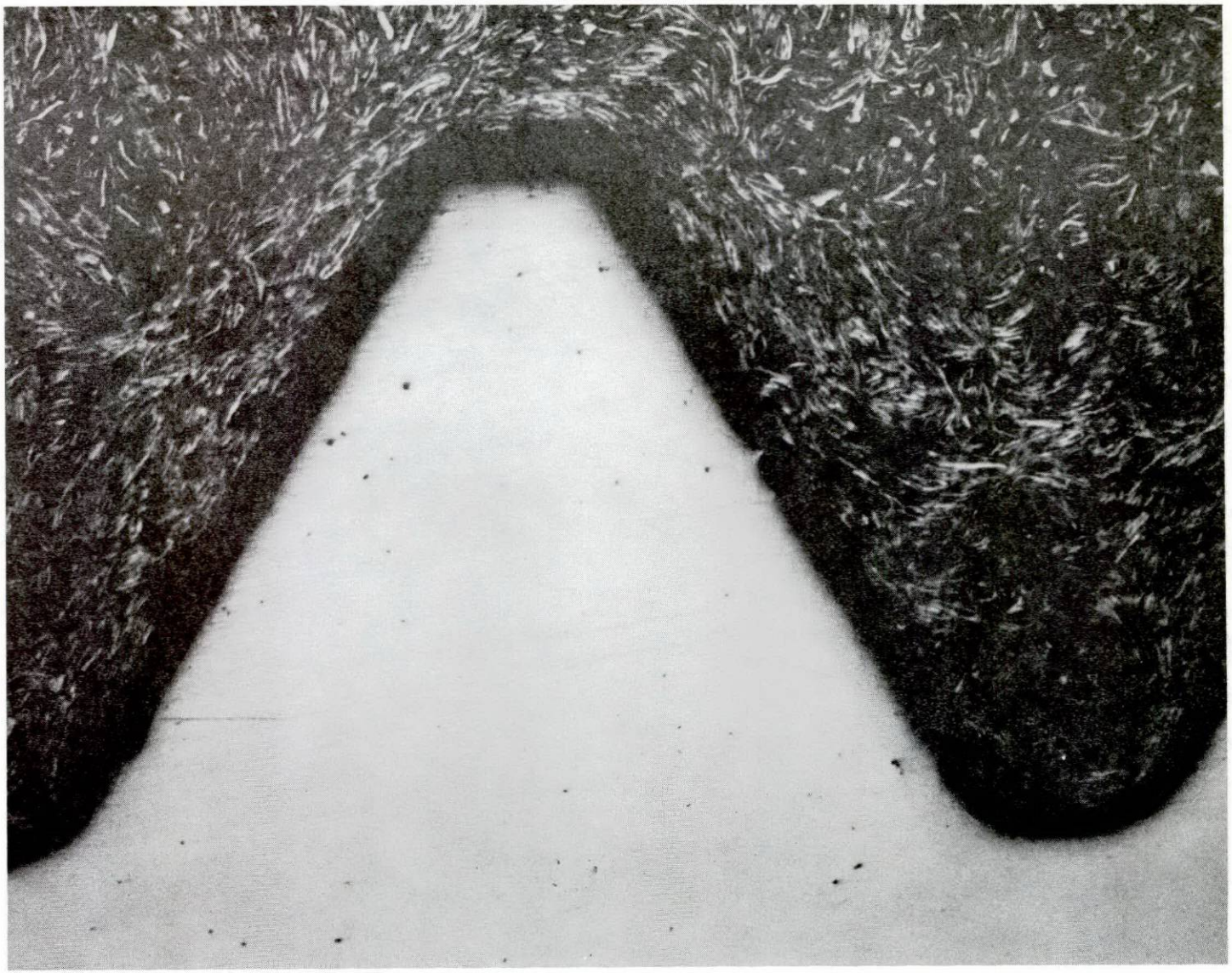
1) Good appearance

2) Uniform and proper film thickness

3) Scratch resistance

4) Coating of entire part

The appearance of autodeposition coated parts conveyed the desired high quality image. Numerous coating thickness checks indicated good uniformity. This is shown in figure 5, which is a cross section of a coated, threaded part. The coating also appeared to be scratch resistant enough to be acceptable after parts have received normal in-house handling. Two thousand autodeposition coated parts were handled as would be typical in



CROSS SECTION OF AN AUTODEPOSITION COATED THREAD

FIGURE 5

house and then assembled on a production line. Overall, the coating sustained only minor scratches. Finally, due to the nature of the process, the entire part is coated both inside and out, since wherever the paint bath contacts the metal surface coating deposition results.

The highest priority production requirement was that the system be economical in terms of capital investment, while at the same time be dependable. In conjunction with a paint system equipment supplier, an estimated cost comparison between a cathodic electrodeposition system and an autodeposition system was developed. As a conservative estimate, it appeared that the autodeposition system would cost about 10 percent less to purchase and install than the previously considered cathodic electrodeposition system.

Operating costs, including energy, chemicals, maintenance and rack stripping, were considered also. Energy costs, estimated for 1984, were calculated in terms of the projected steam, natural gas and electricity usage for both types of systems. The autodeposition system was estimated to require 44 percent less energy to operate than a cathodic electrodeposition system. The projected chemical treatment costs were calculated to be approximately $20 per 1,000 square feet of surface area treated. This was considered a reasonable cost for the corrosion protection provided by the autodeposition coating.

With regard to the maintenance demands of the previously mentioned autodeposition system, it was learned that the vast majority of the maintenance is routine in nature, such as monthly cleaning of tanks. Thus, this type of system appeared to have standard maintenance requirements. Projected rack stripping costs were relatively low, since racks would need to be stripped on the average once every two to three years. This would be possible since the coating would collect very slowly on the racks due to coating dragout, which would be minimized by the bath's low resin solids content and accompanying low viscosity.

The remaining production requirements, which require little explanation, are listed below. The system should:

1) Minimize floor space
2) Minimize operating labor
3) Be capable of handling high production volumes
4) Present few environmental concerns
5) Minimize safety hazards in the plant

An autodeposition system saves floor space by not requiring a phosphate stage or a dry-off stage prior to coating. As for labor, one person could operate the line itself. The system would also be capable of treating the required volume of parts

per day. An autodeposition system would involve treatment of free fluorides and hexavalent chromium, as well as disposal of paint sludge. Since the coating is waterborne and contains virtually no organic solvents, there would be minimal air pollution compared to conventional paint systems. It was concluded that an autodeposition system would not create any major environmental problems. Also, since it is a waterborne process, it would not be a fire hazard. Finally, since deposition occurs via chemical reactions rather than electrical attraction, autodeposition would be less hazardous than systems which require high DC voltage levels.

A process parameter investigation was conducted through specific case salt spray testing to further increase the confidence level for the autodeposition process. Two duplicate sets of parts were prepared by the coating supplier for 28 different specific cases. Each part was stamped prior to treatment with an identification number from which the processing it had experienced could be traced. The cases were chosen to learn the effect on corrosion resistance for process parameter variations in the following areas:

1) Coating thickness
2) Chrome rinse
3) Overcure
4) Undercure
5) Reduced cure time
6) Paint solids
7) Low redox potential
8) Low level of free fluorides
9) Low chrome concentration in chrome rinse
10) Rusty parts

The cases tested are specifically described in figure 6, which also shows the corresponding identification numbers.

Six coating thickness checks were taken per part and then a set of parts for each specific case was assembled on the production line. This assembly procedure was followed to simulate the condition of the coating after it had received the nicks, scratches and silicone fluid exposure typical on the production line. The parts were exposed to a neutral salt spray for 240 hours. An evaluation of each assembly was made after 96, 168, and 240 hours of exposure. A summary of these evaluations is shown in figure 7. The large majority of the ratings were very good, with parts showing only slight red rust (less than five percent of the total part surface). The major surfaces of the parts were to exhibit almost no red rust. The

FIGURE 6

DISCRIPTIONS OF SPECIFIC CASE TEST VARIATIONS

| Test I.D. Number | Description of Test Variations |
|---|---|
| 2051 | Coating thickness 0.9-1.0 mil |
| 2057 | Coating thickness 0.4-0.5 mill |
| 2060 | 30 second chrome rinse |
| 2062 | 60 second chrome rinse |
| 2064 | 90 second chrome rinse |
| 2108 | No chrome rinse |
| 2068 | Overcure-time stage 1: 15 min. @ 248°F; stage 2: 40 min. @ 356°F. |
| 2066 | Overcure-time stage 1: 30 min. @ 248°F; stage 2: 20 min. @ 356°F |
| 2091 | Overcure-time stage 1: 15 min. @ 248°F; stage 2: 8 hrs. @ 356°F |
| 2071 | Overcure-temp. stage 1: 15 min. @ 248°F; stage 2: 20 min. @ 456°F |
| 2069 | Overcure-temp. stage 1: 15 min. @ 356°F; stage 2: 20 min. @ 356°F |
| 2084 | Undercure temp. stage 1: 15 min. @ 120°F; stage 2: 20 min. @ 180°F |
| 2079 | Undercure-temp. stage 1: 15 min. @ 248°F; stage 2: 20 min. @ 248°F |
| 2085 | Undercure-coating thickness 0.4-0.5 mil stage 1: 15 min. @ 120°F; stage 2: 20 min. @ 180°F |

FIGURE 6

DESCRIPTIONS OF SPECIFIC CASE TEST VARIATIONS (CONT.)

| Test I.D. Number | Description of Test Variations |
|---|---|
| 2088 | Undercure-coating thickness 0.9-1.0 mil<br>stage 1: 15 min. @ 120°F;<br>stage 2: 20 min. @ 180°F |
| 2078 | Reduced cure time stage 1: 10 min. @ 248°F;<br>stage 2: 10 min. @ 392°F |
| 2171 | Reduced cure time stage 1: 12 min. @ 248°F;<br>stage 2: 18 min. @ 356°F |
| 2173 | Reduced cure time stage 1: 10 min. @ 248°F;<br>stage 2: 15 min. @ 356°F |
| 2073 | Reduced cure time stage 1: 10 min. @ 248°F;<br>stage 2: 20 min. @ 356°F |
| 2075 | Reduced cure time stage 1: 15 min. @ 248°F;<br>stage 2: 10 min. @ 392°F |
| 2097 | Reduced cure time stage 1: 9 min. @ 248°F;<br>stage 2: 9 min. @ 392°F |
| 2096 | Four percent paint solids |
| 2099 | Eight percent paint solids |
| 2102 | Low redox potential 275-325 mV |
| 2104 | Low free fluoride concentration |
| 2106 | Three percent chrome rinse concentration |
| 2089 | Rusty parts-no pickle |
| 2169 | Rusty parts-dip pickled at 160°F |

FIGURE 7

EVALUATIONS OF SPECIFIC CASE TEST RESULTS

(Scale from 0 to 10 where ten signifies no rust.)

| Test I.D. Number | 96 Hr. | 168 Hr. | 240 Hr. | Comments |
|---|---|---|---|---|
| 2051 | 9 | 9- | 9- | Slight staining |
| 2057 | 9 | 9- | 8+ | Dull finish |
| 2060 | 9 | 9 | 9 | |
| 2062 | 9 | 9 | 9 | |
| 2064 | 9+ | 9 | 9 | Very good gloss |
| 2108 | 6 | 3 | 1 | Severe red rust |
| 2068 | 9 | 9 | 9 | |
| 2066 | 9+ | 9 | 9 | |
| 2091 | 9+ | 9 | 9 | |
| 2071 | 9 | 9 | 9- | |
| 2069 | 9+ | 9 | 9- | |
| 2084 | 6 | 4+ | 3 | Severe red rust |
| 2079 | 8 | 7 | 6 | Moderate staining and blistering |
| 2085 | 3 | 2 | 1 | Severe red rust |
| 2088 | 7 | 5 | 4 | Moderate red rust |
| 2078 | 9 | 9- | 9- | |
| 2171 | 9 | 9 | 9- | |
| 2173 | 9 | 9 | 8+ | |
| 2073 | 9+ | 9 | 9 | |
| 2075 | 9+ | 9 | 9 | |
| 2097 | 9+ | 9 | 9 | |

FIGURE 7

EVALUATIONS OF SPECIFIC CASE TEST RESULTS (CONT.)

| Test I.D. Number | 96 Hr. | 168 Hr. | 240 Hr. | Comments |
|---|---|---|---|---|
| 2096 | 9+ | 9 | 9 | Slightly duller finish |
| 2099 | 9+ | 9 | 9 | Very good gloss |
| 2102 | 9+ | 9 | 9 | |
| 2104 | 9 | 9 | 9- | |
| 2106 | 9+ | 9 | 9 | |
| 2089 | 9+ | 9 | 8+ | |
| 2169 | 9+ | 9 | 9 | |

comments in figure 7 refer to the appearance of the entire assembly, and for the cases with no comments, it should be understood that their red rust was not located on major surfaces. Results after the 240 hour salt spray exposure are briefly discussed below.

The first two specific case salt spray tests involved variations in the nominal coating thickness of 0.7 to 0.8 mil. A thicker, 0.9 to 1.0 mil coating, and a thinner, 0.4 to 0.5 mil coating, were tested. The thicker case showed slight staining of the coating from rust run-down, but the interlock area of the assembly looked very good. The thinner case had a duller finish and about twice the amount of red rust in the part interlock area. As expected, the thicker coating resulted in better corrosion protection and appearance.

The second group of specific case tests dealt with the influence of the chrome rinse. Cases were processed with 30, 60 and 90 second chrome rinse dips. The results for the 60 second case were considered representative of those for the proposed process. There was no significant difference in the salt spray performance for the 30 and 60 second dip cases. The 90 second dip case did have better gloss and less red rust. The case of no chrome rinse was tested to confirm the requirement for and influence of the chrome rinse. Very severe red rust resulted for this case. These results revealed that the chrome rinse has a very strong influence on the corrosion protection of the coating, and it is indeed a requirement for an autodeposition paint system.

Several cases of overcured samples were also investigated to determine if excessive cure time or temperature would reduce corrosion resistance. Two cases were prepared with twice the cure time for the first and second oven stages, respectively. These cases were to simulate possible short-term stoppage of the conveyor with parts in the oven. The results indicated that the corrosion resistance of the coating was not significantly affected in either circumstance. The case with double the time in stage one did, however, exhibit slightly less rust. Parts were also prepared to simulate coated parts which had received an extended cure time in the second stage. The coating for this case performed comparably well and appeared to be only slightly adversely affected; it had just a few more rusty nicks.

Two cases involving an increase in cure temperature were tested. For the first of these, the temperature in the second oven stage was raised to 456°F, 100°F over the proposed cure temperature, to simulate an improper temperature setting. For the second variation, the first oven stage was set at 356°F, the same temperature as the one proposed for stage two. This case simulated results for either a single stage oven, or an improper

temperature setting. Salt spray results were generally good for both cases, but there did appear to be an increase in the number of rust spots on the major surfaces of the parts. Thus, both cases presented acceptable corrosion protection, although it was not as good as that for the recommended process.

Four specific cases involved undercured samples. The first of these was prepared by setting the temperatures in the oven stages to 120°F and 180°F, rather than the recommended 120°C and 180°C. This case was to simulate results for an improper oven temperature setting. Test results were very poor, with approximately 75 percent red rust and severe blistering. Different results were obtained for the second case, for which both oven stages were set at 248°F, the recommended temperature for stage one. This case simulated a possible mistaken temperature setting for the second stage, approximately 100°F lower than the recommended 356°F. Moderate blistering and staining of the coating primarily influenced the rating of this case, which showed red rust areas comparable to that of results for the recommended process. The outcome of these tests reinforced the belief that undercure due to a low second stage temperature results in blistering and staining of the coating.

The next two undercure cases were prepared utilizing the same oven temperatures as for the first undercure case, but in these cases the coating was thin (0.4 to 0.5 mil) and thick (0.9 to 1.0 mil), respectively. Severe and moderate red rust results indicated that the thin coating provided less corrosion protection than the thick coating for these cure temperatures.

One of the most important variations in the proposed process was a reduced cure time. The recommended cure cycle was 15 minutes at 248°F for stage one, and 20 minutes at 356°F for stage two. The first variation tested reduced the time in each stage to 10 minutes, and increased the temperature of stage two to 392°F. The results for this case were given a rating of nine minus. These favorable results were much better than expected, and led to the testing of the next two variations. For these cases, the recommended oven temperatures were maintained, but the time in stages one and two were decreased to 12 and 18 minutes, and 10 and 15 minutes, respectively. Results for these were rated as nine minus and eight plus. A slightly higher amount of red rust accounted for the lower rating for the latter case. The favorable outcomes for these two cases indicated that the recommended cure time could be reduced. Further testing was planned to reinforce this assumption and to determine a possible cure cycle.

The three remaining cure variations all involved some modification of both time and oven temperature. The time in stage one was reduced to 10 minutes for the first of these cases, while the temperature was raised to 257°F (an increase of 9°F);

stage two's time and temperature remained unchanged. This variation in the cure cycle did not appear to adversely affect the corrosion resistance of the coating from that of the proposed cure. Results were similar for the next case, for which the first cure stage followed the recommendation, but the second cure stage was altered to 10 minutes at 392°F. As in the previous case, the cure temperature was increased while the time was decreased. These results further indicated that the cure time could be reduced without a significant decrease in the corrosion resistance of the coating. For the final reduced cure time case, the two stages were set at 248°F and 392°F, but the time in each stage was reduced to 9 minutes. This case was tested to give some indication of the margin of acceptance for the first reduced cure time case. If results for the last variation had been a failure, it would have been assumed that those for the first were fairly close to failure. As it occurred, the results for the last were good, and from this, the assumption followed that the results for the first reduced cure time had not been close to failure. Furthermore, from the data it appeared as if the first cure stage may be reduced by 5 minutes, while remaining at 248°F, without adversely affecting the coating's salt spray performance. Similarly, it seemed safe to drop the second cure stage by 5 minutes, while maintaining a 356°F cure temperature. A further modification of the second cure stage to 10 minutes at 392°F was decided to have good potential. An example of a new possible cure is 10 minutes at 248°F followed by 12 to 15 minutes at 392°F.

Two variations of the recommended six percent paint solids were tested, four percent and eight percent. The corrosion resistance of the coating appeared not to be significantly affected by these variations of the paint bath solids, based on the salt spray results for the three cases. One noticeable difference between the three variations (four, six and eight percent paint solids) was the amount of gloss, which increased with the amount of paint solids. This result was predictable, since a higher solids bath is more likely to produce a denser wet coating which is effectively self healing. In contrast, the lower solids bath would probably produce a more permeable coating. A second difference was found in the two extreme variations in the form of average coating thickness. Six thickness checks were taken on each of the four parts for the two cases. The average coating thickness was 0.76 mil and 0.89 mil for four and eight percent solids, respectively. Thus, both gloss and coating thickness increase with the percent solids in the paint bath.

The next two cases also involved variations in parameters for the coating bath. The recommended oxidation/reduction, or redox, potential for the bath was 350 to 400 millivolts, but a case was prepared with a redox potential between 275 and 325

millivolts to simulate a neglected bath condition. The results were reassuringly good, and it was concluded that this variation did not decrease the coating's corrosion resistance. For the second case, parts were coated in a paint bath which exhibited a low level of free fluorides, approximately 130 microamperes. It was recommended that this reading be maintained within 170 and 240 microamperes. This case also simulated a neglected paint bath. The favorable results indicated that similar reductions in free fluoride levels would not diminish the corrosion protection of the autodeposition coating.

Another specific case was chosen to deal with a variation in the concentration of the chrome rinse from the recommended four percent to three percent. This case was designed to simulate neglect of the reaction rinse stage which might result in dilution of the solution's concentration. From the salt spray results, it appeared that a slight reduction in the concentration of the chrome rinse would have no effect on the corrosion resistance of the coating.

The final two specific case tests concerned the processing of rusty parts. One case was prepared according to the proposed process, except the acid pickle and the following rinse were omitted. Prior to coating, these parts showed large areas of light rust. One such area was located on the upper left side of a part. Careful examination revealed red rust breaking through the coating in this area. Consequently, the corrosion resistance exhibited for this case was slightly below that of the final case, which was prepared according to the recommended process including immersion in a heated acid pickle. These results indicated the need for the acid pickle and showed expected typical salt spray performance for rusty parts which have received the pickle.

In summary, twenty-three of the twenty-eight process variations tested showed little or no significant effect on the corrosion resistance of the coating. The ratings for these cases were all eights or nines. Only five of the cases tested showed a moderate or severe effect on the coating's corrosion resistance. Three of these had received the same severe undercure, another was undercured by different means, and the fifth case had received no chrome rinse. The occurrence of undercured samples in production could be prevented by installing temperature monitoring equipment, and parts would always receive a chrome rinse dip if the tank were charged. Thus, little concern was developed for the five cases with poor salt spray results. On the other hand, the ability of the autodeposition coating to provide satisfactory corrosion protection, even when the process is altered slightly, was established.

The effects on the corrosion resistance of the coating in the specific case salt spray tests are summarized below:

A. No significant reduction in corrosion resistance

| | | | |
|---|---|---|---|
| 2060 | 30 second chrome rinse | | |
| 2062 | 60 second chrome rinse | | |
| 2064 | 90 second chrome rinse | | |
| 2068 | Overcure-time | stage 1: | 15 min. @ 248°F; |
| | | stage 2: | 40 min. @ 356°F |
| 2066 | Overcure-time | stage 1: | 30 min. @ 248°F; |
| | | stage 2: | 20 min. @ 356°F |
| 2091 | Overcure-time | stage 1: | 15 min. @ 248°F; |
| | | stage 2: | 8 hrs. @ 356°F |
| 2073 | Reduced cure time | stage 1: | 10 min. @ 257°F; |
| | | stage 2: | 20 min. @ 356°F |
| 2075 | Reduced cure time | stage 1: | 15 min. @ 248°F; |
| | | stage 2: | 10 min. @ 392°F |
| 2097 | Reduced cure time | stage 1: | 9 min. @ 248°F; |
| | | stage 2: | 9 min. @ 392°F |
| 2096 | Four percent paint solids | | |
| 2099 | Eight percent paint solids | | |
| 2102 | Low redox potential 275-325 mV | | |
| 2106 | Three percent chrome rinse concentration | | |
| 2169 | Rusty parts-dip pickled at 160°F | | |

B. Slight reduction in corrosion resistance

| | | | |
|---|---|---|---|
| 2051 | Coating thickness 0.9-1.0 mil | | |
| 2057 | Coating thickness 0.4-0.5 mil | | |
| 2071 | Overcure-temp. | stage 1: | 15 min. @ 248°F; |
| | | stage 2: | 20 min. @ 456°F |
| 2069 | Overcure-temp. | stage 1: | 15 min. @ 356°F: |
| | | stage 2: | 20 min. @ 356°F |
| 2078 | Reduced cure time | stage 1: | 10 min. @ 248°F. |
| | | stage 2: | 10 min. @ 392°F |

2171 Reduced cure time stage 1: 12 min. @ 248°F;
stage 2: 18 min. @ 356°F

2173 Reduced cure time stage 1: 10 min. @ 248°F;
stage 2: 15 min. @ 356°F

2104 Low level of free fluorides (120-130 uamps)

2089 Rusty parts-no pickle

C. Moderate reduction in corrosion resistance

2079 Undercure-temp. stage 1: 15 min. @ 248°F;
stage 2: 20 min. @ 248°F

2088 Undercure-coating thickness 0.9-1.0 mil
stage 1: 15 min. @ 120°F;
stage 2: 20 min. @ 180°F

D. Severe reduction in corrosion resistance

2108 No chrome rinse

2084 Undercure-temp. stage 1: 15 min. @ 120°F;
stage 2: 20 min. @ 180°F

2085 Undercure-coating thickness 0.4-0.5 mil
stage 1: 15 min. @ 120°F;
stage 2: 20 min. @ 180°F

Summary

It was concluded that autodeposition is a satisfactory means of improving the corrosion protection for the parts evaluated.

Autodeposition rated very well against the criteria established for a coating and its method of application. It was judged sound and dependable based on over five years of experience. The coating met all underhood class finish tests and product requirements, and the process satisfied the production requirements. Finally, the process parameter investigation established the ability of the autodeposition coating to provide acceptable corrosion protection, even when the process is varied slightly.

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Private communication from Mr. Terry A. Neubauer to Mr. Frank Glick, December 18, 1981.

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# Organic & Chemical Pretreatment Session G

## Automatic Control for Prepaint Systems

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# AUTOMATIC CONTROLS FOR PREPAINT SYSTEMS

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One of the most critical parameters of a high quality coating line is the quality of the precoat system. This is becoming more evident as line speeds increase finished parts and end users refuse to purchase poor quality. If the prepaint chemicals are not collectively within the manufacturing limits required to produce high quality parts, the coating cannot meet quality standards set by your customer. A poorly engineered prepaint system will result in increasing scrap, with a resulting decrease in profit dollars.

Recent advances in microelectronics have allowed us to develop compact, reliable, very sensitive equipment, capable of effectively controlling prepaint systems within very close tolerances.

In the past, these systems were maintained by manually determining the chemical solution concentration and adding the chemicals as required. This solution checking and addition of chemical would be performed 2-4 times per day, as dictated by production and the people involved. Another procedure involved simply feeding the chemical into the working bath at a set rate over an eight hour day. Both procedures produced poor results, especially on fast lines, lines run intermittently and operations suffering from drastic personnel cutbacks.

The problem of maintaining the prepaint system under these adverse conditions, and produce high quality results has been accomplished by a third approach electronically connecting the solution control unit with an electronic sensing device that continually measures the chemical concentration, and "calls for" chemical feed only when required to maintain a very precise working solution. This provides continual solution control and activates the feed unit adding the right amount of chemical to maintain the optimum concentration, only when actually needed. This is accomplished by measuring the electrical resistance (or its reciprocal, the electrical conductivity) of the working solutions, which is proportional to the chemical concentrations.

Concentration control of chemical solutions is based on the electrical resistance of solutions varying with concentrations. It is this variation in resistance that is measured and used by the solution control unit to maintain a uniform chemical concentration.

The resistance of chemical solutions is measured with a Wheatstone bridge circuit. The basis of the Wheatstone bridge is known variable resistance on one side and the unknown resistance of the solution on the other side. The variable resistance is adjusted until it just equals the resistance of the chemial solution as indicated by no current flow. The variable resistance reading equals the resistance of the chemical solution, as

measured by the sensing device.

The sensing device consists of two conductive surfaces having a definite size and definite distance between them. The standard probe, having a constant of 1, measures the conductivity of 1 cu. centimeter of the chemical solution. Materials of construction vary from stainless steel to nickel to platinized surfaces along with the various others necessary to withstand the corrosive effects of the particular chemical solution being measured.

All of these units operate by passing the current through the sensing device in the chemical solution. The current, or what remains after overcoming the resistance of the chemical solution, returns to solution control unit.

The current returning from the sensing device is then rectifed from AC to DC and is amplified so that the change in current can be more easily measured. Amplified current can then actuate the relay which will turn on or turn off a pump, solenoid valve, feeder, or other device through the electronic solution control equipment.

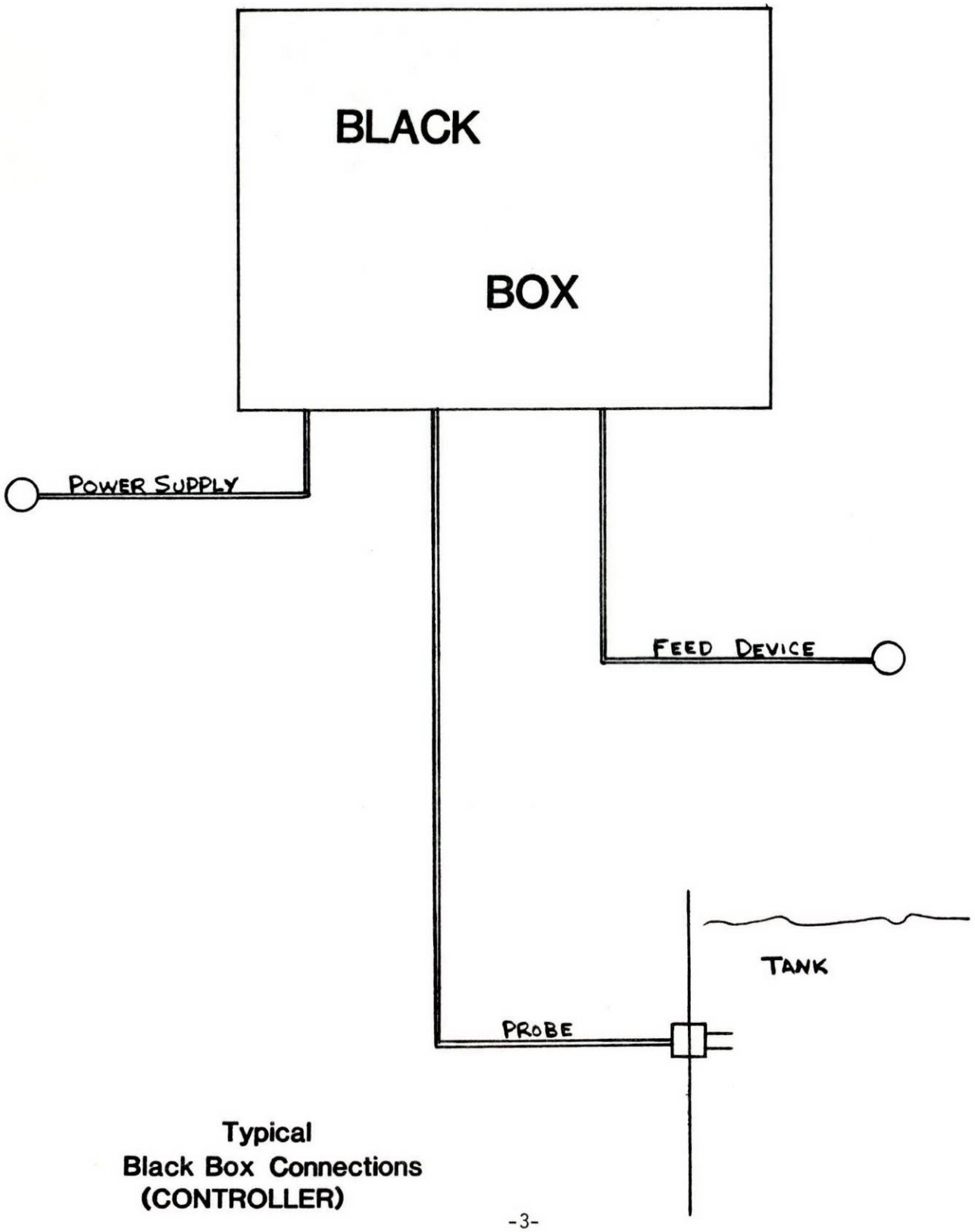
The unit used to control the concentration of cleaning solution is usually called an electronic solution control unit. This operates a relay which can activate a pump, solenoid valve, or other electrical device to feed product to the solution or stop feeding product to the solution as measured by the sensing device.

When the temperature of a solution increases, the resistance of the solution decreases. When controlling the concentration of chemical solutions, a temperature increase of the solution using a fixed setting results in a decrease in concentration. This is because the controller attempts to maintain a uniform resistance and as the resistance decreases with the increase in temperature, the concentration must decrease to compensate or maintain a uniform resistance. Therefore, an adjustment is required when the temperature of the solution is changed.

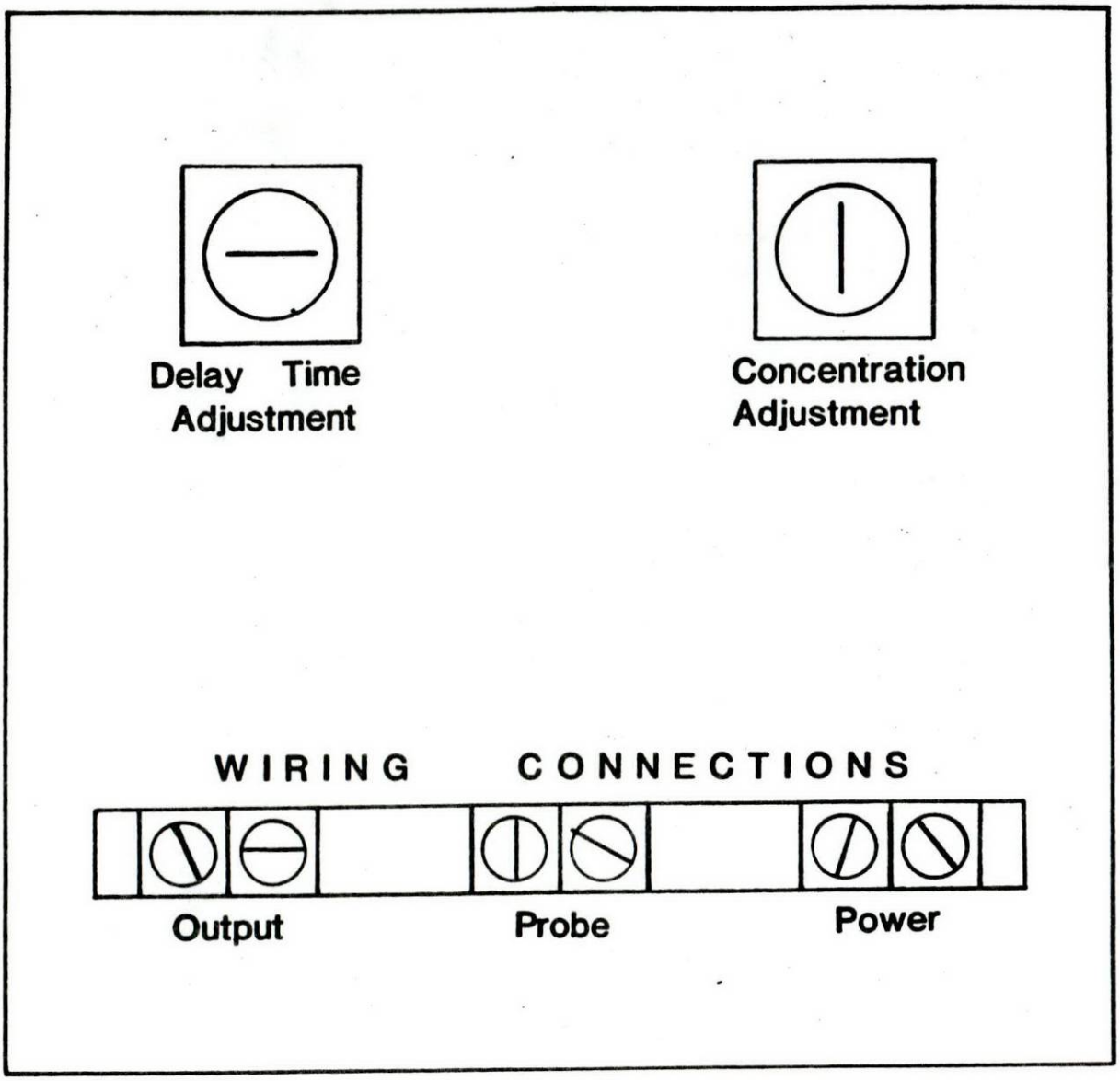
This practical application of microelectronics can be used to efficiently monitor and control systems of multiple one stage washers using prepaint chemicals from a single bulk supply tank, to a standard five stage spray washer using cleaner, phosphate, and seal. Proper installation and maintenance of these units results in:

1) Reduced overall cost.
2) Increased efficiency and output.
3) Lower chemical inventories.
4) Minimize human intervention.
5) Uniform quality.
6) More effective labor utilization.
7) Increased profits.

With the advent of increased manufacturing rates, higher quality standards, automated systems (robotic's) and computer programming, automatic chemical solution control is a necessity to remain competitive in a very competitive world.




**Typical**
**Black Box Connections**
**(CONTROLLER)**




**Typical**
**Controller Adjustments**
**(Black Box)**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