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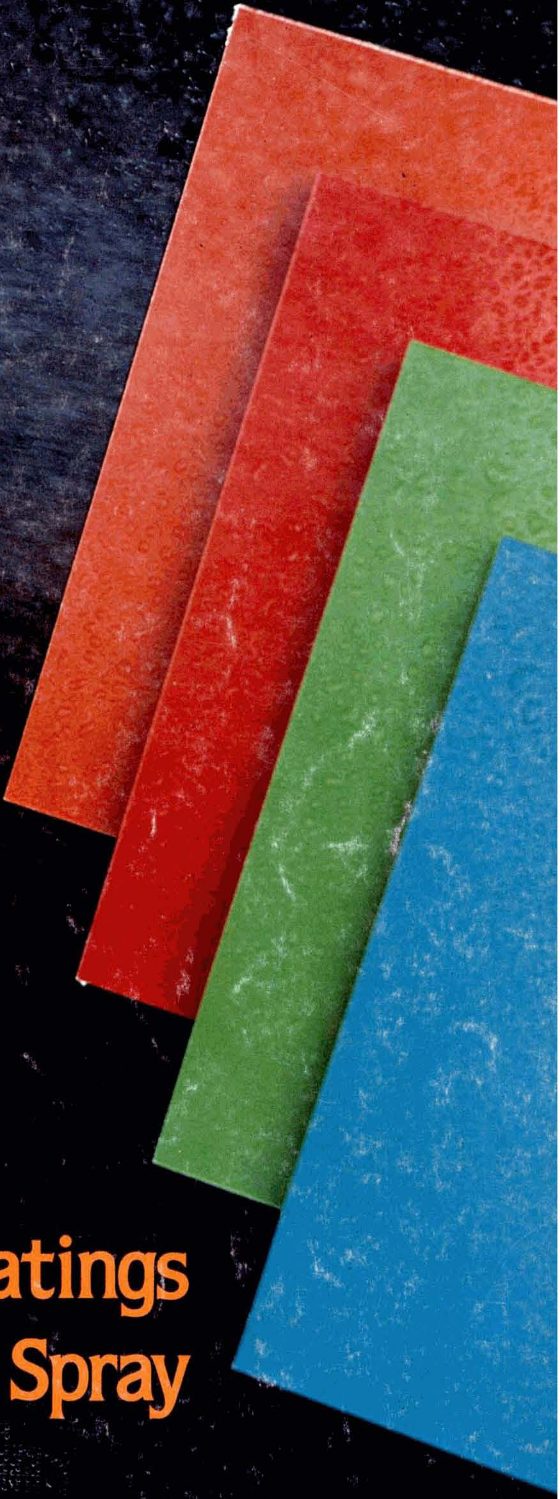
JOURNAL OF
COATINGS
TECHNOLOGY

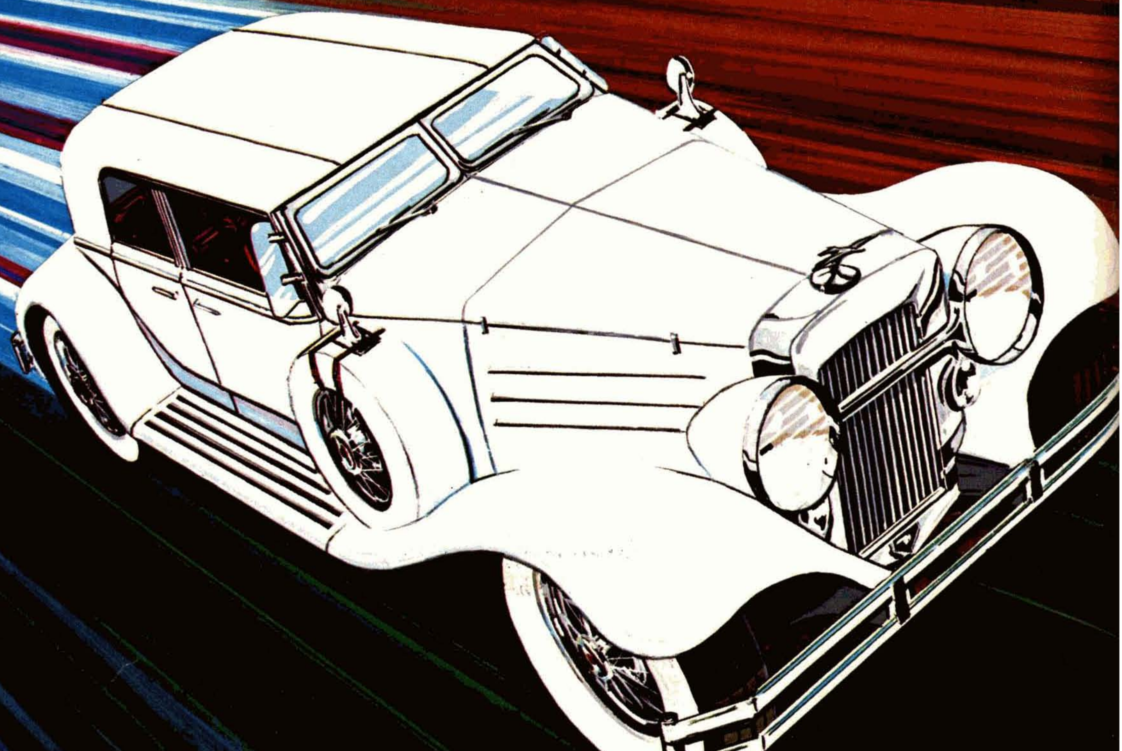
JCTAX 54 (686) 1-76 (1982)

MARCH 1982



# Reaction of Coatings in Salt Spray

60TH ANNUAL MEETING
Federation of Societies for Coatings Technology
1922
1982
YE OLDE PAINT STONE
1737



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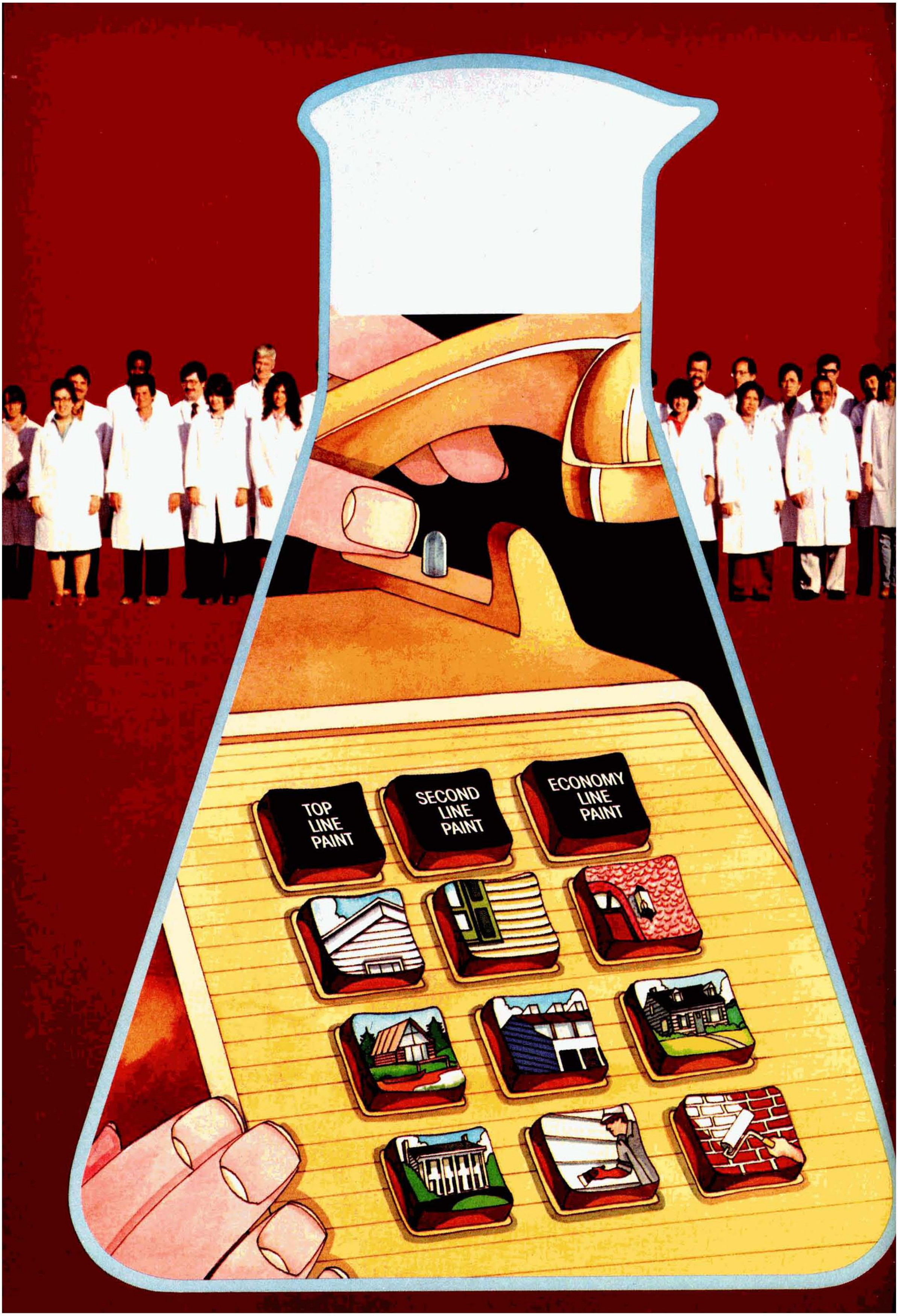
THE JOURNAL OF COATINGS TECHNOLOGY (ISSN 0361-8773) is published monthly by the Federation of Societies for Coatings Technology, 1315 Walnut St., Philadelphia, PA 19107. Phone: (215) 545-1507.

Second class postage paid at Philadelphia, PA and at additional mailing offices. POSTMASTER: Send address changes to JOURNAL OF COATINGS TECHNOLOGY, 1315 Walnut St., Philadelphia, PA 19107.

Subscriptions: U.S. and Canada—1 year, $20; 2 years, $37; 3 years, $52. Europe (Air Mail)—1 year, $40; 2 years, $77; 3 years, $112. Other countries—1 year, $30; 2 years, $57;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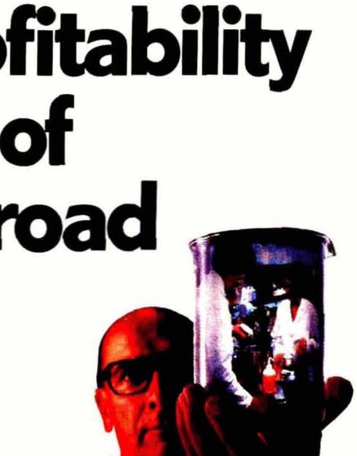

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Annual dues for Active and Associate Members of the Federation of Societies for Coatings Technology is $15.00. Of this amount, $10.00 is allocated to a membership subscription to this publication. Membership in the Federation is obtained through prior affiliation with, and payment of dues to, one of its 26 Constituent Societies. Non-member subscription rates are:

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When available, single copies of back issues of the JOURNAL OF COATINGS TECHNOLOGY are priced as follows: $3.00 each for current calendar year issues; $4.00 each for all other issues.

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A Guide for Authors is published in each January issue.

The JOURNAL OF COATINGS TECHNOLOGY is available on microfilm from University Microfilms, a Xerox Co., Ann Arbor, Mich. 48106.

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# Comment

## Tracing Our Roots

Anyone who has conducted a literature search for historical data on paint is aware of the overall dearth of published material.

A number of excellent articles (some of them appearing on the pages of this Journal) have dealt with various aspects of the topic, or have treated it generally, but no definitive work on the subject has been produced.

Believing that such an effort is an idea whose time has come, a Federation Ad Hoc Committee is currently working on an in-depth compilation of historical data with the object of developing a paint "family tree," to establish our industry's heritage.

This is obviously an ambitious undertaking (much like the dedicated efforts which resulted in publication of the *Paint/Coatings Dictionary),* but the Committee members have high hopes. They also have need of all the help they can get, and anyone interested in lending a hand is urged to do so.

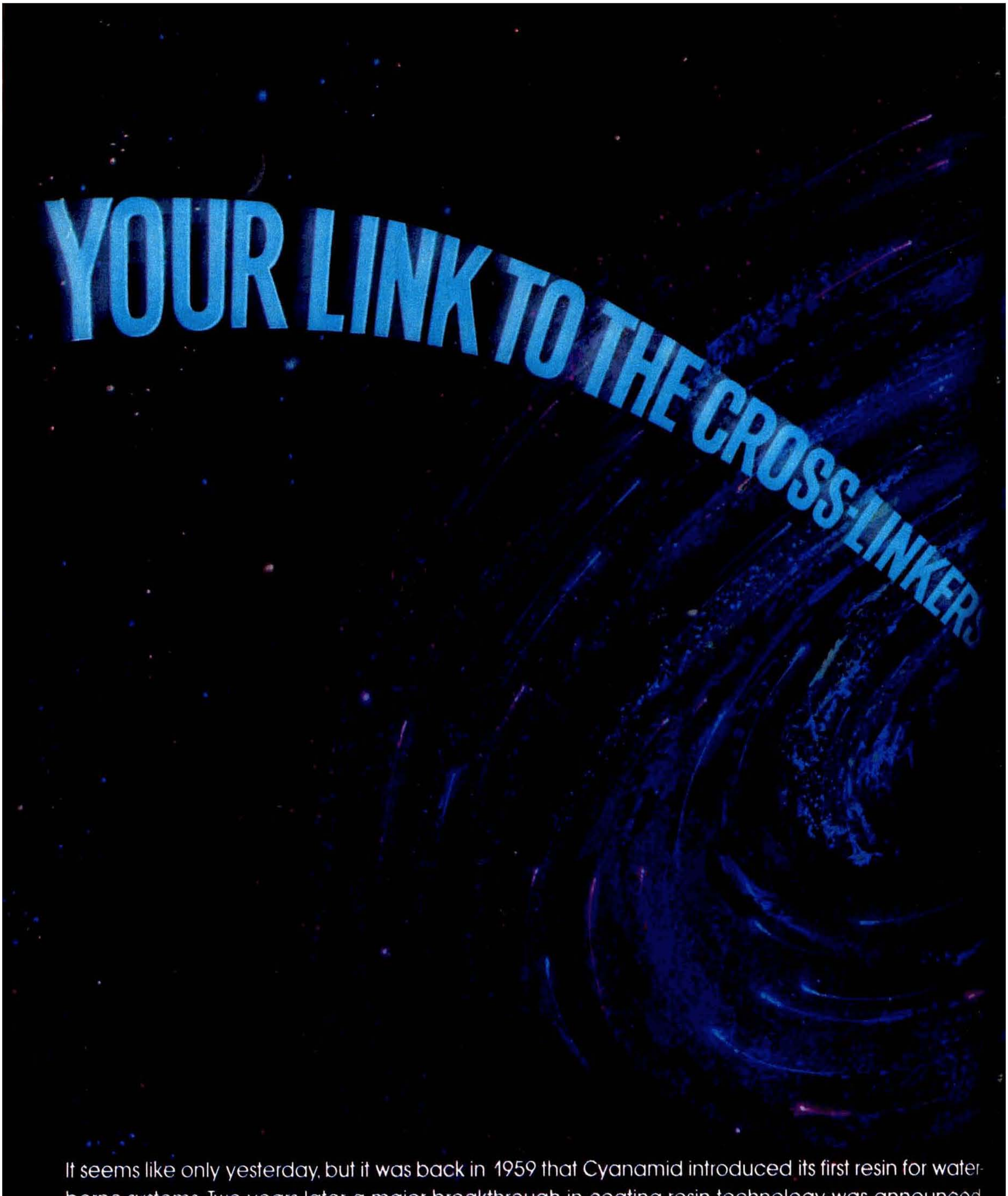
Of particular interest at the moment is assistance from anyone who has acquaintance with, or is interested in, the following areas:

—Biblical to Egyptian Uses of Bitumen and Asphalt
—Egyptian Tempera and Decorations
—Early Greco-Roman Art and Decorations
—Early Musical Instrument Manufacturers
—Early U. S. Paint Ingredients
—History of Paint Making Machinery

If you'd like to help with the above, or any other aspect of the project, the Committee would welcome your participation. Contact the Chairman: Joe Boatwright, 6412 Mills Creek Lane, North Ridgeville, Ohio 44039 (216) 327-7700. He'd be pleased to hear from you.

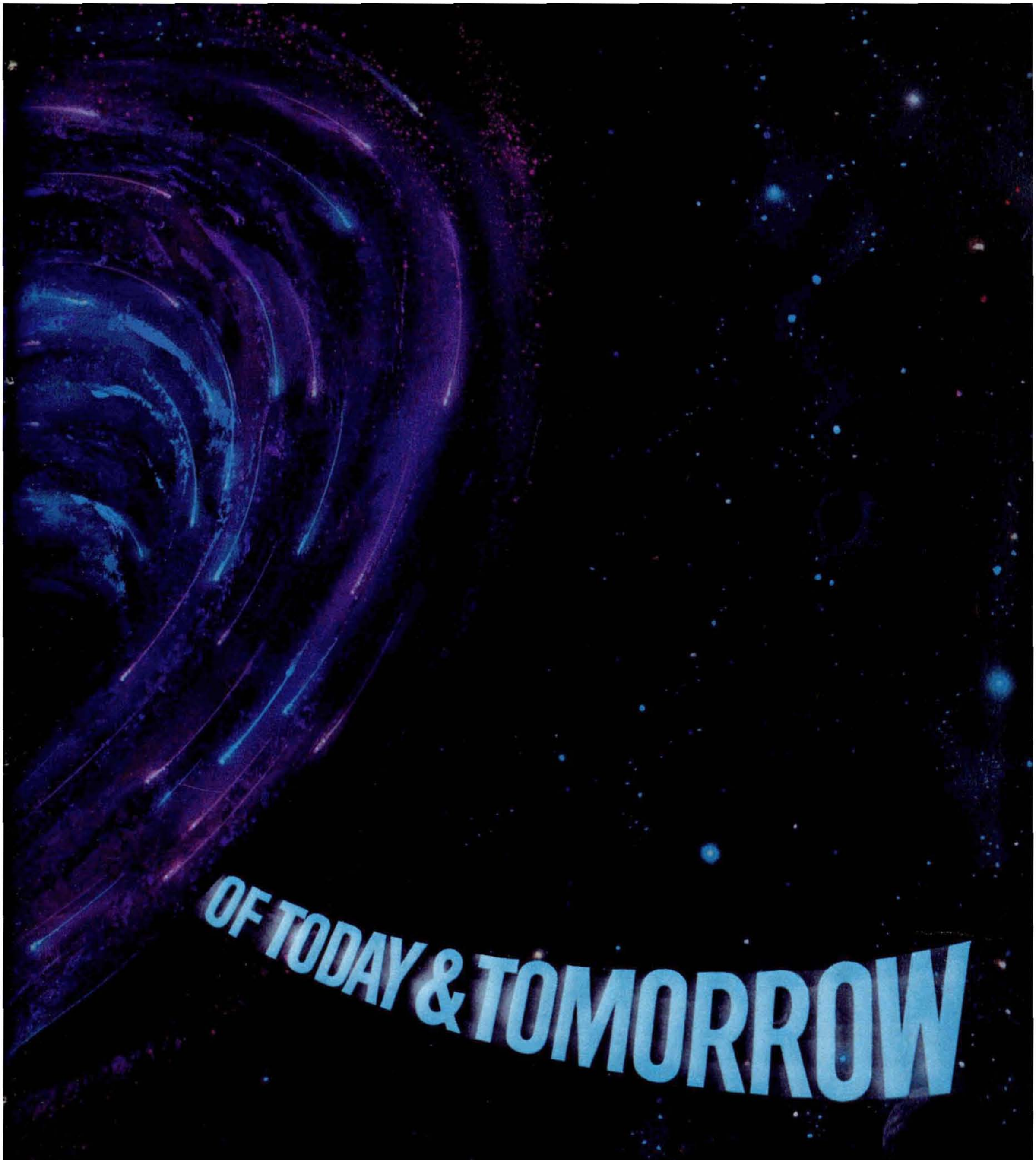
Thomas A. Kocis
T. A. Kocis
Contributing Editor

# YOUR LINK TO THE CROSS-LINKERS



It seems like only yesterday, but it was back in 1959 that Cyanamid introduced its first resin for waterborne systems. Two years later a major breakthrough in coating resin technology was announced — hexamethoxymethylmelamine, the first high solids, fully methylated monomeric melamine cross-linking agent. It was followed by CYMEL® 1116 resin, the first melamine-formaldehyde designed specifically for electro-deposition. And the innovations just kept coming.

During the last two decades, new CYMEL® and BEETLE® cross-linking agents with unique properties have enabled formulators to expand their capabilities in many directions. For example, a fully alkylated urea-formaldehyde resin, introduced in 1974, made it possible to formulate high solids automotive primers. More recent high solids developments include two outstanding melamine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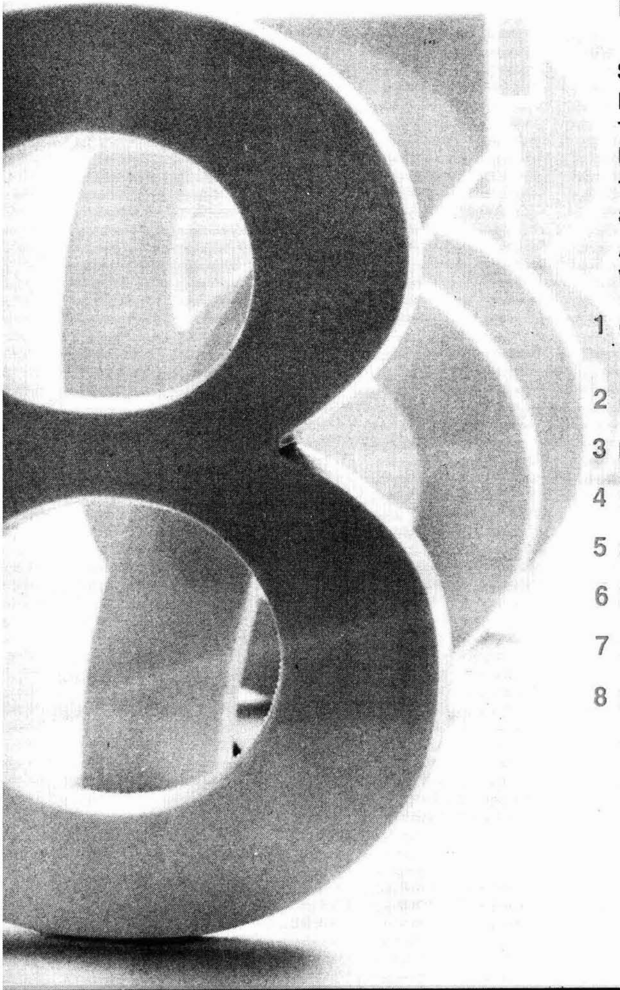


# Abstracts of Papers in This Issue

## SALT SPRAY TESTING FOR SHORT-TERM EVALUATION OF COATINGS. PART I: REACTION OF COATINGS IN SALT SPRAY—B.R. Appleman and P.G. Campbell

Journal of Coatings Technology, 54, No. 686, 17 (Mar. 1982)

Various aspects of short-term testing of coatings for steel are examined, with particular emphasis on the salt spray test. The salt spray test is the most widely used and the most widely criticized of the accelerated tests. Many of the conclusions and considerations concerning the salt spray test are relevant to other accelerated test methods. The salt spray test continuously exposes a coating to a neutral salt solution at an elevated temperature. The test excludes ultraviolet light and atmospheric pollutants. The chemical and physical consequences of this artificial environment are reviewed. The coating's ability to protect against corrosion is examined in light of the principal mechanisms (i.e., barrier, inhibitive, sacrificial). In addition, the observed and expected effects of salt spray are discussed for specific coating binder types including oil and alkyd systems, vinyls and other thermoplastic polymers, catalyzed epoxies, latexes, and zinc-rich primers.

## ESTERIFICATION OF N(2-HYDROXYALKYL) AMIDES-Z.W. Wicks, Jr. and N. Chiang

Journal of Coatings Technology, 54, No. 686, 27 (Mar. 1982)

It has been previously reported that N(2-hydroxyalkyl) amides esterify more rapidly than alcohols and was implied that the reaction was not acid catalyzed. The high rate of esterification has been confirmed and it has been shown that the esterification is not acid catalyzed. Furthermore, the 2-hydroxyalkylamides esterify more rapidly with benzoic acid than with octanoic acid reversing the order with octanol. Possible mechanisms are proposed to account for these unusual reactivities. It was also shown that some unidentified side reaction(s) occur.

## POLYMER COMPOSITIONS FOR CATIONIC ELECTRODEPOSITABLE COATINGS—P.I. Kordomenos and J.D. Nordstrom

Journal of Coatings Technology, 54, No. 686, 33 (Mar. 1982)

Within the past 10 years a large number of patents have been issued dealing with the preparation and characterization of aqueous coating compositions which are electrodeposited on the cathode.

The scope of this paper is to summarize the information that is revealed in the patent literature in connection with the polymer compositions that have been used for cathodic electrodeposition systems. Specifically, this paper discusses the topic of ionizable groups and counterions and the synthetic techniques that have been employed to introduce these groups into polymer backbones. The chemical composition of the polymer backbone, their crosslinking and their effect on coating properties, are also discussed.

## WEATHERING CHARACTERISTICS OF FINISHED WOOD-BASED PANEL PRODUCTS—W.C. Feist

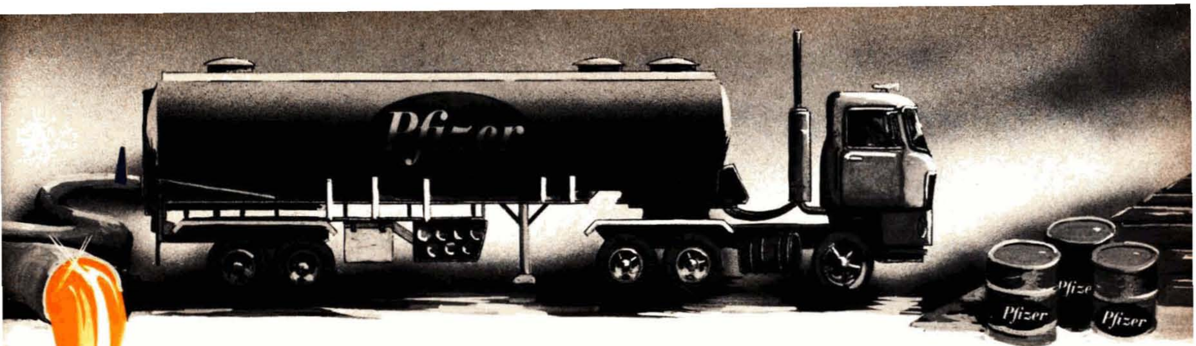
Journal of Coatings Technology, 54, No. 686, 43 (Mar. 1982)

Outdoor exposure studies on the performance of several finish systems on four wood-based panel products and one solid wood substrate showed that enhanced protection was found with two- and three-coat finish systems. The four panel products evaluated (hardboard siding, roughsawn redwood plywood, smooth Douglas-fir plywood, and aspen waferboard) exhibited varying degrees of substrate and finish performance. Aspen waferboard had the poorest overall performance, primarily due to particle delamination and the presence of white-rot decay organisms. Best overall finish performance was found for hardboard siding, especially for opaque paint finish systems. A semitransparent oil stain offered the least protection of all finish systems studied, due to its partial transparency to ultraviolet light. Good overall performance of all-acrylic latex finish systems on all substrates was clearly demonstrated.

## GRAPHICAL SOLUTION TO CPVC PROBLEMS IN LATEX PAINTS—R.H. Rowland and F.B. Stieg

Journal of Coatings Technology, 54, No. 686, 51 (Mar. 1982)

Utilizing a simplified constant-volume technique for the determination of a volumetric oil absorption ($OA_V$), it is shown how a graphical method may be used to modify the pigmentation of any flat latex paint without altering film porosity, and how the CPVC may be calculated for the resulting formulation. Much of the paper is concerned with the theory necessary to establish that this approach is consistent with earlier more complex and more time-consuming methods. Practical examples are used to illustrate the procedure for matching the dry-film porosity of a standard at both equal and improved hiding power levels. Volumetric oil absorption values are provided for a broad selection of common extenders used in latex paints.



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## NPCA Seminars To Discuss Superfund Law

The National Paint and Coatings Association (NPCA) has scheduled three one-half day seminars to explain the complex compliance duties and potential liability under the new Superfund law. The law, which has been in effect since January 1981, was designed to assure the identification and clean-up of abandoned hazardous waste dumpsites and toxic waste spills.

Under Superfund, paint manufacturers whose wastes are traced to a problem waste site are now subject to open-ended financial and even criminal liability for past waste disposal practices, regardless of whether a company adhered to the best waste disposal practices at the time or if the fault lies primarily with the hauler or the site operator.

Because the law is already being vigorously enforced by the Environmental Protection Agency (EPA) and the U.S. Department of Justice, NPCA Executive Director Larry Thomas urges company officers, corporation counsels, and plant supervisory personnel to attend one of the "Facing Superfund—A Legal Explanation and Strategy" sessions.

The program speakers, all of whom have had direct experience in the development of the Superfund law and in the handling of the first cases, are: Timothy L. Harker, an attorney with the Washington firm of Peabody, Lambert & Meyers, is a former Assistant General Counsel of EPA who has more than ten years of experience in the environmental law area. Mr. Harker has represented paint manufacturers in some of the initial enforcement actions; Thomas J. Graves, NPCA Counsel, who actually drafted liability language in the bill passed by the U.S. House of Representatives and has handled NPCA's waste and water legal negotiations with EPA for the past three years; Robert J. Nelson, NPCA Manager of Environmental Affairs, is a chemist with first-hand experience in coatings operations and has extensive knowledge of paint industry waste practices; and James J. Geraghty, President, Geraghty and Miller, Inc. and one of the country's foremost groundwater hydrologists, serves as an industry consultant in pending hazardous waste lawsuits because of his expertise in proper control methods for hazardous waste disposal.

Two of the seminars were conducted in New Orleans, LA and San Francisco, CA, on February 4 and March 4, respectively. The final seminar will be held from 10:00 am—3:15 pm on March 15, at the Essex House Hotel, New York City, NY.

The registration fee of $100 per person is intended to cover expenses only and is based on a minimum of 50 registrants per session. If the response is less than needed to meet expenses, registrants' payments will be refunded promptly.

For further information, or to register, contact: Karen Welch, Director, Meetings and Conventions, NPCA, 1500 Rhode Island Ave., N.W., Washington, D.C. 20005.

## NPCA Favors Amendments to OSHA Lead Standard

Amendments to the Occupational Safety and Health Administration's standard on occupational exposure to lead, announced early this month, could save millions of dollars for users and manufacturers of spray paints and industrial coatings, and still provide optimum protection for workers, according to the National Paint and Coatings Association.

The most significant aspect of the amendments, as far as the industry is concerned, is the provision for the continued use of respirators in situations where engineering and work-practice controls are not feasible for limiting workers' exposure to lead to safe levels. OSHA had previously maintained that respirator use must be phased out in favor of engineering controls, such as sophisticated spray paint booths, robot application, or electro-deposition of paints and coatings containing lead.

The original OSHA position had favored replacement of lead with other substances; NPCA had pointed out that for some types of applications, no acceptable substitute exists.

While engineering controls are feasible in certain industrial applications, they are impractical in many others, such as the painting of ships, aircraft, and bridges, or in situations such as autobody repair shops.

Field studies indicate that respirators provide a high degree of protection, even when compared to currently-available engineering controls.

In announcing the amendments, OSHA cited NPCA's documentation of the fact that engineering and work-practice controls are not always feasible, and that respirator use is a needed backup method which should be continued. NPCA's views, the agency said, "precisely parallel OSHA's traditional compliance policy. . . . This explicit change in regulatory language grants NPCA the flexibility it sought . . . and should additionally eliminate any lingering problems of interpretation."

Other provisions of the amendments include a limited exclusion from engineering-control requirements for workers intermittently exposed to lead levels above permissible limits on fewer than 30 days a year. The amended standard also provides for a two-and-a-half-year extension of compliance deadlines, to allow time for the design and installation of engineering controls where they are feasible.

NPCA praised OSHA's action in amending the standard, and feels that this decision reflects the current Administration's legitimate concern for worker health and safety, along with a willingness to listen to industry and to provide employers with enough operational latitude to develop sensible, cost-effective solutions.

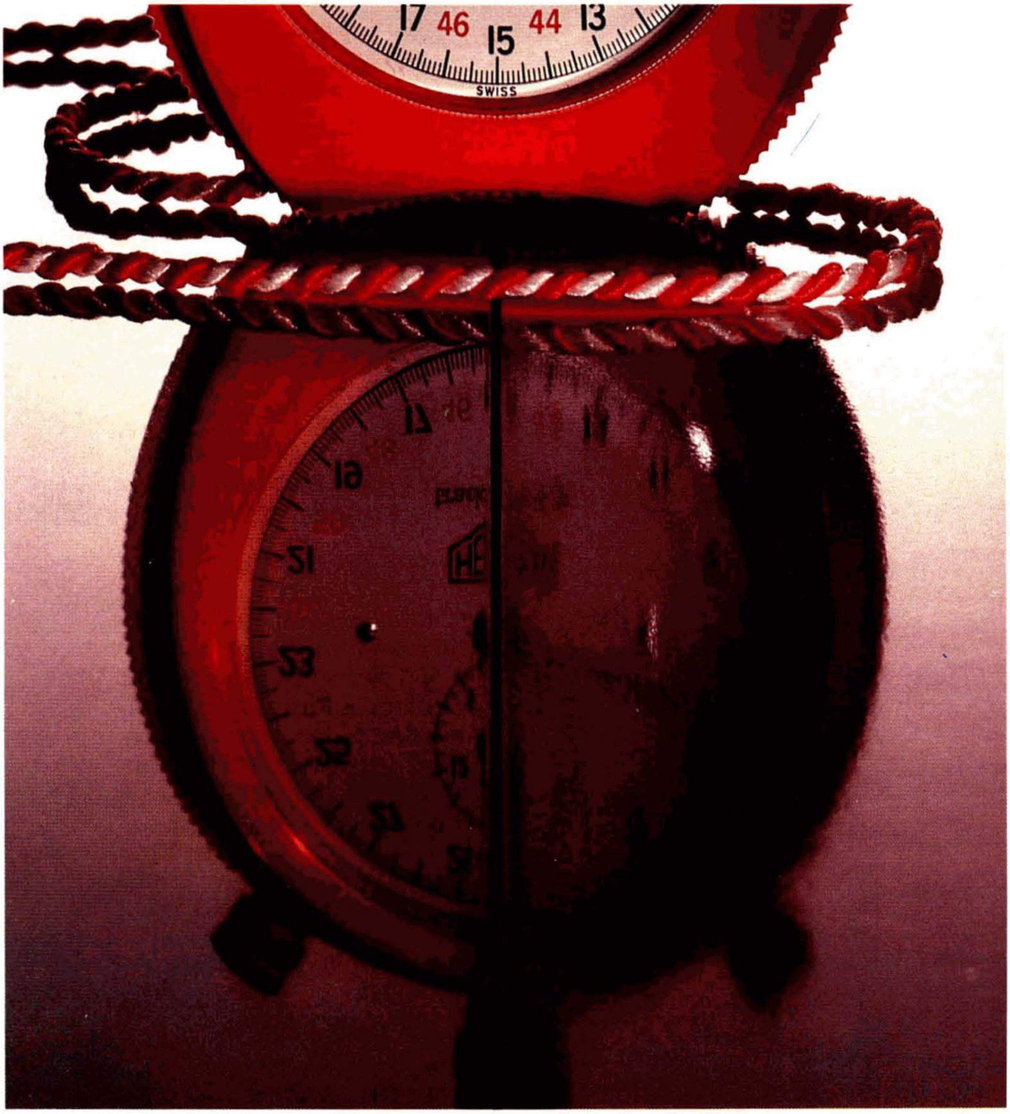
### Hazardous Materials Guide Available From NPCA

The National Paint and Coatings Association (NPCA) has just produced a new publication, "A Guide to the Shipment of Paints and Coatings," which explains how the U.S. Department of Transportation's (DOT) Hazardous Materials Regulations apply to the paint and coatings industry.

The publication, which was developed by NPCA's Transportation and Distribution Committee, has three sections: Shipping Hazardous Coatings, Shipping Hazardous Wastes, and Shipping Hazardous Substances. It discusses how to properly package, mark, label, and placard shipments of paint in accordance with DOT regulations. As an additional aid, the Guide contains easy-to-read charts detailing the proper procedures to be used when shipping a particular hazardous paint product.

NPCA member companies have each been sent one copy of the guide. Members may purchase additional copies at $15 per copy; the copy price for non-members is $45 prepaid. For further information or to order, contact: San Fink at NPCA, 1500 Rhode Island Ave., N.W., Washington, D.C. 20005.

# Which fast-drying, water-borne polymer is really high gloss?



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Joncryl 537 doesn't take second place in drying time and handleability, either. It air-dries tack-free in under one hour, with 80% of ultimate hardness in just 24 hours. Plus, it can be applied by any common method on most substrates.

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**CXW** A unit that meets specifications calling for the Open Flame or Sunshine Carbon Arc light source, the CXW has an ultraviolet rich spectral output that makes it particularly effective in accelerated weathering tests for products such as paints and plastics. The CXW is ideal for the "Dew Cycle" method of testing for determining chalk resistance of paints.

**CDMC** Featuring improved solid-state controls, the CDMC continues to meet test methods that require the Enclosed Carbon Arc light source. The unit, supplied with two lamps, has had a long association with the textile industry and lightfastness testing. The CDMC also meets several commonly used automotive specifications.

**Ci65/XW** This "combination" unit offers versatility to users whose requirements demand both Xenon and Sunshine Arc testing but whose on-line demands do not justify two pieces of equipment. Changing from one light source to the other requires less than one hour.

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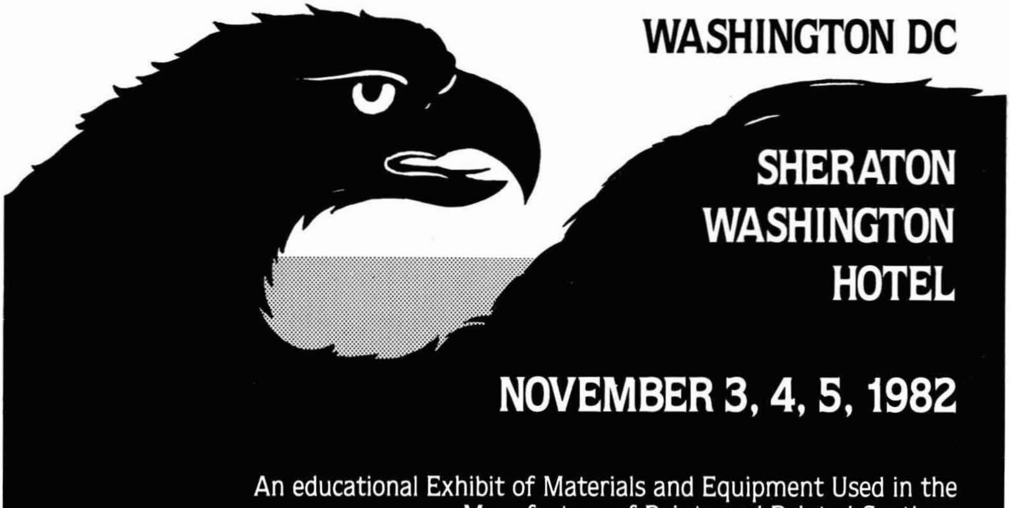

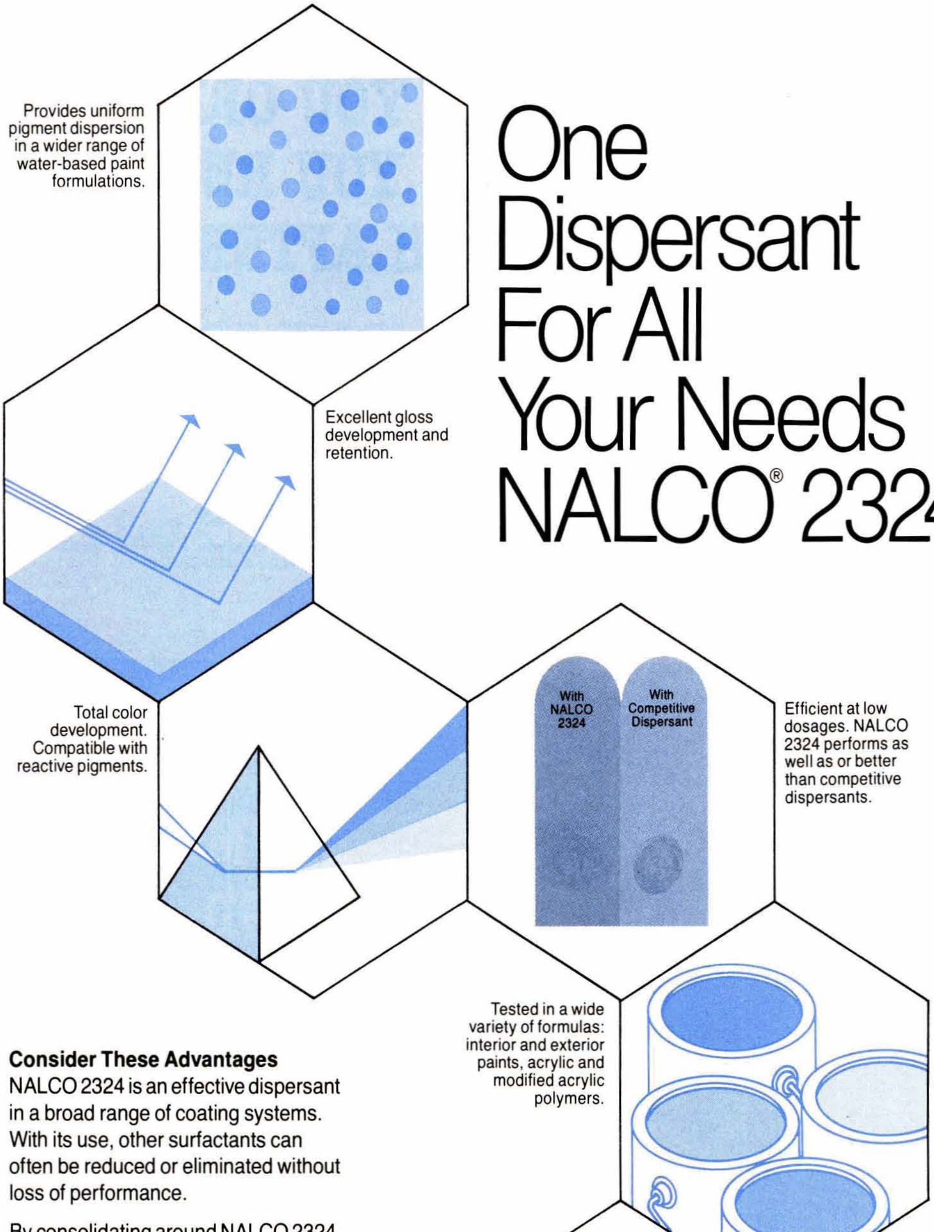
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"I'M COMMITTED TO IT."
John S. Kim
Manager, Quality Assurance
BARECO

# Salt Spray Testing
# For Short Term Evaluation of Coatings

## Part I: Reaction of Coatings in Salt Spray

Bernard R. Appleman
Federal Highway Administration[*]

and

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Various aspects of short-term testing of coatings for steel are examined, with particular emphasis on the salt spray test. The salt spray test is the most widely used and the most widely criticized of the accelerated test methods. The salt spray test continuously exposes a coating to a neutral salt solution at an elevated temperature. The test excludes ultraviolet light and atmospheric pollutants. The chemical and physical consequences of this artificial environment are reviewed. The coating's ability to protect against corrosion is examined in light of the principal mechanisms (i.e., barrier, inhibitive, sacrificial). In addition, the observed and expected effects of salt spray are discussed for specific coating binder types including oil and alkyd systems, vinyls and other thermoplastic polymers, catalyzed epoxies, latexes, and zinc-rich primers.

### INTRODUCTION

Environmental and economic pressures, along with new coatings technology, have intensified the need for short-term prediction of performance of coating systems designed to last 10 to 20 years. Under a Federal Highway Administration research contract, the National Bureau of Standards (NBS) has undertaken an evaluation of the validity and usefulness of short-term test procedures for structural steel coatings.[1] The ultimate objectives of the program are to establish recommended procedures for evaluating and selecting coatings and to develop performance specifications.

Short-term evaluation and decision-making can be approached in several ways. The best known approach is the use of accelerated tests, in which one or more stress factors (e.g., ultraviolet light, salt) are intensified to accelerate the normally slow coating deterioration process. Another approach to short-term evaluation is based on increasing the sensitivity to detecting changes in the coating's characteristics during real time (natural) exposures. A third approach is the use of chemical, mechanical, or electrical tests on the unaged coating.

Although each of the above approaches has its drawbacks, each provides information upon which to base a decision. The other choice is to select a coating system based on nontechnical factors such as testimony or intuition.

The chosen approach depends on the particular applications and conditions. The second approach, which describes methods for early detection of failure (e.g., chemiluminescence, dynamic mechanical testing), is primarily suitable for laboratory research studies rather than routine evaluations. The third approach is considered most suitable for use in coating specifications and quality control of known and previously tested coatings.

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Presented by Dr. Appleman at the 1980 Annual Meeting of the Federation of Societies for Coatings Technology in Atlanta, GA, October 29, 1980.

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**Table 1—Accelerated Tests**

| Type | Stress Applied | Mode(s) of Failure |
|---|---|---|
| Salt spray test | Salt spray, high humidity | Undercutting at scribe, blistering, corrosion |
| Humidity test | High humidity, elevated temperature | Blistering, corrosion, chalking, gloss and color changes |
| Immersion | Salt solution, water | Corrosion, blistering, film softening |
| Kesternich | $SO_2$, $H_2SO_3$, high humidity | Corrosion, blistering, color changes |
| Cathodic (bullet hole) | 3% NaCl | Corrosion of exposed base substrate |
| Cyclic weathering | Controlled cyclic exposure to light, high relative humidity, water spray | Corrosion, blistering, chalking, gloss and color changes |
| EMMAQUA, EMMA | Intensified UV radiation, intermittent water spray | Gloss and color changes |
| Prohesion | Salt, $(NH_4)_2SO_4$ intermittent drying | Undercutting, loss of adhesion |

Even the option of no testing at all may be appropriate in some situations, for example, when a user relies on the word and experience of a trusted supplier.

This paper concentrates on the accelerated testing methods and strongly emphasizes one particular type of accelerated test, the salt spray test. This test is the most frequently used accelerated test procedure. Accelerated tests for coatings have been the subject of numerous articles and discussions. Brand, *et al.*[2] stated "it would be extremely difficult if not impossible to develop a reliable accelerated test method in which the balance of all deteriorative factors present in nature is maintained," a conclusion with which we have no quarrel. The so-called natural exposure is extremely complex, including sunlight, wind, ozone, rain, dew, salt spray, temperature variation, sulfur dioxide, and grime. It is extremely unlikely that all these factors could ever be combined in one test and even more unlikely in an accelerated test.

From another point of view, however, it may not be necessary or even desirable to intensify all of the stresses on a coating. A prime objective of an accelerated test is to cause the coating to degrade or fail in a shorter time period than under natural conditions without changing the failure mechanisms. The actual definition of failure depends on what one considers the main function of the coating. Chalking may be a sign of failure for an automotive topcoat, but not for a tank.

If a test could be designed to degrade a coating in accordance with one's definition of failure, the test could provide useful information. It is, of course, important that the test not significantly distort the behavior of the coating compared to service conditions. And were such a test developed, it would be necessary to carefully interpret the results and establish the limitations of the test. The point of the discussion, though, is that one ought not to be looking for some hypothetical, universal test to reproduce all conditions. Rather, one needs to choose or design the test method based on the specific applications and requirements of the coating.

In considering a test for a specific coating, one should ask the following questions:

- What is the function of the coating?
- What constitutes a failure?
- How does failure occur under natural conditions?
- What factors are intensified or accelerated in the test?
- How does failure occur in the test?
- Does the test provide useful information?
- What are the limits of the test?

*Table* 1 lists the intensified factors and modes of failure for a number of accelerated tests for coatings durability, several of which are described below.

Some of the specialized tests are described briefly:

(1) The "EMMA" and "EMMAQUA" test exposure machines are exposure racks designed to follow the sun, having 10 flat mirrors positioned so that the sun's rays strike them at 90° all day and reflect to the samples in the target area. The EMMAQUA machine also includes a system for spraying the samples with distilled water for about eight minutes out of each operating hour.

(2) The Kesternich test is based upon DIN 50018, "Testing of Materials, Structural Components and Equipment; Method of Test in Damp Heat Alternating Atmosphere Containing Sulfur Dioxide." The exposure test utilizes a lead-lined chamber. For each test cycle, two liters of distilled water are placed in the bottom of the test cabinet and then two liters of sulfur dioxide are introduced at ambient temperatures. The heating elements in the bottom of the test cabinet are turned on and within 90 minutes the lower part of the cabinet reaches 35° C and the resultant sulfurous fog maintained for eight hours. The cabinet is then cooled overnight (16 hours) with the doors ajar and the cycle repeated. Test specimens are hung vertically and samples are visually examined after exposure.

(3) "Prohesion" is a test based on the philosophy that "Protection is Adhesion." The exposure cycle consists of six three-hours periods of salt spray $(NH_4)_2SO_4$ and NaCl alternating with six one-hour drying periods using ambient air. The test chamber is a Weather-Ometer® with its UV lamp replaced by a salt fog spray. Adhesion failure (undercutting corrosion) is measured at cross hatch areas.

(4) The "bullet hole" test is an immersion test in 3.1% sodium chloride. The panel is prepared by placing circular masking tape, 1.5 inches (3.8 cm) (or other selected diameter or shape), in the center, applying the protective coating, removing the masking tape immediately after spraying, and curing the coated film until immersion. The panels remain immersed in salt solution until the base area of the steel is corroded. It tests the ability of a zinc-rich primer or other sacrificial coating to protect the bare area cathodically.

The most widely used accelerated test to mesure the performance of a coating for corrosion protection is the salt spray test. Whether or not the salt spray test is the best accelerated test to measure corrosion protection has often been questioned; nevertheless, the impact of this test on the industry and consumer (user) makes this

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Weather-Ometer is a registered trademark of Atlas Electric Devices Co.

the most significant test for measuring corrosion protection. There have been cases reported where coating systems have been formulated with the prime consideration given to having the paint system pass the salt spray test—for the customer would not purchase a paint system that did not pass this test. For these reasons, this paper will focus upon a discussion of the salt spray method and its variations.

## SALT SPRAY TEST

### Background

The salt spray test (ASTM B 117)[3] is extensively used for evaluating performance of coatings and metals. It is one of the oldest and also one of the most highly criticized accelerated test methods. The original ASTM standard dates back to 1939. The literature over the past 40 years is replete with disclaimers and derogations ranging from careful explanation of its limitations to complete denunciations. We shall briefly review some of the main characteristics of the test and assess its significance and validity in relation to the various test objectives described.

### Description of Test

The test itself consists of a box or test chamber in which test panels are held at a 15–30 degree angle and sprayed indirectly with a 5% salt spray solution. The test is normally run at 35 ± 1.5°C (95 ± 3°F). The deposition of the salt solution on the surface of the panel promotes the formation of electrolytic corrosion cells.

The salt spray test was originally designed to simulate the effect of sea salt air on metal specimens. It was soon discovered that this artificial salt environment also produced accelerated deterioration of coated metal specimens. The test has subsequently become deeply entrenched in the psyche of the coatings testing industry; countless evaluations and comparisons have been made and conclusions drawn based on the results, many of which may not be justified. The test is too often used for purposes for which it was never intended.

The results obtained are very sensitive to the operating conditions of the test. Among the conditions that must be carefully controlled are specimen angle, pH, purity and concentration of salt solution, rate of settling of salt solution, atomization pressure, nozzle design, and collection rate.

### Variations on the Salt Spray Test

The acetic acid-salt spray (fog) testing method (ASTM B287), and the copper accelerated acetic acid-salt spray (fog) testing (CASS Test) (ASTM B368) are variations of the salt spray tests where a 5% salt spray is also used. Another, older variation of the salt spray test includes the use of a 20% salt solution (FTMS No. 141a[4] and some paint specifications). Harrison[5] utilized a 3.25% $(NH_4)_2SO_4$ and 0.25% NaCl solution in the salt spray test to more closely correspond to an industrial environment and found better correlation with 14 years external exposure than with a 3.5% NaCl solution. The BSI standard method for resistance to continuous salt spray (BS 3900: Part F4[6] utilizes a mixed salt spray (NaCl, 26.5 g; $MgCl_2$, 2.4 g; $MgSO_4$, 3.3 g; KCl, 0.73 g; $NaHCO_3$, 0.20 g; NaBr, 0.28g; $CaCl_2$, 1.1 g, water to 1000 mL). The ARE salt spray droplet test (BS 1391)[6] involves daily spray of a synthetic sea salt (NaCl, 23 g; $Na_2SO_4 \cdot 10H_2O$, 8.9 g; $MgCl_2 \cdot 6H_2O$, 9.8 g; $CaCl_2$, 12 g/L) on coated panels.

**Table 2—Cyclic Tests Using Salt Spray**

| User or Organization | Other Tests Included |
|---|---|
| Timmins (Prohesion)[8] | Drying |
| Tooke[9] | Ultraviolet (UV) light |
| Sakae, *et al.*[10] | Weatherometer, Sulfur dioxide |
| ASTM D2933 Part 27 | Humidity, heat-cold |
| Michigan DOT[11] | UV-condensation, freeze-thaw |
| Texas Highway Dept.[11] | Dry heat |
| NY-NJ Port Authority[11] | Weatherometer, freeze-thaw |
| Paint Company[a] | UV, drying |
| Goethner[7] | Sunlight, atmosphere |

(a) Personal communication.

Many of the cyclic tests for the short-term testing of coatings on steel include salt spray as part of the cycle. Goethner described a method in which panels are sprayed with salt in a particular protected environment. It allows access to sunlight and air pollution but not to direct rainfall.[7]

Other variations on the salt spray test utilize cyclic exposures of one type or another to accelerate coatings failures. As part of the "Prohesion" test procedure, Timmins[8] utilizes a cycle replacing the 5% NaCl solution with Harrison's $(NH_4)_2SO_4$ -NaCl mixture and cycling over 24 hours, i.e., three-hour period of salt spray alternating with a one-hour drying period using ambient air. One major paint company utilizes a unique test cabinet where the samples are exposed to a one-hour, 5% salt spray, one-hour exposure to UV, one-hour darkness cycle. Tooke[9] and Sakae[10] have described combinations of salt with UV and sulfur dioxide. The Texas Highway Department uses a cycle of 24 hours heat lamp exposure (140°F black panel temperature) and 48-hour salt spray, 20% NaCl. The NY-NJ Port Authority has recently initiated a multi-step cycle, including accelerated weathering, salt spray, and freeze-thaw which is designed to simulate a year or more of natural exposure in New York City. The Michigan Highway Department has developed a weathering cycle of 200 hours UV-condensation exposure, 50 hours salt spray, and five freeze-thaw cycles.[11] These are listed in *Table* 2.

### Extent of Usage

Our survey of the coatings industry and the literature revealed that the salt spray is used to some extent by virtually every coating manufacturer, raw material supplier, and R&D group involved with corrosion resistant coatings. The extent of use and the manner in which it is used vary considerably. In most cases the test is used in conjunction with other tests such as accelerated weathering or outdoor fence testing. Several of the raw material

**Table 3—Effect of High Salt Concentration On Coating Protection Mechanisms**

| | |
|---|---|
| Barrier coating | Accelerated attack at holidays.<br>Severe test of undercutting.<br>Osmotic forces reduced. |
| Inhibitive coating | Chlorides adsorbed on metal.<br>Chlorides prevent passivation. |
| Sacrificial coating | Zinc may not form protective oxide.<br>High conductivity enhances cathodic protection. |

suppliers have used it as the principal means to determine the suitability of new formulations for corrosion protection. It is then up to the customer, e.g., paint manufacturer or specifying agency, to evaluate the overall performance of the product. Several paint manufacturers use the salt spray as the principal screening test before conducting service evaluations, often on company-owned structural facilities.

The users, particularly large corporations and government agencies, have expressed lack of confidence in the reliability of the salt spray. Several State highway departments rely primarily on field testing of new coatings. The salt spray test is, however, widely used in dozens of Federal, State, and Military specifications. The user agencies that conduct extensive performance evaluations rely most heavily on outdoor fence testing. The salt spray test is of secondary importance, sometimes used for initial screening of candidate coatings and in quality control.

The trend is also observed in the literature where most of the published accounts of performance evaluation report outdoor fence testings. Salt spray is frequently used where the objective is to investigate a particular mechanism of corrosion or evaluate film properties (e.g., flexibility, permeability, stress) as a function of aging or composition.[12]

In many respects the salt test has achieved a unique position, in which salt spray resistance is considered an intrinsically desirable property of a coating along with temperature stability, ease of application, and gloss retention. Thus, paint manufacturers and raw material suppliers, being convinced that their customers desire a certain degree of salt spray resistance, will develop and formulate accordingly. It matters not that the test results may correlate little with durability, corrosion resistance, or other normally desired attributes. If the user thinks he needs salt spray resistance, the supplier is going to provide it.

This deep entrenchment and acceptance of the salt spray test is partly responsible for the large amount of criticism directed toward it. From a technical standpoint, correlation of test results with exterior durability and corrosion resistance is of paramount importance. In order to break out of this condition of unquestioning acceptance, it is first necessary to thoroughly examine the salt spray test and how it affects coating performance.

## SALT SPRAY AND PROTECTIVE MECHANISMS

In order to evaluate a coating for salt spray resistance, it is normally necessary to apply the coating to a metal substrate. The film thickness, type of substrate, and the methods of preparation and application, though critical to the results, are not part of the test *per se*. Let us assume that a 76 μm (3.0 mil) primer has been applied over a suitably prepared steel panel. What types of stresses is this coated specimen subjected to and how do they compare with other types of exposure?

The initial effect of the salt spray is the deposition of a solution of salt on the surface of the coating. How this salt solution affects the coating depends to a large extent on the type of protective coating. As Hare[13] and others have discussed, there are three basic corrosion protection mechanisms. These are barrier coating, inhibitive coating, and sacrificial coating. *Table* 3 summarizes the effect of the high salt concentration on each of these types. Additional details on the mechanisms are provided below.

### Barrier Coating

This type of coating provides a barrier against penetration through the coating of water, oxygen, and ions, which must reach the metal for corrosion to occur. The coating can be envisioned as a dielectric providing a high electrical resistance between the surface electrolyte (salt solution) and the conductive metal. The degree of resistance is determined by the coating's ability to prevent ion transfer.

For a barrier coating to be effective, it must be holiday free. The salt spray test will greatly accelerate the attack at holidays and discontinuities. The salt spray test, in principle, can serve as a sensitive detector of the presence of holidays and their susceptibility to chloride attack.

At the holidays, the metal will contain small anodic and cathodic areas. The anodes will dissolve into ferrous ions ($FE^{++}$), while at the cathodes, hydroxyl ions ($OH^-$) will be formed. The hydroxyl ions will tend to react with any acidic or hydrolyzable group of the binder, such as ester linkages. In other words, any coating which is not resistant to alkali will be degraded, leading to loss of adhesion and further corrosion. The process is known as undercutting.

The salt spray test, therefore, provides a severe test of the alkali resistance of coatings once the film is broken. Frequently the panel is deliberately scratched or scribed to the metal to allow corrosion to initiate (at the scribe) in order to observe the resistance of the coating to undercutting.

The phenomenon of hydroxyl formation at the cathode is common to almost all instances of iron corrosion in the atmosphere. There are, however, some differences between the salt spray environment and a so-called natural exposure. The chloride concentration of salt spray is higher and more uniform than outdoor exposure, even a marine atmosphere, because the substrate is never permitted to dry. In addition, the absence of other elements such as sulfur dioxide, ozone, ultraviolet light, and grime, and the elevated temperature, may alter the chemistry of the formation of corrosion products.

An important mechanism for coating failure is by osmotic blistering. Under ambient conditions, the concentration of a soluble contaminant at the metal-coating interface will be much higher than in the relatively pure water condensed or sprayed onto the surface.

If the coating is considered a semi-permeable membrane (permeable to water, but not to ionic species), the only way for the concentration of the two solutions (at metal and surface) to be equalized is for water to pass through the film from the surface to the metal. This causes swelling, blistering, and eventually loss of adhesion.

In the salt spray test, this mechanism for blistering will not be observed. Because of the high concentration of chloride on the surface, the osmotic forces are neutralized or reversed. This lack of osmotic blistering is a serious drawback of the salt spray test. It may be surmised that the salt spray results would not correlate with an exposure in systems in which osmotic blistering is prevalent (i.e., high humidity, low salt).

Other factors that affect the permeability of a given film are the temperature, the extent of film degradation, and the film mechanical stress. The rates of permeation, absorption, and diffusion, along with all chemical reaction rates, increase with temperature. The temperature also influences these processes by its effect on rheology, stability, and structure.

Coatings are often formulated so that the glass transition temperature ($T_g$)* occurs at or near ambient conditions. At 35°C, many coating binders will be above the glass transition temperature. This may result in greatly increased polymer mobility and a higher susceptibility to hydrolysis, chain rupture, or other deleterious effects. Conversely, some thermoplastic (e.g., vinyls) or oxidative coatings (e.g., alkyds), may form a tighter, more resistant structure at the higher temperature due to leaching out of plasticizers. Oils and alkyds may also undergo additional crosslinking and curing, which also results in a tighter film structure. Ultraviolet light, ozone, and various atmosphere contaminants have an important effect on the degradation of organic films, particularly at the surface. The absence of those factors in the salt spray may result in a longer time to initiate a break on the film, or may result in the occurrence of completely different processes.

## Inhibitive Coating

Certain slightly soluble heavy metal pigments (e.g., zinc chromate, red lead) control corrosion by changing the electrode potential at the anodes (polarization) such that iron does not oxidize. In order for these inhibitors to be effective they must supply water soluble species to the metal-coating interface. The exact mechanisms are complex and not fully understood. As long as soluble inhibitor is present at the interface to protect the iron, corrosion will be prevented.

Protection breaks down when the inhibitor is consumed by complexing with other ions, e.g., chlorides, or when it is blocked from reaching the interface. Thus, the relative mobility and water and ion permeability of the film are important. As discussed in the previous section on barrier mechanism, the salt spray test would not be expected to accelerate those factors uniformly or even in a consistent direction.

The ability of an inhibitive coating to withstand chloride attack depends on the nature of the inhibitive pigment and the relative concentrations. Chlorides are readily adsorbed on the metal surface and compete with passivating pigments such as chromates, thereby preventing passivation. At high concentrations of chlorides (e.g., holidays, scribes), chromates may lose their effectiveness completely due to the inability to provide high enough inhibitor concentration. As the temperature is increased, even more pigment is required to prevent depassivation.

The high pH (basic) inhibitive pigments (e.g., red lead) are believed to react with the coating binder to form slightly soluble soaps. In the presence of oxygen and water, the soaps oxidize to yield soluble inhibitive degradation products.[14] It is likely that the presence of high concentrations of chloride would also interfere with this inhibitive mechanism.

Thus, the abnormally high chloride concentration in salt spray may greatly decrease the effectiveness of inhibitive pigments compared to their action in a less chloride-intensive environment. As noted by Hare,[13] "the inhibitive primer is most safely restricted to areas where access of continuous corrosive electrolyte is unlikely." The salt spray is, therefore, not the way to test an inhibitive pigment.

## Sacrificial Coating

The principal members of this group, the zinc-rich primers, contain a very high loading of zinc particles to maintain a conductive film. The presence of zinc in electrical contact with iron effectively prevents the formation of anodic areas in the iron; the zinc becomes the anode and the iron the cathode. In the presence of an electrolytic solution, the zinc corrodes, thereby protecting the iron.

The protective features of zinc-rich coatings (or of galvanized steel) do not depend solely or even primarily on the continued consumption of zinc. To simplify the discussion, consider the zinc-rich coating to consist of an inorganic silicate matrix containing a high loading of zinc dust. The zinc corrosion process produces zinc oxides, hydroxides, carbonates, and other salts which fill up the highly porous matrix and create a barrier to further ingress of oxygen and moisture. This greatly limits the corrosion rate of zinc within the film.

The rate and type of corrosion products depend on several factors including the type of exposure environment. It has been hypothesized that the salt spray test is not appropriate for a zinc coating because the rate of reaction of zinc is too high and a protection barrier may not be formed as readily.[15] Newton and Guest[16] have shown by X-ray diffraction that in some instances the corrosion products formed in salt spray are significantly different from those formed under atmosphere exposure.

On the other hand, the zinc-rich primer is very effective in protecting films having breaks or discontinuities.

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*Temperature at which the noncrystalline portion of the polymer is transformed from a tough, rubbery material to a brittle glass-like material. (*Paint/Coatings Dictionary*, Federation of Societies for Coatings Technology, 1315 Walnut St., Philadelphia, PA, 19107, 1978.)

**Table 4—Stresses Produced in Salt Spray Testing**

| Stress Factor | Effect Compared to Outdoor Exposure |
|---|---|
| High chloride | See *Table* 3. |
| Constant wetness | More conductive surface.<br>No wet-dry cycling effects on film.<br>More water permeation and hydrolysis of film. |
| Absence of UV | No chalking, bond rupture, or light induced degradation. |
| Absence of ozone and sulfur dioxide | Less oxidative or acid-catalyzed degradation.<br>No increased corrosion of exposed metal. |
| Elevated temperature | More permeable to water, oxygen, and ions.<br>Loss of volatiles.<br>Temperature near $T_g$ for some films. |

Thus, if the iron at the holiday remains in electrical contact with the zinc, it will remain cathodic and not corrode. The salt spray test, as discussed previously, is a severe test of a coating's ability to protect at holidays. Zinc-rich coatings, therefore, are expected to perform well in this aspect of the salt spray test.

The salt spray test may also influence the pattern of corrosion observed. A zinc-rich coating will fail to protect at a holiday if the metal at that holiday is electrically isolated from the metallic zinc. In the salt spray test, there is an abundance of electrolyte solution, and the entire surface, including holidays, will tend to remain conductive. For less aggressive environments, there is a greater tendency to develop isolated areas not in electrical contact. This would result in more intense corrosion at isolated points as opposed to the more uniform corrosion pattern expected for a zinc-rich primer in a salt spray test.[15]

The elevated temperature of the salt spray is expected to have little effect on the inorganic zinc coating because of the stability of the silicate binder. For the organic zinc-rich primers, the effect of temperature would depend on the type of binder.

## EFFECT OF SALT SPRAY ON DIFFERENT BINDERS

The manner in which salt spray affects different types of coatings depends on the type and characteristics of that coating. The principal stresses, listed in *Table* 4, were described in general terms in the preceding section. This section describes how the salt spray test affects different generic coatings. For such an analysis the following may be derived:

(1) understanding of previous empirical results and conclusions.

(2) approach to establish limits of salt spray test for comparing performance.

(3) insight for design of improvements in testing procedure.

### Oil and Alkyd Coatings

These coatings are characterized by a drying or oxidation process which is required to form a tight crosslinked film. The oxidation occurs over a period of time. Normally after several days, the coating is sufficiently cured to be handled. As the oxidation process continues, the film becomes more brittle and the glass transition temperature ($T_g$) increases. Under the slightly elevated temperature of the salt spray test, the increased rate of oxidation and the possible loss of additives would cause the alkyd coating to become harder, more brittle, and more resistant to penetration of the film.

Malik and Aggarwal[17] have shown that the ion exchange capacity of linseed oil alkyds decreases linearly with time in the salt spray chamber. After 500 hours, the ion exchange capacity decreases by 30 to 50%, depending on the particular binder selected. The study also examined the effect of inhibitive pigments on the ion exchange capacity. Zinc chromate and red lead decreased the capacity considerably and provided the best corrosion protection.

Because of the prevalence of free acid groups and ester linkages, the oil and alkyd coatings are highly susceptible to alkali attack. Thus, the alkyd is expected to deteriorate rapidly at holidays or breaks in the film.

### Synthetic Thermoplastic Coatings (Vinyls, Chlorinated Rubber)

The binders for these types of coatings consist of plasticized high molecular weight linear polymers. The plasticizer, added to impart flexibility, also lowers the $T_g$ to about room temperature. In the salt spray, the elevated temperature would initially soften the film, making it more susceptible to penetration by water and ions. However, after a period of time some of the more volatile or soluble plasticizer would be leached out. The $T_g$ would be increased, making the film more brittle (not a liability in salt spray test) and more resistant to ion exchange.

The vinyls and chlorinated rubber coatings, unlike the alkyds, are quite resistant to alkali attack. Thus, overall these coatings would be expected to perform very well in the salt spray test. A recent Steel Structures Painting Council (SSPC) report[18] supports this claim for vinyls. Vinyls showed outstanding salt spray resistance (over 5000 hours) irrespective of the pigment used. High molecular weight chlorinated rubber coatings have also shown little deterioration after 3000 or more hours in the salt spray test.[19]

The high build versions of these coatings are composed of lower weight polymers and more film additives. They are considerably less effective in salt spray tests, with the number of hours before deterioration given in the range of 500–1000 hours.[20]

It is noted that vinyls are susceptible to degradation in the presence of ultraviolet light.[21] Therefore, the absence of UV in the salt spray is another factor which favors good performance of vinyls in this test.

**Table 5—Comparative Performance of Different Binders in Salt Spray**

| Binder | Stress[a] Factor | Binder Property or Effect | How[b] Affected | Overall[c] Comparison |
|---|---|---|---|---|
| Oil and Alkyd | High $Cl^-$ | Sensitive to undercutting | − | Slightly worse |
| | No UV | Sensitive to UV | + | |
| | High T | Brittle film | − | |
| Synthetic Thermoplastic | No UV | Sensitive to UV | + | Much better |
| | High T | Tighter film formed | + | |
| Thermoset (2 pack) | High $Cl^-$ | Resistant to undercutting | + | Better |
| | No UV | Sensitive to UV | + | |
| Water-borne | High $Cl^-$ | Leached additives form channels | − | |
| | Wetness | Film not completely cured | − | Much worse |
| | | Soft films near $T_g$ | − | |
| Zinc-rich Primer | High $Cl^-$ | Conductive surface provides cathodic protection at holidays | + | |
| | Wetness | Formation of protective oxide layer hindered | − | Varies |
| | No $SO_2$ | Zinc consumption not accelerated | + | |

(a) See *Table* 4.
(b) Performance in salt spray compared to "natural," unaccelerated exposure: + binder does better in salt spray; − binder does worse in salt spray.
(c) Relative ranking of class of coating binders in salt spray test compared to ranking in outdoor exposures.

### Thermosetting Two-Package Coatings (Catalyzed Epoxy and Urethane)

These coatings, when cured, are characterized by high molecular weight and a highly crosslinked structure. The coatings are relatively insensitive to the elevated temperature of the salt spray test, as the $T_g$'s are normally well above room temperature.

These coatings typically form good bonds with the metal substrate and are resistant to alkali attack, the urethane probably more so than the epoxy. For multicoat applications, there may be some intercoat adhesion problems. Such problems are more likely to occur in the field where a longer time may elapse between applications. In general, catalyzed epoxies and urethanes give very good salt spray resistance.

Epoxies are particularly vulnerable to UV degradation and, therefore, are favored in test methods where this factor is excluded. Epoxies are also noted for their ability to wet less than ideal surfaces. This fact would tend to make the salt spray result less dependent on the surface preparation than for less tolerant primers such as vinyl and inorganic zinc rich.

### Water-Borne Coatings

The type of water-borne coating most used for corrosion protection is latex, in which a film is formed by coalescence of emulsified coating particles. The early latex maintenance coatings exhibited extremely poor salt spray resistance, often failing within 20 to 50 hours. The oil-alkyds, which they were intended to replace, frequently lasted up to several hundred or a thousand hours before rusting became evident. In outdoor fence and service testing, however, many of these latex coatings (e.g., acrylic latex) were providing performance comparable to or superior to the oil alkyds. It became evident that the salt spray test had a particularly devastating effect on the latex coating systems, which was either absent or compensated for in natural atmospheric exposures.

The poor performance of latex coatings in the salt spray was an important factor in retarding the growth of this market.[22] Apparently, many of the potential users of the latex coatings required a certain minimum salt spray performance, based on their experiences with solvent-borne coatings. Because of this attitude, at least one major latex supplier decided to investigate the factors that influence latex performance in salt spray. It was decided to direct the R&D effort at improving the salt spray resistance of the coating, since this was what the customer required. It was presumed that any changes in formulation would not degrade its outdoor performance.

The latex coatings perform poorly in salt spray testing for several reasons. The coatings contain a number of additives such as emulsifying agents, coalescing aids, surfactants, and wetting agents.[23] These are necessary to insure good film formation, but once the film is formed, they often have a detrimental effect on performance. Under atmospheric conditions, they may be gradually leached out and washed away. In the salt spray chamber, however, they provide channels for penetration of water and ions, leading to premature deterioration.

Another important factor is the effect of the elevated temperature of the test. At this temperature, many latex coatings are above the $T_g$ and exhibit soft films. The coating is then more susceptible to erosion and hydrolysis. In addition, the rates of ion penetration and leaching of film additives will be increased. In the salt spray test, any substance leached out from the film can be immediately replaced with chloride and sodium ions.

It is claimed that latex coatings perform comparatively well over hand-cleaned steel. This claim is somewhat surprising because of the poor wetting ability and high surface tension of water. A related fact is the observation that latex coatings may undergo the phenomena of early rusting and/or flash rusting when applied over blast-cleaned steel.[22] The blast-cleaned steel is a very active surface, which is very sensitive to moisture introduced either from the application of a water-borne film or from condensation through a thin, poorly coalesced latex film.

Over the last several years the performance of latex coatings in salt spray tests has improved dramatically. As with any other broad class of coatings, the actual ratings will vary over a wide range. Several latex coatings are reported to last over 1000 hours before onset of rusting. Almost all of these salt resistant latexes require a certain amount of inhibitive pigmentation. In choosing pigments for latex coatings, it is necessary to achieve a balance between early resistance (favoring more soluble pigments) and long term resistance (favoring less soluble pigments). Such choice may be influenced by whether the objective is a coating for a salt spray test or for outdoor performance.[22]

### Zinc-Rich Primers

The mechanism for corrosion of zinc-rich coatings was described earlier.[24] Available data indicate that certain inorganic zinc-rich primers can last 10,000 hours or more without significant rusting. Scribed panels may give a 10 rating (no rusting) for 2000–3000 hours. Many specifications include 1000-hour minimum no-rust and no-scribe-undercutting criteria. Other experiments have shown that it may be possible to reduce the loading of zinc with conductive or nonconductive extenders and still retain a perfect rating after 2500–5000 hours.[25]

One-package inorganic zinc primers and organic zinc-rich primers have generally shown slightly inferior salt spray resistance to the two-package primers.[26] The results vary greatly with the particular coating system. An SSPC study has reported that after 6000 hours, all untopcoated organic zinc-rich primers had completely failed, whereas several two-package inorganics remained in good condition.[27] The performance of topcoated organic zinc-rich primers often is considerably better than for the primer alone. It is necessary to consider each generic type of organic-rich primer on its own merits and to recognize the possibility of large variations in performance among different proprietary and composition formulations within a given class.

The inclusion of multicoat systems in salt spray further complicates the analysis and interpretation. It introduces new variations such as intercoat adhesion, solvent blistering, and coating incompatibilities. This is particularly so in the situation where the topcoat is of a different chemical or generic type. For zinc-rich primers, in which the mechanism of protection entails formation of specific reaction products, the topcoat may in some cases degrade the performance of the system. For this article, we are particularly interested in studying the effects of one coat systems.

*Table* 5 summarizes the impact upon the various binders of the stresses produced by the salt spray test. The salt spray test greatly enhances the performance of synthetic thermoplastic and two part thermosetting coatings while severely degrading that of waterborne coatings. For oils and alkyds and zinc-rich primers there are competing processes; the overall performance varies with the specific coatings.

## SUMMARY

Short term test methods are required to decide among coatings designed for long-term durability. The principle of accelerated testing is the application of specific stresses (e.g., high temperature, high humidity, ultraviolet light) at elevated levels to produce accelerated aging or deterioration. The most important accelerated test for corrosion of steel coatings is the salt spray test, in which a fine mist of salt water is sprayed onto the surface. The background, test variations, and extent of usage of the salt spray test are described.

The principal stress is the presence of a salt solution on the surface. This results in a highly conductive surface and facilitates penetration of water and salt through the film to the coating-steel interface. The chemical and physical reactions to these stresses depend on the type of protection mechanism (i.e., barrier, inhibitive, sacrificial). Because of the high surface conductivity, any bare spots or holidays will be subject to accelerated attack; this effect is most pronounced in barrier coatings. For sacrificial coatings, the high conductivity enhances the ability of the zinc or aluminum in the coating to cathodically protect the bare steel. Most inhibitive pigments are not very effective in competing with chloride ion in complexing with iron and will provide reduced protection when chloride reaches the substrate. On the other hand, the likelihood of osmotic blistering is reduced because of the relatively high concentration of salt on the surface.

Performance in salt spray testing is also influenced by the properties of the coating binder, such as glass transition temperature, permeability, and chemical and physical stability of the polymer matrix. Solution vinyls, catalyzed epoxies, and certain zinc-rich primers tend to give very good salt spray resistance. Water-borne coatings, on the other hand, are expected and observed to do poorly in salt spray, while oils and alkyds fall in the poor to fair range. These tendencies are not necessarily expected for other accelerated tests or for outdoor testing, which produce different stresses and require separate analyses.

## ACKNOWLEDGMENTS

The authors thank Ms. Mildred A. Post and Dr. Mary E. McKnight, of the National Bureau of Standards, for their assistance in collecting and reviewing source materials.

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# Esterification of N(2-Hydroxyalkyl) Amides

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North Dakota State University[*]

It has been previously reported that N(2-hydroxyalkyl) amides esterify more rapidly than alcohols and was implied that the reaction was not acid catalyzed. The high rate of esterification has been confirmed and it has been shown that the esterification is not acid catalyzed. Furthermore, the 2-hydroxyalkylamides esterify more rapidly with benzoic acid than with octanoic acid reversing the order with octanol. Possible mechanisms are proposed to account for these unusual reactivities. It was also shown that some unidentified side reaction(s) occur.

## INTRODUCTION

Lomax and Swift[1] have reported that N(2-hydroxyalkyl) amides are esterified by carboxylic acids much more rapidly than alcohols. They also showed that polyfunctional 2-hydroxyalkylamides such as N,N,N′,N′-tetrakis-(2-hydroxypropyl) adipamide are effective crosslinkers for carboxylic acid functional polymers. The film properties of such crosslinked polymers were said to be comparable to those obtained when HMMM type (highly methoxymethylated melamine) resins were used with acid catalysts as crosslinkers for the same polymers. The detergent resistance of the hydroxyalkylamide crosslinked films was markedly superior. The crosslinkers have the advantage that the reaction by-product is water so that volatile loss is minimized and no formaldehyde is emitted. However, relatively high curing temperatures were required (30 min at 150°C) and the crosslinking reaction was not catalyzed by "conventional" acid and base catalysts.

Lomax and Swift offered no explanation of the high reactivity and lack of catalysis of the 2-hydroxyalkylamides. It seemed possible that a greater understanding of the reactivity might provide a basis for designing some related type crosslinking agents which would permit curing at lower temperatures.

## EXPERIMENTAL

### N,N,N′,N′-Tetrakis-(2-Hydroxyethyl)Adipamide, I

Amide I was synthesized from dimethyl adipate and N,N-di(2-hydroxyethyl) amine by the method of Swift and Cenci.[2] The product was recrystallized from methanol, m.p. 124–126°C (lit[1] 120–122°C). The structure was confirmed by IR and NMR.

### N,N′-bis(2-hydroxyethyl)-N,N′-dimethyl Adipamide, II

Amide II was synthesized from dimethyl adipate and N-(2-hydroxyethyl)-N-methylamine by the same procedure. The product was recrystallized from chloroform/ethyl acetate, m.p. 78–80°C (lit[1] 77–79°C). The structure was confirmed by IR and NMR.

### N-(2-hydroxyethyl)-N-methyl Acetamide, III

A solution of 39.3 g (0.5 mole) of acetyl chloride in 300 mL of toluene was added over a six hour period to a well-stirred mixture of a solution of 37.6 g (0.5 mole) N-(2-hydroxyethyl)-N-methylamine and 69.1 g (0.5 mole) $K_2CO_3$ in 250 mL of $H_2O$ and 250 mL of ether. The reaction mixture was allowed to stand overnight; then the aqueous layer was separated. The organic layer was washed with water. The combined aqueous layers

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were dried, extracted with methanol, and filtered. Residual amine was removed by treating the filtrate with Amberlite® IR-120. After drying over anhydrous $MgSO_4$, the solvent was distilled off. The crude product was vacuum distilled to give 41 g (70%) of acetamide III, b.p. 102–105°C/0.13 mm (lit[3] 84–86°C/0.05 mm); $\eta_D^{26}$ 1.4690 (lit[3] $\eta_D^{26}$ 1.4672). IR (neat) $cm^{-1}$ 3320 (OH), 1625 (C = O); NMR ($CDCl_3$) $\delta$ ppm: 2.1 (s,3H,$CH_3CO$); 2.9–3.1 (d,3H,$CH_3N$); 3.3–3.9 (m,4H,$\overset{\text{O}}{\overset{\|}{\text{C}}}\text{NCH}_2\text{CH}_2\text{O}$); 4.4 (s,1H, OH).

### N-(2-hydroxyethyl)-N-methyl Benzamide, IV

The same procedure was used to prepare IV except that the product was in the organic layer. The crude product was purified by vacuum distillation to yield 65% of benzamide IV; b.p. 140–144°C/0.15 mm; IR (neat) $cm^{-1}$ 3350 (OH), 1620 (C = O); NMR ($CDCl_3$) $\delta$ ppm = 3.05 (s,3H,$CH_3N$); 3.1–3.9 (b,5H,$CH_2CH_2OH$), 7.4 (s,5H,Ph). The NMR agrees with that reported in the literature.[4]

### Amide Esters of N-2-hydroxyethyl-N-methylamine

In order to have reference IR and NMR spectra, octanoate and benzoate esters of amides III and IV were prepared by reacting the amides with octanoyl chloride and benzoyl chloride, respectively. For example, 2-(N-acetyl-N-methylamino) ethyl octanoate was synthesized as follows: a solution of 3.51 g (0.03 mole) of III, 3.15 g (0.03 mole) of triethylamine and 50 mL of $CH_2Cl_2$ was cooled in an ice bath and 4.88 g (0.03 mole) of 1-octanoyl chloride in 20 mL of $CH_2Cl_2$ was added over 30 min. After addition was complete, the mixture was allowed to stir for an additional two hours at room temperature. The triethylamine hydrochloride was removed by filtration. The filtrate was washed with 100 mL portions of $H_2O$, 5% NaOH, 1 N HCl and $H_2O$. The solution was dried over $MgSO_4$ and the solvent removed. The other amide esters were synthesized by analogous procedures. The IR and NMR spectra were as follows:

2-(N-acetyl-N-methylamino) ethyl octanoate
IR (neat) $cm^{-1}$ 1725 (COO); 1640 (CON).
NMR ($CDCl_3$) $\delta$ ppm: 0.7–1.9 (m,13H,$CH_3(CH_2)_5$); 1.95–2.6 (m,5H,$CH_3CO$ and $CH_2COO$); 2.9–3.1 (d,3H, $NCH_3$), 3.5–3.8 (t,2H,$NCH_2$); 4.2–4.4 (t,2H,$OCH_2$).

2-(N-acetyl-N-methylamino) ethyl benzoate
IR (neat) $cm^{-1}$ 1725 (COO); 1635 (CON).
NMR ($CDCl_3$), $\delta$ ppm: 2.1 (s,3H,$CH_3CO$); 2.9–3.2 (d,3H,$NCH_3$); 3.6–3.9 (t,2H,$NCH_2$), 4.4–4.6 (t,2H, $OCH_2$); 7.3–7.7 (m,3H,Ph); 7.8–8.2 (m,2H,Ph).

2-(N-benzoyl-N-methylamino) ethyl octanoate
IR (neat) $cm^{-1}$ 1730 (COO), 1630 (CON).
NMR ($CDCl_3$) $\delta$ ppm: 0.7–1.8 (m,13H,$CH_3(CH_2)_5$); 2.1–2.5 (m,2H,$CH_2CO$), 3.1 (s,3H,$NCH_3$); 3.4–3.8 (b,2H,$NCH_2$); 4–4.4 (b,2H,$OCH_2$), 7.4 (s,5H,Ph).

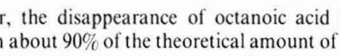
2-(N-benzoyl-N-methylamino) ethyl benzoate
IR (neat) $cm^{-1}$ 1715 (COO), 1620 (CON).
NMR ($CDCl_3$) $\delta$ ppm: 3.1 (s,3H,$NCH_3$), 3.6–4.1 (b,2H,$NCH_2$), 4.3–4.8 (b,2H,$OCH_2$), 7.2–7.7 (m,8H,Ph), 7.9–8.3 (m,2H,Ph).

## ESTERIFICATION RATE STUDIES

Esterifications were carried out using 0.12 equivalents of alcohol and 0.12 equivalents of carboxylic acid in 120 mL of xylene. When catalyst was used, 0.78 meq of p-toluene sulfonic acid (p–TSA) was added. The solution of alcohol in xylene was heated to reflux temperature, then the carboxylic acid was added quickly with stirring. Zero time was taken to be when addition of the carboxylic acid was finished. Water was removed azeotropically with a Dean-Stark trap. One mL samples were withdrawn periodically by syringe and titrated with standardized alcoholic NaOH. The amount of water collected in the Dean-Stark trap was also recorded. After esterification was stopped, the xylene was evaporated off under vacuum, the residue dissolved in $CH_2Cl_2$ and washed with 5% NaOH and with $H_2O$. The organic layer was dried over $MgSO_4$ and the solvent evaporated. The NMR spectrum of the residue was compared with the NMR spectrum of the authentic samples.

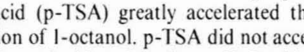
## RESULTS AND DISCUSSION

Initial studies of the esterification of N,N,N′,N′-tetrakis (2-hydroxyethyl) adipamide, I, and N,N′-bis(2-hydroxyethyl)-N,N′-dimethyl adipamide, II, compared with 1-octanol confirmed the observations of Lomax and Swift.[1] Equal equivalents (0.76 equiv/L) of 2-hydroxyalkylamide and 1-octanoic acid were reacted in refluxing xylene while removing the water formed by azeotropic distillation. Carboxylic acid disappeared substantially more rapidly with both I and II than with octanol.



$$(\text{HOCH}_2\text{CH}_2)_2\text{N}\overset{\text{O}}{\overset{\|}{\text{C}}}-(\text{CH}_2)_4\overset{\text{O}}{\overset{\|}{\text{C}}}\text{N}(\text{CH}_2\text{CH}_2\text{OH})_2$$

I



$$\text{HOCH}_2\text{CH}_2\overset{\text{CH}_3}{\overset{|}{\text{N}}}-\overset{\text{O}}{\overset{\|}{\text{C}}}(\text{CH}_2)_4\overset{\text{O}}{\overset{\|}{\text{C}}}\overset{\text{CH}_3}{\overset{|}{\text{N}}}\text{CH}_2\text{CH}_2\text{OH}$$

II

However, the disappearance of octanoic acid levelled off when about 90% of the theoretical amount of COOH had reacted. The amount of water collected approached the theoretical amount. Thus, it appeared that some side reaction occurred. Addition of 5 meq/L para toluene sulfonic acid (p-TSA) greatly accelerated the rate of esterification of 1-octanol. p-TSA did not accelerate the esterification of either 2-hydroxyalkylamide. During reaction of 2-hydroxyalkylamides in the presence of p-TSA, the disappearance of COOH levelled off at about 85% theoretical and increasing the p-TSA concentration to 6.7 meq/L further reduced the extent of loss of carboxylic acid to about 75% theoretical. When either I or II were refluxed in xylene without the octanoic acid, it was found that water was slowly evolved and polymeric products precipitated from the solutions.

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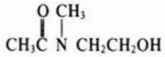
The tetrafunctional amide I is not completely soluble in refluxing xylene. As a result, the initial rate of esterification is slow until sufficient amide has reacted to achieve miscibility. Therefore, further work was done with N-(2-hydroxyethyl)-N-methyl acetamide, III. Esterification of III was studied with both 1-octanoic acid and



$CH_3C(=O)N(CH_3)CH_2CH_2OH$

III

benzoic acid with and without p-TSA in comparison with 1-octanol. The esterifications of this hydroxyalkylamide also levelled off somewhat below full conversion. In the case of III plus octanoic acid, the NMR spectrum was identical with that of the authentic octoate ester of III. With benzoic acid, the NMR spectrum of the product showed the presence of a very minor amount of benzamide and octanoic ester groups. III reacted much more rapidly than 1-octanol in the absence of catalyst. Addition of p-TSA led to slightly slower reaction with III but greatly increased the reaction rates with 1-octanol.

The reactions followed second order kinetics through 80-90% disappearance of carboxylic acid. This was demonstrated by the linearity of a plot of $x/A_0(1-x)$ [where x is fraction of carboxylic acid reacted and $A_0$ is initial concentration in moles/L] versus time.[5] The rate constants given in *Table* 1 were obtained by least squares calculation of the slope of the line.

As can be seen in *Table* 1, both octanoic and benzoic acids react more rapidly with hydroxyalkylamide III than with octanol without catalyst. However, octanoic acid reacted more rapidly with octanol than did benzoic acid while the reverse was true with the amidoalcohol.

A possible explanation of the reactivities is illustrated in Scheme I.

Scheme I

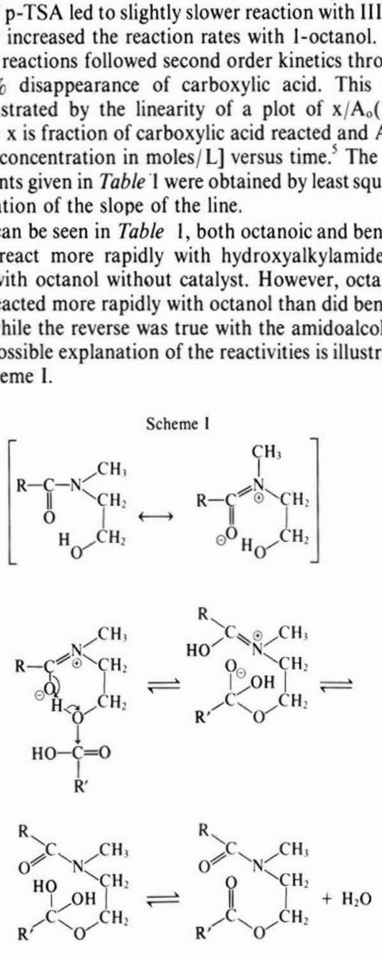


**Table 1—Second Order Rate Constants For Esterification of 1-Octanol and N-(2-hydroxyethyl)-N-Methyl Acetamide (III) with Octanoic and Benzoic Acids in Refluxing Xylene While Azeotropically Removing Water**

| Alcohol | Acid | Catalyst | k(L mol$^{-1}$min$^{-1}$) × 10$^4$ |
|---|---|---|---|
| 1-octanol | octanoic acid | — | 15 |
| | octanoic acid | p-TSA | 1,000 |
| | benzoic acid | — | 2.5 |
| | benzoic acid | p-TSA | 640 |
| N-(2-hydroxyethyl) N-methyl Acetamide (III) | octanoic acid | — | 320 |
| | octanoic acid | p-TSA | 280 |
| | benzoic acid | — | 660 |
| | benzoic acid | p-TSA | 500 |

The resonance of the amide group can result in a significant negative charge on the carbonyl oxygen. The simultaneous breaking of the hydroxyl OH bond and formation of the O—C bond with the carboxylic acid would be expected to favor such an addition as compared with a similar reaction with a simple alcohol.

When octanol reacts with a carboxylic acid, the rate limiting step is the addition of the alcohol to the carboxylic acid to form the tetrahedral intermediate rather than the loss of water. Since the formation of the tetrahedral intermediate with benzoic acid involves loss of conjugation of the carbonyl group with the aromatic ring, the energy requirement for the formation of the tetrahedral intermediate would be greater than with octanoic acid. Thus, the esterification proceeds more slowly with benzoic acid than with octanoic acid. In the case of a hydroxyalkylamide, addition of the hydroxy to the carboxylic acid to form the tetrahedral intermediate may be facilitated to the degree that it is not the rate controlling step and instead loss of water from the tetrahedral intermediate may be rate controlling. Loss of water from the tetrahedral intermediate in the case of esterification of benzoic acid leads to formation of a carbonyl group conjugated with an aromatic ring in the benzoate ester. This would facilitate the loss of water as compared with the loss of water in the reaction with octanoic acid. The more rapid esterification of 2-hydroxyethylamides with benzoic acid is consistent with this hypothesis. Further work would be required to verify the proposed mechanism.

The failure of strong acid (p-TSA) to catalyze the esterification implied by the results of Lomax and Swift[1] and confirmed in these studies (see *Table* 1) is surprising. We have not been able to find any other example in the literature of an esterification reaction that is not acid catalyzed. Acid catalyzed esterification has been extensively studied.[6] The reaction is believed to proceed via the protonation of the carboxylic acid by a specific acid catalyst.

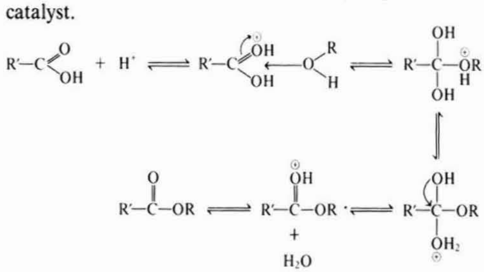
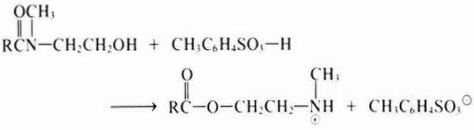


**Table 2—Second Order Rate Constants for Esterification Of N-(2-hydroxyethyl)-N-Methyl Benzamide, IV, In Refluxing Xylene While Removing Water Azeotropically**

| Acid | Catalyst | $k(L\ mole^{-1}min^{-1}) \times 10^4$ |
|---|---|---|
| Octanoic | — | 90 |
| | p-TSA | 94 |
| Benzoic | — | 170 |
| | p-TSA | 150 |

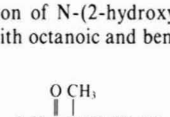
There are at least three possible explanations for the lack of catalysis by acid. First, p-TSA may cause an acyl shift to form the p-TSA salt of the corresponding 2-aminoalkylester. Many such rearrangements with acid have been reported.[7]



$$R\overset{O\,CH_3}{C\,N}-CH_2CH_2OH + CH_3C_6H_4SO_3-H \longrightarrow R\overset{O}{\overset{\|}{C}}-O-CH_2CH_2-\underset{\oplus}{\overset{CH_3}{\overset{|}{N}}}H + CH_3C_6H_4SO_3^{\ominus}$$

The possible occurrence of such an acyl shift was confirmed by monitoring the NMR spectrum of an equimolar solution of N-(2-hydroxyethyl)-N-methylbenzamide, IV, and p-TSA in (dimethylsulfoxide)-$d_6$ at 65-70°C. The singlet peak from the protons on the aromatic ring on the amide changes to the two sets of multiplets from the protons on the aromatic ring on an ester. Formation of the amine salt would effectively remove p-TSA as a specific acid catalyst. Second, amides are stronger bases than carboxylic acids,[8] the presence of an equal number of amide groups might, therefore, substantially reduce the concentration of protonated carboxylic acid. Third, amides hydrolyze in the presence of acid catalysts to form amines. If hydrolysis occurred, the amine would neutralize the p-TSA as a specific acid catalyst.

The esterification of N-(2-hydroxyethyl)-N-methylbenzamide, IV, with octanoic and benzoic acid was also studied.



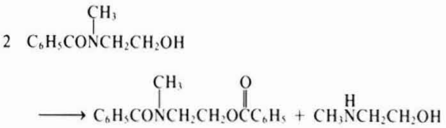
$$C_6H_5\overset{O}{\overset{\|}{C}}\,\overset{CH_3}{\overset{|}{N}}CH_2CH_2OH$$

IV

The apparent esterification rates were significantly slower than with the acetamide derivative. The calculated second order rate constants are shown in *Table* 2.

As can be seen by comparing data in *Tables* 1 and 2, the apparent esterification rate constants with the hydroxyalkylbenzamide are intermediate between those of the hydroxyalkylacetamide and octanol. The esterification levelled off significantly below theoretical conversion. The apparent esterification rates could have been significantly affected by a side reaction(s). Based on NMR analysis of the product obtained from the reaction with octanoic acid, about 15% of the benzamide groups had been converted to benzoate ester groups. The product from the reaction with benzoic acid was essentially identical with that of known benzoic ester of IV.

Amides III and IV were refluxed in xylene with and without p-TSA in attempts to identify possible side products. In the case of acetamide III, no water was evolved even after heating for 72 hours. However, with p-TSA approximately one mole of water was evolved per mole of amide. NMR analysis showed that the crude product was a very complex mixture. To date, we have not been successful in separating the mixture. In the case of benzamide IV, approximately one mole of water was evolved in 48 hours refluxing either with or without catalyst. NMR spectra again indicated that the crude product was a complex mixture. The mixture was separated into ether-soluble and water-soluble fractions. The NMR spectrum of the ether-soluble fraction (roughly 50%) closely corresponded to the NMR spectrum of the benzoate ester of benzamide IV. The NMR spectrum of the water soluble fraction indicated that it was still a complex mixture. If part of the benzamide reacted with itself to form the benzoate benzamide, N-2-hydroxyethyl-N-methyl amine would also be formed.



$$2\ C_6H_5CO\overset{CH_3}{\overset{|}{N}}CH_2CH_2OH \longrightarrow C_6H_5CO\overset{CH_3}{\overset{|}{N}}CH_2CH_2O\overset{O}{\overset{\|}{C}}C_6H_5 + CH_3\overset{H}{N}CH_2CH_2OH$$

However, the crude reaction product was not basic and only a trace of base was present in the water collected in the Dean-Stark trap. Further work would be required to identify the products.

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## SUMMARY

Previous reports of faster uncatalyzed esterification of 2-hydroxyalkylamides as compared with alcohols have been confirmed. The esterification is not catalyzed by acid. Possible explanations for the lack of catalysis have been proposed. It was also found that in contrast to ordinary alcohols, esterification of 2-hydroxyalkylamides proceeds more rapidly with benzoic acid than with octanoic acid. A possible mechanism to explain this difference has also been suggested. One or more side reactions also occur during esterification. Further work will be necessary to identify the products.

## ACKNOWLEDGMENT

Financial support from International Minerals and Chemicals Corporation is gratefully acknowledged. The authors also wish to thank Dr. Marshall Logue and Dr. S. Peter Pappas for their assistance in suggesting possible reaction mechanisms.

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# Polymer Compositions For Cationic Electrodepositable Coatings

P.I. Kordomenos and J.D. Nordstrom
Ford Motor Company*

Within the past 10 years a large number of patents have been issued dealing with the preparation and characterization of aqueous coating compositions which are electrodeposited on the cathode.

The scope of this paper is to summarize the information that is revealed in the patent literature in connection with the polymer compositions that have been used for cathodic electrodeposition systems. Specifically, this paper discusses the topic of ionizable groups and counterions and the synthetic techniques that have been employed to introduce these groups into polymer backbones. The chemical composition of the polymer backbone, their crosslinking and their effect on coating properties, are also discussed.

## INTRODUCTION

Electrodeposition has long been recognized as a superior method of applying primers to cars, truck bodies and parts because it permits the application of a protective coating to areas of the work piece that are not accessible to spray application. As pressures developed to reduce organic emissions from painting operations, the electrodeposition process delivered advantages because it utilizes water-based paints and applies that paint at a high efficiency.

In the past three years, a flurry of activity has occurred in the commercialization of cathodic electrodeposited primers for automotive uses because of significant advances shown in corrosion protection compared to earlier anodic systems.

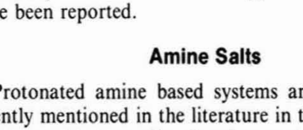
This paper surveys the recent patent literature on polymers that has been developed for cathodic electrodeposited coatings.

## IONIZABLE GROUPS AND COUNTERIONS

The cationic electrodeposition systems which have been described in the literature have different degrees of hydrophilicity ranging from soluble systems to emulsions, dispersions, or combinations of the above. The hydrophilic nature of these systems is primarily attributed to the ionizable groups contained in the electrodeposition resins. Several types of cationic groups have been reported.

### Amine Salts

Protonated amine based systems are the most frequently mentioned in the literature in the last 10 years. Work on this type of system is reported in a series of patents by Jerabek, Marchetti, and co-workers[1-4] in which they describe electrodeposition of dispersions having a $-N^{+}-H$ cation as the attractive vehicle. In general, the protonated amine groups exist either as end groups in the polymer,[3] or they are introduced randomly in the polymeric chain during a chain extension step.[5,6] The most frequently employed method of introducing protonated amine groups as end groups in a polymeric chain is the reaction of the oxirane ring of an epoxy polymer or copolymer with a monofunctional secondary amine and subsequent neutralization of the newly formed tertiary amine group with an organic acid.



A variety of amines has been reported[2] to be suitable for this type of reaction including dialkyl amines such as dimethylamine, diethylamine, dipropylamine, etc. The

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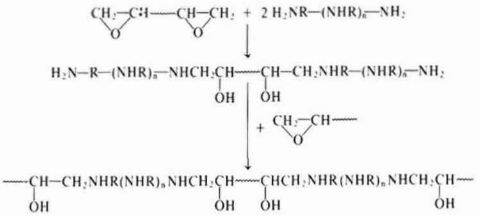
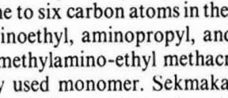
acids that are used for the neutralization of the amine groups include formic acid, acetic acid, or phosphoric acid. The extent of the neutralization depends upon the particular resin, and it is only necessary that sufficient acid be added to solubilize or disperse the resin.

Protonated amine groups can be introduced in the middle of the polymeric chain during a chain extension step. Belanger[7] and Anderson[8,9] prepared resinous electrodepositable compositions by adducting a polyepoxide resin with a polyamine, using an excess of polyamine, removing the unreacted polyamine, and reacting the adduct with a monoepoxide or monocarboxylic acid.



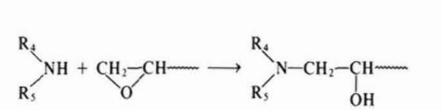
A variety of epoxy resins can be used in the above reaction with the most preferable being diglycidyl ethers of Bisphenol-A with epoxy equivalent weights of 450 to about 2000. The polyamines which are reacted with the epoxy resins contain at least two nitrogen atoms per molecule, at least three amine hydrogen atoms, and no other groups reactive with epoxide groups. The more preferred amines are the ethylene polyamines such as triethylenetetramine and tetraethylenepentamine. The monoepoxides that are used in this method are usually epoxidized hydrocarbons, epoxidized unsaturated fatty esters, monoglycidyl ethers of aliphatic alcohols, and monoglycidyl esters of monocarboxylic acids.

A different method of introducing protonated amine groups, at random, in the macromolecular chain has been reported by Anderson and Marchetti.[10] In their work they used ethylenically unsaturated aminoalkyl monomers, which they copolymerized with other types of ethylenically unsaturated monomers such as hydroxyethyl methacrylate, styrene, etc. The unsaturated aminoalkyl monomers were generally acrylate or methacrylate esters having one to six carbon atoms in the alkyl radical, such as the aminoethyl, aminopropyl, and aminohexyl esters. N, N-dimethylamino-ethyl methacrylate was the most frequently used monomer. Sekmakas and Shah[11] also used ethylenically unsaturated amine functional monomers of the following structure,



$$CH_2{=}\overset{X}{\overset{|}{C}}-\overset{O}{\overset{\|}{C}}-\overset{H}{\overset{|}{N}}-R_1-N\begin{matrix}R_2\\R_3\end{matrix}$$

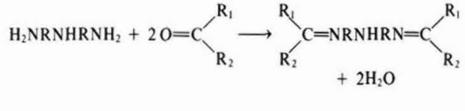
where X is hydrogen or methyl, $R_1$ is $C_1$-$C_4$ alkylidine, and $R_2$ and $R_3$ are $C_1$-$C_4$ alkyl, preferably methyl. The above monomer was copolymerized with an unsaturated amine adduct of an epoxy resin, which was prepared according to the following scheme:



where $R_4$ and $R_5$ are polymerized ethylenically unsaturated hydrocarbons such as in disoyaamine.

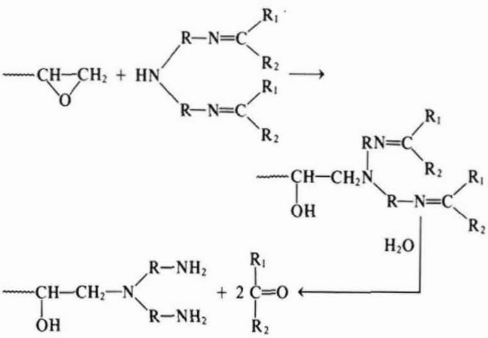
In all the above mentioned methods of introducing protonated amine groups in the macromolecular chain, the amines used were secondary or tertiary amines. However the relatively weak nature of these amines frequently results in poor dispersibility of these systems, especially at low levels of theoretical neutralization. For this reason in certain polymer systems it is desirable to incorporate primary amine groups which is extremely difficult to achieve in the case of amine-solubilized epoxy resins since primary amine groups readily react with epoxy groups.

Jerabek and co-workers[12,13] and McGinnis[14] prepared electrodepositable resins containing ketimine blocked primary amine groups. In their work, primary amine groups in polyamine compounds were converted to ketimines by reaction with ketones according to the following scheme:



$$H_2NRNHRNH_2 + 2\,O{=}C\begin{matrix}R_1\\R_2\end{matrix} \longrightarrow \begin{matrix}R_1\\R_2\end{matrix}C{=}NRNHRN{=}C\begin{matrix}R_1\\R_2\end{matrix} + 2H_2O$$

The above shown diketimine can be used to solubilize an epoxy functional resin and subsequently can be hydrolyzed to produce primary amine groups.

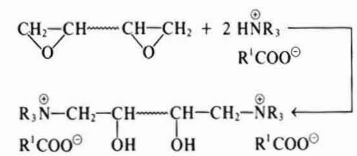


The ketimine formation was also used by Spencer[15] to block the primary amine groups of a polyamide.

## Onium Salts

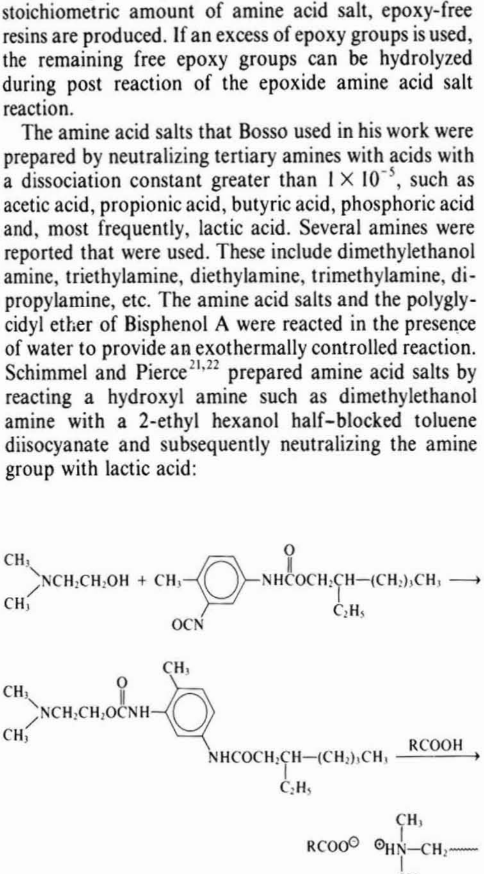
QUATERNARY AMMONIUM SALTS: As in the case of protonated amine salts, quaternary ammonium groups can be incorporated in the macromolecular chain, at random, as end groups, and in the middle as a result of chain extension.

Work on electrodeposition systems that contain quaternary ammonium salts as end groups was reported in a series of patents by Bosso, et al.[16-20] In this work, the quaternary ammonium groups were formed by reacting the oxirane rings of a polyglycidyl ether of Bisphenol A with an amine acid salt according to the following scheme:



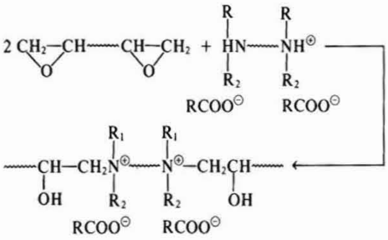
If the epoxide groups are reacted with at least the stoichiometric amount of amine acid salt, epoxy-free resins are produced. If an excess of epoxy groups is used, the remaining free epoxy groups can be hydrolyzed during post reaction of the epoxide amine acid salt reaction.

The amine acid salts that Bosso used in his work were prepared by neutralizing tertiary amines with acids with a dissociation constant greater than $1 \times 10^{-5}$, such as acetic acid, propionic acid, butyric acid, phosphoric acid and, most frequently, lactic acid. Several amines were reported that were used. These include dimethylethanol amine, triethylamine, diethylamine, trimethylamine, dipropylamine, etc. The amine acid salts and the polyglycidyl ether of Bisphenol A were reacted in the presence of water to provide an exothermally controlled reaction. Schimmel and Pierce[21,22] prepared amine acid salts by reacting a hydroxyl amine such as dimethylethanol amine with a 2-ethyl hexanol half-blocked toluene diisocyanate and subsequently neutralizing the amine group with lactic acid:



The above amine salt was then reacted with an epoxy resin to form quaternary ammonium salt groups.

Internally ionized quaternary ammonium salt groups containing polymers suitable for electrodeposition were synthesized by Schimmel.[23,24] His method of introducing ionizable groups in the macromolecular chain consisted of reacting a difunctional epoxy resin with a polyamine that contained at least two tertiary amine salt groups. The resulting polymer contained quaternary ammonium salt groups which were located along and towards the middle portion of the polymer backbone.



In addition to the positioning of the quaternary ammonium salt group in the macromolecule, a great deal of attention has been given by investigators to the type of counterion that is used for the solubilization of the electrodeposition resins. Conventional solubilization techniques which employ acetic or lactic acid result in a build up of the acid in the electrodeposition bath.

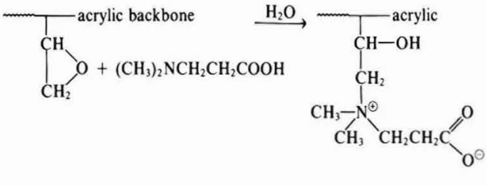
Recently, Buchwalter, et al.[25,26] reported on the synthesis of an aqueous dispersion of a quaternary ammonium carbonate containing polymer. According to their work, electrodeposition of such a resin is carried out without generating excess acid from the counterion since the carbonate ion is continuously evolved from the electrodeposition bath at the anode as carbon dioxide. They also claimed that quaternary ammonium carbonate containing polymers are also useful as feed resins for controlling the pH of aqueous dispersions of acidified cationic resins. Due to their relatively basic character when fed into the bath, the quaternary ammonium carbonate containing polymers react with the excess acid to form the corresponding quaternary ammonium salt of the acid releasing carbon dioxide. The synthesis of the quaternary ammonium carbonate salt was carried out by passing carbon dioxide into a dimethylethanol amine water solution. The dimethylethanolamine carbonate salt was then used to quaternize an epoxy terminated resin.

Carbonate counterions have also been used to solubilize polyamine resins.[27,28] However, Buchwalter, et al. claim that the quaternary ammonium carbonate containing resins have a distinct stability advantage over tertiary amine carbonate resins.

Recently, Hazan[29,30] used phosphoric acid to solubilize a tertiary amine containing acrylic-epoxy graft copolymer.

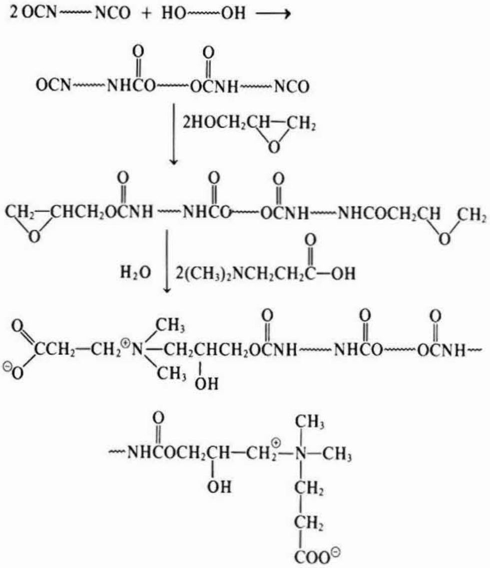
ZWITTERIONS: A different approach to the counterion problem, that is the build-up of acid in the electrodeposition bath, was reported by Wismer and Bosso.[31,32] According to their claim, water dispersible resins were obtained by introducing zwitterion groups in the polymer backbone. The zwitterions were synthesized by reacting an amino carboxylic acid with a base resin in a manner that the amino groups were chemically bonded to the resin molecule forming a quaternary ammonium group. The close proximity of the carboxylic acid group to the base group allowed the zwitterion to appear in a water medium as salt and, thus, solubilizing the resin without the presence of externally neutralizing acids. The base resin was reported to be any resin containing or reacted to contain at least one 1,2-epoxy group.

Among the specific systems that Wismer and Bosso used to incorporate zwitterion groups were acrylic backbones in which one of the building monomers was glycidyl methacrylate. The epoxy groups of the polymer was reacted with β-N, N-dimethylaminopropionic acid in the presence of water to result in the formation of the following compound:



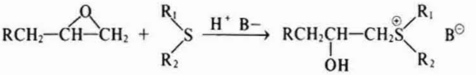
Zwitterions were also introduced in the monomer in the backbone of conventional epoxy resins.

Zwitterions containing polyurethanes were synthesized according to the following scheme:

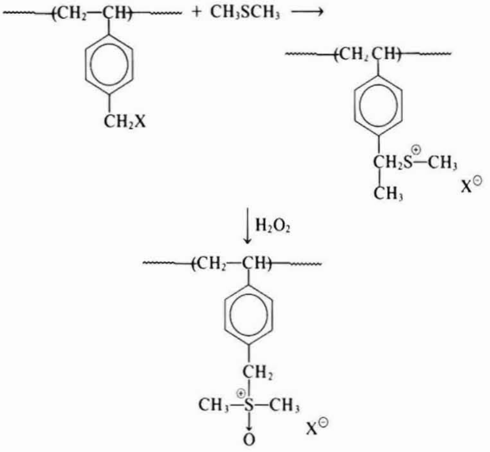


Sulfonium Salts: Sulfonium salt containing resins are prepared by reacting epoxy containing polymers with sulfides in the presence of acids.[33-37] The reaction is said to proceed at temperatures of 70-110°C. A variety of epoxy containing resins are described, including polyglycidyl ethers of polyphenols, epoxy ethers and epoxy esters of a variety of polyols, diepoxies of nitrogeneous heterocycles such as hydantoins and acrylic copolymers of glycidyl acrylate or methacrylate. The preferred acids include organic or inorganic acids with dissociation constants of $1 \times 10^{-5}$

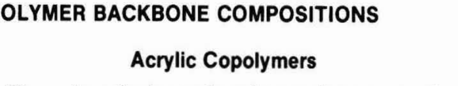
The reaction which is described is:



Another approach to sulfonium ion containing polymers is described[38] in which a structured latex is prepared by copolymerizing an active halogen containing unsaturated monomer, such as vinyl benzyl chloride or bromoethyl methacrylate. In this invention, a latex particle that contains the active halogen monomer on its surface is reacted with a nonionic nucleophile to produce the ion. When a sulfide is used as the nucleophile, a sulfonium ion is produced. This can be further modified by an oxidizing agent to yield a sulfoxonium ion. In another special case, a thiourea is the nucleophile to produce an isothiouronium containing group. The process is said to yield pH independent cationic groups.



Phosphonium Salts: Water dispersible quaternary phosphonium group containing resins are described by Bosso[39,40] who reacted epoxy group containing resins with phosphine/acid mixtures at moderately elevated temperatures. (No examples are given, however.) As in the case of sulfonium salt.



the acid is to have a dissociation constant greater than $1 \times 10^{-5}$.

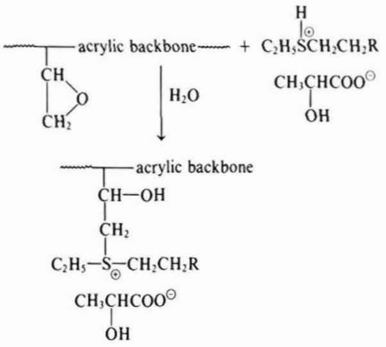
## POLYMER BACKBONE COMPOSITIONS

### Acrylic Copolymers

The early cationic acrylic polymers that were synthesized for electrodeposition applications were simple analogs of their aniomic counterparts with the carboxylic groups replaced with amine groups. Recently,[41-44] several new types of acrylic backbones have been synthesized that have some very distinct characteristics, making them especially useful for cathodic electrodeposition coatings.

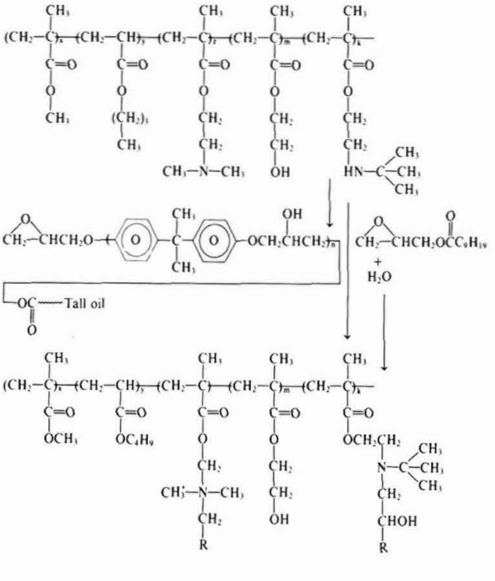
Anderson and Sturni[45] synthesized an acid solubilized carboxyl containing acrylic polymer that can be electrodeposited on the cathode. The polymer contained a variety of monomers including an unsaturated carboxylic monomer which in the presence of a solubilizing acid with a higher ionization constant apparently showed no proton activity and thus, no significant ionization. When the polymer was electrodeposited, the carboxyl groups were available as crosslinking sites or as catalysts for hydroxyl-melamine type of curing. Monomers that were used in this work included alkyl esters of acrylic or methacrylic acid, tertiary nitrogen containing alpha, beta-ethylenically unsaturated aminoalkyl monomers, unsaturated mono-olefinic or diolefinic hydrocarbons, etc.

Using a similar method, Minami, et al.[46] copolymerized ethylenically unsaturated monomers containing epoxy groups with vinyl or acrylic monomers to produce a polymer backbone with pendant epoxy groups. The epoxy groups were subsequently reacted with a secondary amine and neutralized with acid. Examples of epoxy containing monomers used in this work were glycidyl acrylate, glycidyl methacrylate, allylglycidyl ether, or N-glycidyl acrylamide. These monomers were copolymerized with styrene, substituted styrenes, and vinyl esters of alkanoic acid such as vinyl acetate, vinyl propionate and 1-18 carbons containing alkenyl acrylates and methacrylates. Jones[47] also described the preparation of an electrodeposition system based on a copolymer of methylmethacrylate, glycidylmethacrylate, 2-hydroxy ethylacrylate, and ethylacrylate. The polymer was solubilized by reacting the pendant groups with a sulfide-acid mixture according to the following scheme:



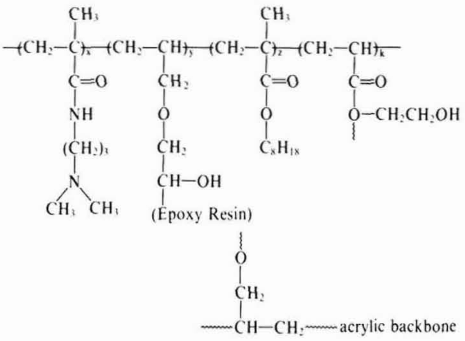
In the example given by Jones, R was a 2-ethylhexanol half-blocked TDI molecule which at elevated temperatures was unblocked to permit reaction with the hydroxyl groups and effect cure.

Hazan[29,48,49] synthesized graft copolymers of epoxides grafted onto acrylic backbones. The acrylic backbones were synthesized from alkyl, aminoalkyl and hydroxyalkyl acrylates, and methacrylates. The epoxides that were used for grafting were glycidyl esters of tertiary carboxylic acids and monoesters of Bisphenol A based epoxy resin. More specifically one of the systems that Hazan synthesized was a copolymer of methylmethacrylate, butyl acrylate, tertbutylaminoethyl methacrylate, dimethylaminoethyl methacrylate, and hydroxyethyl methacrylate. On this backbone was grafted half esterified Epon 1001 with tall oil fatty acids and glycidyl ester of epichlorohydrin and versatic acid 911 (Cardura E-10). This synthesis presumably took place according to the following scheme:



Where R is either the Cardura E-10 or the Epon 1001 tall oil backbone.

Rabi, et al.[28] also prepared graft copolymers of epoxy resins with acrylic backbones. His approach was to form first the diallyl ether of a diglycidyl ether of Bisphenol A and subsequently copolymerize this prepolymer with other acrylic monomers. One of the systems described presumably had the following structure:



This polymer was prepared from the following compositions:

| Monomers | Parts |
|---|---|
| Diallyl ether of Epon 1001 | 30 (64.5% solids) |
| Dimethyl aminopropyl methacrylamide | 18 |
| 2-Ethylhexyl methacrylate | 42 |
| Hydroxyethyl Acrylate | 10 |

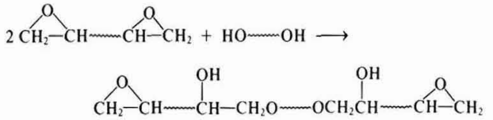
A similar system was synthesized by Sekmakas[11] who replaced the diallyl ether of Epon 1001 with the disoya amine adduct of Epon 1004. Acrylic epoxy copolymers were also synthesized by Tsou.[50]

### Epoxy Polymers and Copolymers

In the last five years a large and diverse class of macromolecules has been synthesized from epoxy group containing polymers and have been used in electrodeposition systems. The most frequently used epoxy group containing polymers were the well known polyglycidyl ethers of polyphenols such as Bisphenol A.[16,17,22,51]

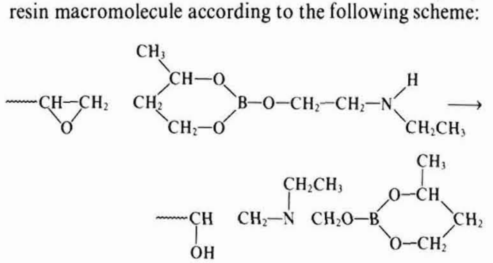
In many instances these resins have been used as such without further modifications other than the introduction of ionizable groups. However, in many cases the epoxy resins were modified by the introduction of certain groups or chain extenders to incorporate additional properties which must exist in an electrodepositable coating such as high throwing power, flexibility, fast curing, etc.

One such modification was described by Jerabek, et al.[52,53] who reacted diepoxides with polymeric diols to obtain chain extended epoxy resins. The reaction took place presumably according to the following scheme:



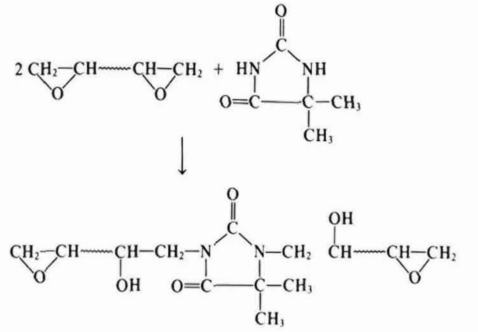
The chain extension was carried out in the presence of a tertiary amine catalyst. It was necessary to have primary hydroxyls on the diol, since with secondary hydroxyls the reaction conditions would have to be severe and would cause reaction of the hydroxyl groups of the epoxy resin, thus forming undesirable three dimensional structures. Both polyester and polyether diols were described. The improvements claimed for these extended epoxy resins were higher rupture voltage, improved flow, coalescence, and flexibility.

Another modification was performed by Bosso and Wismer[54-56] who introduced boron atoms in the epoxy resin macromolecule according to the following scheme:



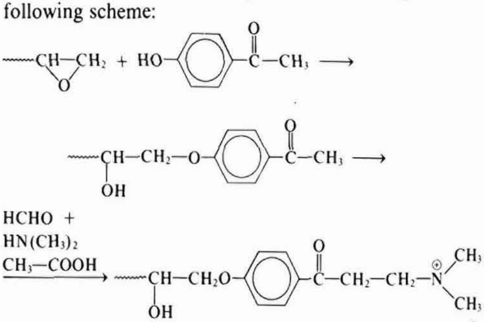
The 2-(beta-ethylaminoethoxy)-4-methyl-1,3,2-dioxaborinane was prepared from 3 moles of 1,3-butane diol, 3 moles of 2-ethylaminoethanol, and 1.5 moles of $B_2O_3$. According to their claim, the presence of boron in the electrodeposited film catalyzed the curing of the resin which apparently took place through the free epoxy groups.

Chain extension of epoxy resins was also reported by Bosso[57] who used N-heterocyclic compounds containing at least two groups reactive with epoxy groups. The reaction took place according to the following scheme:



The heterocyclic ring containing polymers was found to give superior coatings showing high corrosion resistance, reduced yellowing upon aging, and, in some instances, higher throwing power.

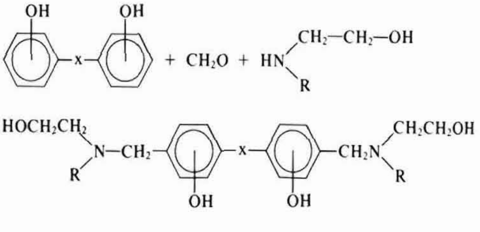
Polycondensation products of epoxy resins were synthesized by Marx and Gulbins[58] using p-hydroxyacetophenone. The adduct of the epoxy resin and the p-hydroxyacetophenone was further reacted with formaldehyde and a secondary amine according to the following scheme:



It was claimed that these polycondensation products had superior adhesion and corrosion protection properties in comparison to conventional epoxy resins.

### Mannich Bases

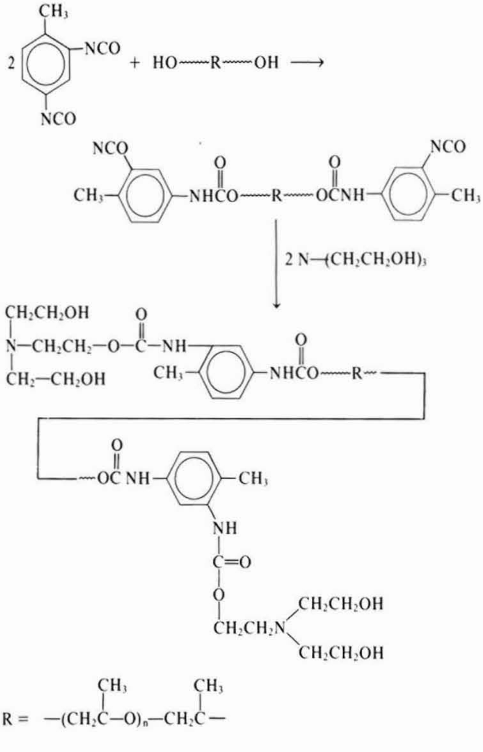
A series of patents[59-62] describe resin systems suitable for cathodic electrodeposition which are Mannich bases derived from the reaction of condensed phenolic compounds with hydroxyl containing secondary amines and formaldehyde.



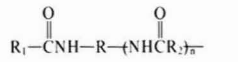
These are said to have the advantage of being capable of deposition at a pH range of 7 to 9, but have the disadvantage of giving off dialkyl amines when heated. The latter disadvantage is said to be overcome by combining epoxy containing resins which contain blocked isocyanate groups on the polymer backbone.

### Polyurethanes

The patent literature contains many references to techniques for synthesizing water soluble or water dispersible urethane resins. However, very few efforts have been made to use such polymers in electrodeposition coating systems. Matsunaga, et al.[63] was the first to synthesize cationic thermosettable urethane resins. The system described was prepared from an isocyanato terminated polyurethane prepolymer by reacting the free isocyanato groups with a tertiary amine which had at least three hydroxyl groups. The polyurethane prepolymer was prepared by reacting a diisocyanate with a diol at a ratio of NCO/OH = 1.5—2.0. One of the examples given was synthesized according to the following scheme:

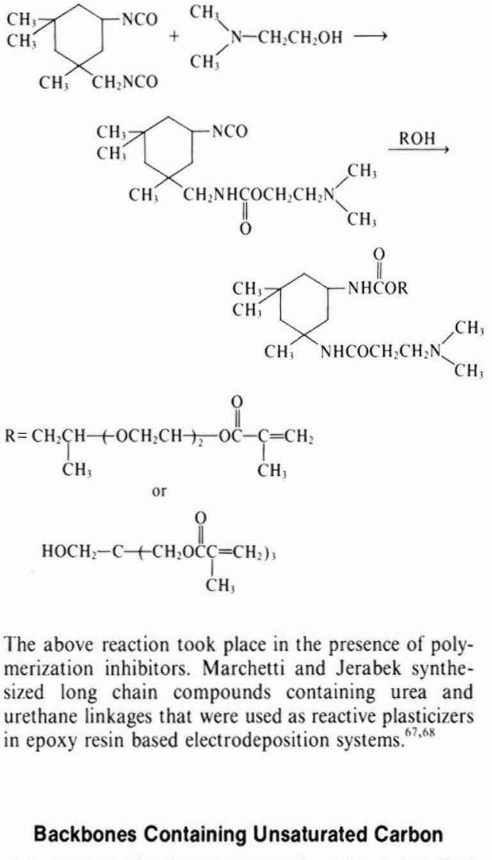


Pampouchidis, et al.[64-66] also synthesized urethane based cationic electrodeposition resins that had the following structure:



$$R_1-\overset{O}{\overset{\|}{C}}NH-R-(NH\overset{O}{\overset{\|}{C}}R_2)_m$$

Where m was 1, 2, or 3, R was the backbone of a diisocyanate that was partially reacted with a dialkylalkanolamine $R_1$ and with a monohydroxylalkylacrylate or methacrylate or similar compound having OH and SC = CR functionality. In one of the examples, one mole of isophorone-diisocyanate was reacted with one mole of dimethylpropanolamine and the remaining isocyanato groups were reacted with 0.5 moles of tripropyleneglycolmonomethacrylate and 0.5 moles of pentaerythritoltrimethacrylate according to the following scheme:

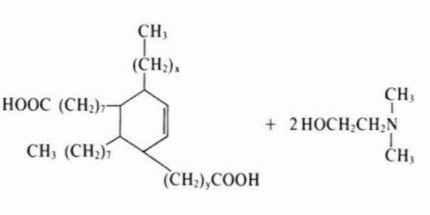


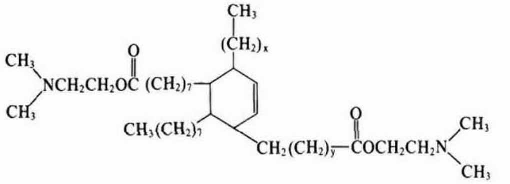
The above reaction took place in the presence of polymerization inhibitors. Marchetti and Jerabek synthesized long chain compounds containing urea and urethane linkages that were used as reactive plasticizers in epoxy resin based electrodeposition systems.[67,68]

### Backbones Containing Unsaturated Carbon

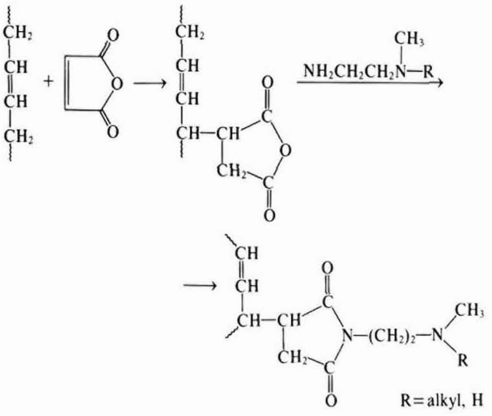
A number of polymer systems have been described which utilize carbon-carbon unsaturation in the curing mechanism. In most cases, the well known autoxidation cure is assumed to occur with resin systems incorporating vegetable fatty acid residues or polybutadiene backbones.

In an early, and chemically simple system[69] a dimerized linseed fatty acid is esterified with a dialkyl ethanolamine, neutralized with phosphoric acid, deposited at the cathode and cured at 350°F without an additional crosslinking agent.

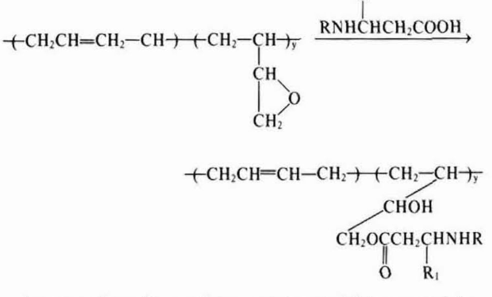




Unsaturated fatty materials, such as linseed oil or polybutadienes have been maleinized (a common reaction for anodic electrodepositable resins) followed by the reaction of dialkylaminoalkyl amines to form amine functional malemides.[70]

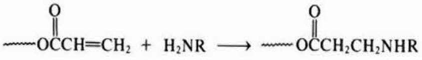


An epoxidized polybutadiene was reacted with an amino acid[71] to yield an oxidizable resin system which was deposited at a cathode.



In a number of inventions, unsaturated fatty materials, such as linseed oil, dehydrated castor oil, and dimerized fatty amines are copolymerized with vinyl monomers to yield coating resins. In one case, the comonomer is an epoxy containing material, which is further reacted with an amino compound in order to introduce cationic sites.[72] In another case, an unsaturated fatty diamine is extended with an epoxy resin and then copolymerized with styrene.[73] An early patent describes the copolymerization of a maleinized linseed oil with vinyl toluene, followed by conversion of the anhydride structure to an amino ester.[27]

In a more unusual crosslinking mechanism, utilizing unsaturated carbon bonds, polyamine resins are codeposited with polyfunctional unsaturated carboxyl crosslinking agents.[14,74] Presumably, the crosslinking mechanism is via Michael Reaction.



$$\sim\!\mathrm{O}\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}\mathrm{CH{=}CH_2} + \mathrm{H_2NR} \longrightarrow \sim\!\mathrm{O}\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}\mathrm{CH_2CH_2NHR}$$

In one example, hexanediol diacrylate is used to cure the reaction product of a Bisphenol A type epoxy resin with the diketimine blocked diethylene triamine, at 150°C, with which it is codeposited. Primary amine groups are generated by hydrolysis of the ketimine upon dilution in the electrodeposition bath.

Pampouchidis[75] reacted the hydroxyl groups of an amine-epoxy adduct with an alpha, beta-unsaturated monoisocyanate in order to synthesize an electrodepositable coating that is thermosetting without addition of crosslinking component.

## CROSSLINKERS

Several crosslinking mechanisms have been employed in cationic electrodeposition systems. Suitable crosslinking agents for the previously mentioned polymer backbones include melamine/formaldehyde, benzoguanamine/formaldehyde and urea/formaldehyde resins.[76-78] Blocked isocyanates have been used quite extensively.[79-86] Usually a trifunctional blocked isocyanate or isocyanate prepolymer was mixed with a hydroxyl or amine functional polymer and then codispersed in a water/acid solution. In many cases, half-blocked diisocyanates were reacted with a hydroxyl-functional backbone resulting in a self-crosslinking system.[87,88]

Phenolic resins have been reported to be compatible with epoxy-urethane systems[89] and produce well cured coatings. A UV curable electrodeposition resin was synthesized[90] from an aminomodified epoxy acrylate which was dissolved in a polyfunctional acrylate monomer. A method of producing an electrodeposition system that reduces or eliminates curing has been reported.[91] This system provided simultaneous electrodeposition and crosslinking.

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# Weathering Characteristics Of Finished Wood-Based Panel Products

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Outdoor exposure studies on the performance of several finish systems on four wood-based panel products and one solid wood substrate showed that enhanced protection was found with two- and three-coat finish systems. The four panel products evaluated (hardboard siding, roughsawn redwood plywood, smooth Douglas-fir plywood, and aspen waferboard) exhibited varying degrees of substrate and finish performance. Aspen waferboard had the poorest overall performance, primarily due to particle delamination and the presence of white-rot decay organisms. Best overall finish performance was found for hardboard siding, especially for opaque paint finish systems. A semitransparent oil stain offered the least protection of all finish systems studied, due to its partial transparency to ultraviolet light. Good overall performance of all-acrylic latex finish systems on all substrates was clearly demonstrated.

## INTRODUCTION

Wood-based products represent almost half of the total surface area of materials used as exterior siding for dwellings and other structures in the United States. In 1978, over two billion square feet of hardboard and plywood siding were used on exterior surfaces.[1] Additional wood products used as exterior siding include solid lumber, waferboard, plywood composites, and medium-density fiberboard. All these siding materials are usually finished in some way (paint, stain, varnish) for outdoor weathering protection and for aesthetic effects.

A wide variety of finishes are applied to wood-based siding products.[2-6] Semitransparent stain finishes[7] are designed to emphasize wood grain and texture characteristics. Solid color stains (also called opaque, hiding, or heavy-bodied) hide wood grain and color while letting texture show. Two- and three-coat house paints form a highly durable coating in addition to hiding grain and some texture. These finish systems offer various degrees of protection against outdoor weathering.[6,8,9]

Several publications have described the weathering performance of finishes on different substrates.[2,4,5,10-12] Review papers on wood finishing and weathering have described past work in this rapidly changing area.[8,9,13,14] Despite this amount of research effort, a great deal of misunderstanding and misconception exists about finishing practices for wood-based products. Little comparative information about finish system performance and substrate interaction effects is available.

The primary objective of this study was to obtain information and to develop an understanding of the weathering performance of representative top-quality finishing systems on various wood-based substrates representing a selection of currently available materials. The effects of finish/substrate interactions and film thickness (number of coats) were emphasized. It is intended that the results of this study would serve as a base for future, more detailed studies in which climatic differences and effects of surface pretreatments would be addressed.

## MATERIALS AND METHODS

### Wood Substrates

Substrates chosen for this study are described in *Table* 1. The unprimed hardboard, roughsawn redwood plywood, and smooth Douglas-fir plywood represent materials whose use is increasing rapidly.[4,12] The aspen waferboard is finding increased use for structural sheathing and has been promoted for possible siding application. Southern pine bevel siding was included for comparative purposes

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The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin.

**Table 1—Substrate Characteristics For Outdoor Exposure Performance Study**

| Substrate[a] | Thickness (in.) | Surface Texture |
|---|---|---|
| Hardboard siding (HB)........ | 0.375 | Simulated wood grain |
| Redwood plywood (RP)....... | 0.625 | Roughsawn T 1-11 |
| Douglas-fir plywood (DFP) ... | 0.25 | Smooth, sanded |
| Aspen waferboard (WB) ...... | 0.25 | Smooth |
| Southern pine bevel siding (SP) ................ | 0.5 | Smooth |

(a) All substrates were unprimed, untreated commercial products; the southern pine was cut from lumber.

**Table 3—Finish Systems Used in Outdoor Exposure Studies**

| Finish System Number | Description | Application |
|---|---|---|
| 1 | Semitransparent oil stain | One coat |
| 2 | Solid color acrylic latex stain | One coat |
| 3 | Solid color oil stain | One coat |
| 4 | Acrylic latex house paint A | One coat left side,<br>Two coats right side |
| 5 | Acrylic latex house paint B | One coat left side,<br>Two coats right side |
| 6 | Alkyd primer paint<br>followed by<br>Acrylic latex house paint B | One coat<br><br>One coat left side,<br>Two coats right side |
| 7 | Water-repellent preservative<br>followed by<br>Alkyd primer paint<br>followed by<br>Acrylic latex house paint B | One coat<br><br>One coat<br><br>One coat |
| 8 | Water-repellent preservative<br>followed by<br>Alkyd primer paint<br>followed by<br>Acrylic latex house paint B | One coat<br><br>One coat<br><br>Two coats |

because this wood represents a substrate that often does not exhibit good finish performance.[6,13,14]

Single 4- and 8-foot sheets of substrate panel were cut into eight 13.5- by 15-inch specimens. The specimens were randomized and single pieces selected for each finish system studied. Thus, matched specimens for all finishes were prepared from a single sheet of each panel product. Southern pine bevel siding specimens were cut from several 1- by 6-inch boards and each panel contained specimens randomly selected from three different boards.

## Finishes

A representative range of top-quality, commercially available finishes was selected for this study (*Table* 2). Finish systems were comprised of combinations of the individual finishes (*Table* 3).

All finishes were applied to the wood substrates with a brush under ideal laboratory conditions and following all the recommendations provided by the finish manufacturers. Top, side, and bottom edges of all test panels were sealed with the finish itself. Spreading rates (square feet per gallon) for all finishes were determined by direct weighing. All substrate surfaces were wiped with a soft cloth before finishing and between coats. No other special surface preparation was used. Specimens for finishes Nos. 4, 5, and 6 were divided in half, one half receiving more coats of finish than the other (*Table* 3; *Figures* 1 through 5). All panels were allowed to dry for two days in the laboratory before being installed on the test fence.

## Exposure Panels

All wood substrates were fastened to 16-inch-wide by 13.5-inch-long frames of ¼-inch exterior-grade plywood with ½-inch-wide by 1-inch-deep side rails. The frames were dip-treated with a water-repellent preservative[15] and edge-coated with latex paint before substrates were attached with stainless steel nails. Southern pine bevel siding was lapped ½ inch. Each frame held only one specimen of each panel substrate. The test frames were hung on vertical fences with southern exposure at Madison, WI. Stainless steel drip caps, 16 inches long and

**Table 2—Individual Finishes[a] Used and Spreading Rate As Applied by Brush to Wood Substrates**

| Finish | Color | Solids Content (%) | Weight (lb/gal) | Average Spreading Rate (coverage) ($ft^2$/gal)[b] Hardboard | Redwood Plywood | Douglas-fir Plywood | Waferboard | Southern Pine Board |
|---|---|---|---|---|---|---|---|---|
| Semitransparent oil stain ............ | green | 47 | 7.4 | 245 | 140 | 325 | 210 | 325 |
| Solid color acrylic latex stain .......... | light brown | 44 | 10.2 | 280 | 170 | 280 | 270 | 320 |
| Solid color oil stain .... | light brown | 76 | 9.4 | 180 | 130 | 200 | 190 | 220 |
| Alkyd primer paint .... | white | 70 | 10.6 | 160–240 | 160–205 | 295–320 | 175–270 | 220–290 |
| Acrylic latex house paint A ....... | light brown | 54 | 10.8 | 215–245 | 160–175 | 240–245 | 190–195 | 245–275 |
| Acrylic latex house paint B ....... | green | 58 | 11.2 | 285–355 | 255–310 | 320–400 | 230–370 | 320–370 |
| Water-repellent preservative ......... | transparent | 16 | 7.0 | 160–210 | 145–160 | 260–295 | 175–190 | 220–235 |

(a) All finishes were commercial products, used according to manufacturer's instructions.
(b) Values represent the range observed. Higher spreading rates were found for second and third coats.

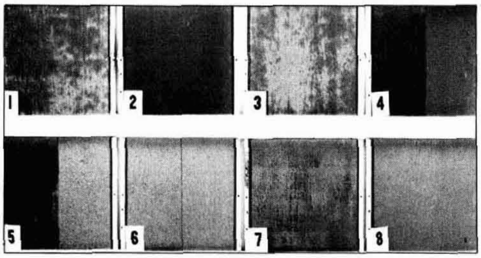

Figure 1—Hardboard substrates after 52 months of exposure. Numbers refer to finish systems described in *Table* 3

extending ¼ inch beyond the edge of the side rails, were placed between frames. Frames were randomly installed in groups of four horizontal rows of four.

## Performance Ratings

Several criteria were used to determine the overall performance ratings of the various finish/substrate systems (*Table* 4). Most of the evaluation methods were based on ASTM Standards. Both substrate and finish performances were considered.

Discoloration (unevenness of color) from any cause was considered a primary indicator of performance because of its visual effect. Substrate integrity was evaluated considering the individual characteristics of each substrate. The elements included (where applicable) erosion, flaking, peeling, cracking, and checking. A general appearance rating (subjective visual assessment) was used as a final criterion.

Thus, the overall performance rating was based on an average of the four elements of discoloration, substrate performance, finish performance, and general appearance of the system, each evaluated on a 10 to 0 scale. A value of 10 indicated no change from the original unweathered condition, total failure was represented by 0, and 5 represented an overall condition at which refinishing would be required but without extensive preparation of the substrate surface.

Completely objective rating observations are difficult to make. For consistency, observations were made by the

Table 4—Inspection Criteria and Methods of Evaluating Performance

| Inspection Criteria | Evaluation Method[a] |
|---|---|
| Discoloration | Subjective visual assessment similar to ASTM D 3274-76[16] |
| Substrate integrity | |
| Checking | ASTM D 660-44[17] |
| Cracking, delamination, warping shelling, flaking | Subjective visual assessment |
| Finish performance | |
| Erosion | ASTM D 662-44[18] |
| Cracking | ASTM D 661-44[19] |
| Checking | ASTM D 660-44[17] |
| Flaking | ASTM D 772-47[20] |
| General appearance | Subjective visual assessment |

[a] All evaluations used a 10 (perfect) to 0 (failure) scale to rate the finish or substrate performance.

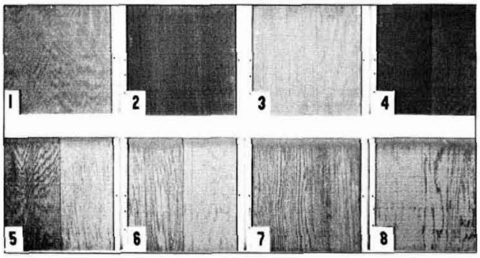

Figure 2—Redwood plywood substrates after 52 months of exposure. Numbers refer to finish systems described in *Table* 3

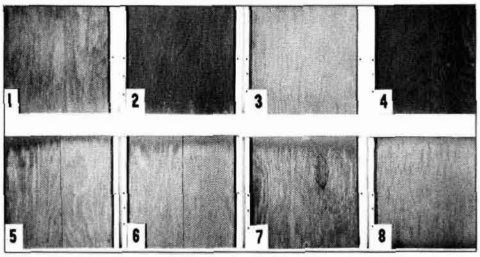

Figure 3—Douglas-fir plywood substrates after 52 months of exposure. Numbers refer to finish systems described in *Table* 3

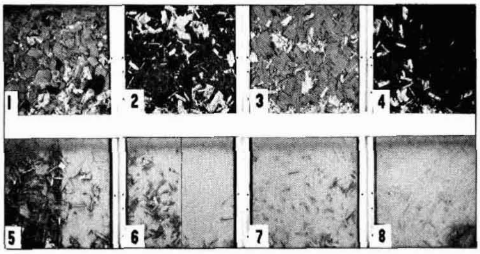

Figure 4—Aspen waferboard substrates after 43 months of exposure. Numbers refer to finish systems described in *Table* 3

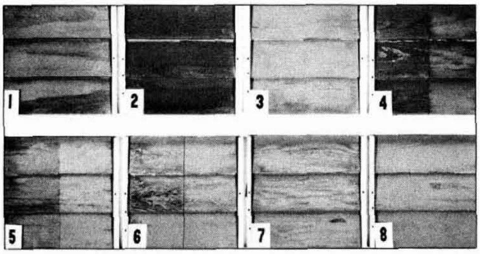

Figure 5—Southern pine board substrates after 52 months of exposure. Numbers refer to finish systems described in *Table* 3

### Table 5—Performance of Finishes on Hardboard Siding

| | | 30 Months | | | | | 44 Months | | | | | 52 Months | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Finish System Number | Number of Coats | Dis-coloration | Sub-strate | Finish | General | Overall Performance Rating | Dis-coloration | Sub-strate | Finish | General | Overall Performance Rating | Dis-coloration | Sub-strate | Finish | General | Overall Performance Rating |
| 1 | 1 | 7 | 10 | 7 | 7 | 7.8 | 3 | 9 | 6 | 5 | 5.8 | 3 | 8 | 6 | 4 | 5.3 |
| 2 | 1 | 9 | 10 | 10 | 9 | 9.5 | 8 | 10 | 9 | 9 | 9.0 | 8 | 9 | 8 | 8 | 8.3 |
| 3 | 1 | 5 | 10 | 9 | 5 | 7.3 | 3 | 10 | 9 | 4 | 6.5 | 2 | 9 | 7 | 4 | 5.5 |
| 4 | 1 | 8 | 10 | 9 | 8 | 8.8 | 8 | 10 | 8 | 7 | 8.3 | 8 | 9 | 8 | 8 | 8.3 |
| | 2 | 10 | 10 | 10 | 10 | 10.0 | 9 | 10 | 8 | 10 | 9.3 | 6 | 10 | 8 | 8 | 8.0 |
| 5 | 1 | 3 | 10 | 9 | 3 | 6.3 | 2 | 10 | 7 | 4 | 5.8 | 7 | 8 | 6 | 7 | 7.0 |
| | 2 | 8 | 10 | 10 | 8 | 9.0 | 7 | 10 | 10 | 7 | 8.5 | 7 | 9 | 10 | 8 | 8.5 |
| 6 | 2 | 8 | 10 | 9 | 8 | 8.8 | 7 | 10 | 9 | 7 | 8.3 | 7 | 9 | 8 | 7 | 7.8 |
| | 3 | 9 | 10 | 10 | 9 | 9.5 | 9 | 10 | 10 | 9 | 9.5 | 8 | 10 | 10 | 9 | 9.3 |
| 7 | 2 | 9 | 10 | 8 | 8 | 8.8 | 7 | 10 | 8 | 7 | 8.0 | 4 | 10 | 9 | 6 | 7.3 |
| 8 | 3 | 10 | 10 | 10 | 10 | 10.0 | 9 | 10 | 9 | 10 | 9.5 | 8 | 10 | 9 | 9 | 9.0 |

### Table 6—Performance of Finishes on Redwood Plywood

| | | 30 Months | | | | | 44 Months | | | | | 52 Months | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Finish System Number | Number of Coats | Dis-coloration | Sub-strate | Finish | General | Overall Performance Rating | Dis-coloration | Sub-strate | Finish | General | Overall Performance Rating | Dis-coloration | Sub-strate | Finish | General | Overall Performance Rating |
| 1 | 1 | 10 | 8 | 7 | 8 | 8.3 | 8 | 7 | 7 | 7 | 7.3 | 8 | 6 | 7 | 7 | 7.0 |
| 2 | 1 | 10 | 5 | 9 | 9 | 8.3 | 9 | 6 | 9 | 8 | 8.0 | 9 | 6 | 8 | 8 | 7.8 |
| 3 | 1 | 9 | 5 | 9 | 8 | 7.8 | 8 | 6 | 8 | 8 | 7.5 | 8 | 6 | 8 | 7 | 7.3 |
| 4 | 1 | 8 | 10 | 9 | 8 | 8.8 | 8 | 10 | 8 | 7 | 8.3 | 8 | 9 | 8 | 8 | 8.3 |
| | 2 | 10 | 10 | 10 | 10 | 10.0 | 9 | 10 | 8 | 10 | 9.3 | 6 | 10 | 8 | 8 | 8.0 |
| 5 | 1 | 8 | 7 | 9 | 9 | 8.3 | 5 | 6 | 7 | 6 | 6.0 | 4 | 6 | 7 | 4 | 5.3 |
| | 2 | 7 | 7 | 10 | 8 | 8.0 | 7 | 7 | 8 | 7 | 7.3 | 6 | 6 | 9 | 6 | 6.8 |
| 6 | 2 | 6 | 6 | 10 | 8 | 7.5 | 6 | 7 | 8 | 7 | 7.0 | 4 | 6 | 7 | 6 | 5.8 |
| | 3 | 8 | 8 | 10 | 8 | 8.5 | 8 | 8 | 9 | 8 | 8.3 | 7 | 9 | 9 | 7 | 8.0 |
| 7 | 2 | 8 | 8 | 8 | 7 | 7.8 | 5 | 9 | 8 | 7 | 7.3 | 5 | 7 | 8 | 6 | 6.5 |
| 8 | 3 | 8 | 10 | 10 | 8 | 9.0 | 6 | 10 | 9 | 7 | 8.0 | 4 | 9 | 9 | 6 | 7.0 |

### Table 7—Performance of Finishes on Douglas-fir Plywood

| | | 30 Months | | | | | 44 Months | | | | | 52 Months | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Finish System Number | Number of Coats | Dis-coloration | Sub-strate | Finish | General | Overall Performance Rating | Dis-coloration | Sub-strate | Finish | General | Overall Performance Rating | Dis-coloration | Sub-strate | Finish | General | Overall Performance Rating |
| 1 | 1 | 9 | 4 | 9 | 8 | 7.5 | 6 | 5 | 7 | 6 | 6.0 | 4 | 3 | 7 | 5 | 4.8 |
| 2 | 1 | 10 | 4 | 9 | 9 | 8.0 | 8 | 6 | 8 | 8 | 7.5 | 8 | 4 | 8 | 7 | 6.8 |
| 3 | 1 | 9 | 5 | 10 | 9 | 8.3 | 8 | 6 | 8 | 8 | 7.5 | 8 | 4 | 8 | 7 | 6.8 |
| 4 | 1 | 10 | 4 | 10 | 10 | 8.5 | 9 | 6 | 7 | 7 | 7.3 | 8 | 4 | 7 | 7 | 6.5 |
| | 2 | 10 | 4 | 10 | 10 | 8.5 | 9 | 7 | 8 | 7 | 7.8 | 5 | 3 | 8 | 6 | 5.5 |
| 5 | 1 | 10 | 3 | 10 | 8 | 7.8 | 6 | 5 | 6 | 6 | 5.8 | 4 | 3 | 7 | 4 | 4.5 |
| | 2 | 10 | 5 | 10 | 9 | 8.5 | 7 | 7 | 8 | 7 | 7.3 | 6 | 4 | 8 | 6 | 6.0 |
| 6 | 2 | 6 | 6 | 8 | 6 | 6.5 | 6 | 6 | 7 | 6 | 6.3 | 4 | 4 | 7 | 5 | 5.0 |
| | 3 | 8 | 7 | 9 | 8 | 8.0 | 7 | 7 | 8 | 8 | 7.5 | 6 | 6 | 8 | 7 | 6.8 |
| 7 | 2 | 10 | 7 | 9 | 8 | 8.5 | 6 | 8 | 7 | 7 | 7.0 | 2 | 4 | 7 | 4 | 4.3 |
| 8 | 3 | 9 | 8 | 10 | 9 | 9.0 | 7 | 9 | 8 | 8 | 8.0 | 6 | 8 | 8 | 7 | 7.3 |

**Table 8—Performance of Finishes on Waferboard Siding**

| | | 21 Months | | | | | 35 Months | | | | | 43 Months | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Finish System Number | Number of Coats | Dis-color-ation | Sub-strate | Finish | General | Overall Perfor-mance Rating | Dis-color-ation | Sub-strate | Finish | General | Overall Perfor-mance Rating | Dis-color-ation | Sub-strate | Finish | General | Overall Perfor-mance Rating |
| 1 | 1 | 8 | 3 | 8 | 2 | 5.3 | 6 | 2 | 7 | 2 | 4.3 | 3 | 2 | 4 | 2 | 2.8 |
| 2 | 1 | 9 | 4 | 8 | 3 | 6.0 | 6 | 2 | 7 | 2 | 4.3 | 4 | 0 | 4 | 3 | 2.8 |
| 3 | 1 | 7 | 5 | 8 | 4 | 6.0 | 7 | 2 | 7 | 3 | 4.8 | 4 | 0 | 5 | 2 | 2.8 |
| 4 | 1 | 9 | 5 | 8 | 4 | 6.5 | 9 | 3 | 9 | 3 | 6.0 | 5 | 2 | 6 | 3 | 4.0 |
| | 2 | 9 | 8 | 9 | 7 | 8.3 | 9 | 6 | 10 | 6 | 7.8 | 8 | 4 | 8 | 5 | 6.3 |
| 5 | 1 | 8 | 6 | 9 | 5 | 7.0 | 5 | 4 | 6 | 4 | 4.8 | 2 | 4 | 6 | 3 | 3.8 |
| | 2 | 9 | 9 | 10 | 8 | 9.0 | 7 | 6 | 8 | 7 | 7.0 | 6 | 7 | 8 | 6 | 6.8 |
| 6 | 2 | 9 | 8 | 9 | 7 | 8.3 | 6 | 6 | 8 | 6 | 6.5 | 4 | 6 | 7 | 5 | 5.5 |
| | 3 | 10 | 10 | 10 | 10 | 10.0 | 8 | 9 | 9 | 8 | 8.5 | 8 | 9 | 8 | 7 | 8.0 |
| 7 | 2 | 9 | 9 | 9 | 8 | 8.8 | 8 | 8 | 8 | 8 | 8.0 | 7 | 8 | 8 | 7 | 7.5 |
| 8 | 3 | 9 | 10 | 10 | 9 | 9.5 | 9 | 9 | 9 | 9 | 9.0 | 7 | 9 | 9 | 7 | 8.0 |

same person on each occasion, and photographs were used to compare results from year to year.

Evaluations were made after 30, 44, and 52 months of exposure. The original schedule would have called for another field evaluation at 56 months, but significant changes noted in several panels from the 44-month evaluation suggested that a thorough observation in the laboratory be made at 52 months.

The initial study did not include the aspen waferboard, but the potential use of this material suggested that it should be included in this study. Therefore, specimens of this substrate were added nine months after the study had commenced. It will be noted that performance ratings of these waferboard substrates were considerably lower than those of other substrates, even with less exposure.

## RESULTS AND DISCUSSION

Overall performance was rated for the eight finish systems on five wood substrates, together with the performance elements of discoloration, substrate, finish, and general appearance for the 52-month period (*Tables* 5 through 9). The panels themselves (*Figures* 1 through 5) were photographed after 52 months of exposure (43 months for the waferboard).

### Substrates

HARDBOARD SIDING: Discoloration of the finish on the commercial-grade hardboard siding (HB) was the single most important element in determining overall performance (*Table* 5). After 30 months of exposure, one coat of solid color oil stain (No. 3) and one coat of acrylic latex paint B (No. 5) exhibited extensive discoloration—primarily uneven darkening. With time, the HB panel with one coat of finish No. 5 became evenly dark and the discoloration rating rose. Generally, oil-based, one-coat systems (Nos. 1 and 3) were the least effective on HB (*Figure* 1). Two- and three-coat systems, using acrylic latex topcoat finishes, were consistently high in overall performance. There was no indication that water-repellent preservative (WRP) pretreatment was beneficial on HB as has been reported for solid wood substrates.[6,15] The value of applying two coats of an acrylic latex paint on HB, thereby increasing film thickness, is illustrated in finishes Nos. 4 and 5, with two coats, and

**Table 9—Performance of Finishes on Southern Pine Board**

| | | 30 Months | | | | | 44 Months | | | | | 52 Months | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Finish System Number | Number of Coats | Dis-color-ation | Sub-strate | Finish | General | Overall Perfor-mance Rating | Dis-color-ation | Sub-strate | Finish | General | Overall Perfor-mance Rating | Dis-color-ation | Sub-strate | Finish | General | Overall Perfor-mance Rating |
| 1 | 1 | 5 | 7 | 8 | 6 | 6.5 | 5 | 5 | 6 | 6 | 5.5 | 4 | 6 | 5 | 5 | 5.0 |
| 2 | 1 | 8 | 5 | 9 | 8 | 7.5 | 9 | 5 | 7 | 5 | 6.5 | 7 | 5 | 6 | 5 | 5.8 |
| 3 | 1 | 7 | 7 | 9 | 7 | 7.5 | 8 | 7 | 7 | 7 | 7.3 | 6 | 8 | 8 | 6 | 7.0 |
| 4 | 1 | 8 | 4 | 7 | 4 | 5.8 | 6 | 5 | 5 | 5 | 5.3 | 5 | 4 | 6 | 4 | 4.8 |
| | 2 | 8 | 7 | 9 | 7 | 7.8 | 9 | 6 | 7 | 7 | 7.3 | 5 | 7 | 8 | 6 | 6.5 |
| 5 | 1 | 5 | 6 | 8 | 5 | 6.0 | 5 | 6 | 7 | 5 | 5.8 | 3 | 6 | 8 | 4 | 5.3 |
| | 2 | 8 | 8 | 9 | 8 | 8.3 | 8 | 8 | 8 | 8 | 8.0 | 7 | 8 | 8 | 7 | 7.5 |
| 6 | 2 | 6 | 7 | 5 | 4 | 5.5 | 5 | 5 | 4 | 5 | 4.8 | 3 | 6 | 4 | 3 | 4.0 |
| | 3 | 8 | 9 | 8 | 8 | 8.3 | 8 | 8 | 8 | 8 | 8.0 | 7 | 8 | 7 | 7 | 7.3 |
| 7 | 2 | 8 | 9 | 9 | 7 | 8.3 | 6 | 8 | 8 | 6 | 7.0 | 4 | 9 | 7 | 6 | 6.5 |
| 8 | 3 | 9 | 9 | 10 | 8 | 9.0 | 7 | 9 | 9 | 8 | 8.3 | 7 | 8 | 9 | 8 | 8.0 |

Table 10—Combined Performance Rating[a] and Ranking[b] Of Wood Finishes on Five Substrates After Outdoor Exposure

| | | 30 Months | | 44 Months | | 52 Months | |
|---|---|---|---|---|---|---|---|
| Finish System Number | Number of Coats | Combined Performance Rating | Rank | Combined Performance Rating | Rank | Combined Performance Rating | Rank |
| 1 | 1 | 35.3 | 10 | 28.8 | 10 | 24.8 | 11 |
| 2 | 1 | 39.3 | 6 | 35.3 | 6 | 31.3 | 7 |
| 3 | 1 | 36.8 | 8 | 33.5 | 8 | 29.3 | 8 |
| 4 | 1 | 38.3 | 7 | 35.0 | 7 | 31.8 | 6 |
| | 2 | 44.5 | 2 | 41.3 | 3 | 34.3 | 4 |
| 5 | 1 | 31.0 | 11 | 28.0 | 11 | 25.8 | 10 |
| | 2 | 42.8 | 4 | 38.0 | 4 | 35.5 | 3 |
| 6 | 2 | 36.5 | 9 | 32.8 | 9 | 28.0 | 9 |
| | 3 | 44.3 | 3 | 41.8 | 2 | 39.3 | 1-2 |
| 7 | 2 | 42.0 | 5 | 37.3 | 5 | 32.0 | 5 |
| 8 | 3 | 46.5 | 1 | 42.8 | 1 | 39.3 | 1-2 |

(a) A value of 50 indicates no weathering changes.
(b) Ranked from best (1) to poorest (11).

Nos. 6 and 7, with two topcoats over one primer coat (*Table* 5). Two coats of an acrylic latex (Nos. 4 and 5) were more durable than one coat of acrylic latex over one coat of oil-based primer paint (Nos. 6 and 7).

REDWOOD PLYWOOD SIDING: Redwood plywood (RP) was the only roughsawn substrate used in this study. More finish was required for coverage on RP than was required on any of the others (*Table* 2). The presence of more finish would suggest better performance on outdoor weathering. Finish performance was quite good on RP, even after 52 months of exposure (*Table* 6), but overall performance rating was affected both by discoloration due to extractives and by face checking of the plywood (*Figure* 2). Best overall performance was found for one and two coats of acrylic latex house paint (No. 4) and the alkyd primer/acrylic latex topcoat system (No. 6).

DOUGLAS-FIR PLYWOOD: The smooth, sanded Douglas-fir plywood (DFP) used in this study is not considered as a siding substrate but does find extensive applications as soffit covers and in similar uses.[4] With the various finish systems used, it performed fairly well after 30 months of exposure (*Table* 7). Overall performance ratings for DFP declined after that, with discoloration and substrate performance (plywood face checking) being the major contributing factors to the lower performance values (*Figure* 3). Best overall performance, as illustrated by the highest rating in *Table* 7, was found for the complete finish system No. 8 (WRP, primer paint, two acrylic latex topcoats). The element of finish performance alone showed consistently good results after 52 months of exposure. The lower performance ratings of this smooth surface DFP, compared to roughsawn RP (*Table* 6), was observed in earlier studies.[4,5] Possible explanations for poorer performance of finishes over smooth plywood surfaces have been discussed by Emery.[4]

ASPEN WAFERBOARD: The aspen waferboard (WB) panels exhibited substrate failure (delamination or flaking) after 21 months of exposure with one-coat finish systems (*Table* 8; *Figure* 4). This substrate failure became more severe with continued exposure and was the single major element affecting overall performance rating. Two- and three-coat systems provided a greater degree of protection than did any one-coat system. The value of alkyd primer paints in combination with acrylic latex topcoats, and in some cases a WRP, in controlling moisture movement is illustrated in the improved performance of finish systems Nos. 6, 7, and 8. Finish No. 8 would have had a high overall performance rating except for some discoloration that occurred in the last eight months of exposure. This discoloration was due to growth on the substrate of a white-rot decay fungus in the family *Corticiaceae*. Another white-rot decay fungus, *Schizophyllum commune* Fr., was found on the substrate panel of finish No. 6. No decay was observed for all-latex systems. Thus, the WB substrate appears to be prone to decay under certain finishes, even on fences in Madison, WI, where decay hazard is considered low[6] and on substrates pretreated with WRP. Finish systems with alkyd primers may serve to hold moisture that penetrates through finish defects (defects encouraged by substrate delamination and flaking and by stress-cracking of the more brittle alkyd film) and enhance conditions for decay. This observation of decay has prompted a further, more detailed study.

SOUTHERN PINE SIDING: The southern pine siding (SP) offered a surface with varying degrees of hardness, dimensional instability, and subsequent reduced finish performance as reported earlier.[6,13,14] Overall performance ratings were significantly lower (*Table* 9; *Figure* 5) due to reduced substrate performance coupled with a significant discoloration tendency. One-coat systems showed fairly rapid reduction in the overall performance rating. Failure of many finish systems over dense, hard latewood was observed after 44 months of exposure. Significant finish deterioration for several finishes was found after 52 months. WRP pretreatment was beneficial in improving overall durability ratings when alkyd primers were used (compare finish No. 6, one topcoat, with No. 7; and finish No. 6, two topcoats, with No. 8 in *Table* 9). Both of the solid color stains (Nos. 2 and 3) showed better overall performance in one-coat applications than did one-coat acrylic latex house paints (Nos. 4 and 5). As was found with the other substrates, the overall performance rating for the semitransparent oil stain (No. 1) was the lowest of all the finishes evaluated.

## Finish System Performance

Individual performance trends for any finish/substrate combination can be determined by comparing overall performance ratings from each finish system after exposure for 30, 44, and 52 months on the five substrates evaluated (*Tables* 5 through 9). The one-coat stains and the one-coat paints exhibited the lowest overall performance ratings of all the finish systems. The semitransparent oil stain permitted some ultraviolet light to penetrate to the wood surface,[4] and was consistently the poorest of the three stain systems evaluated. The solid color acrylic latex stain performed like acrylic latex house paint A applied in one coat. The expected greater performance of two- and three-coat finish systems is illustrated most clearly. The three-coat systems, with their greater film thickness, provided the most protection and also provided the highest performance ratings observed for all finish systems in this study.

The overall performance for each finish system can be compared to the other systems by adding all the ratings for that system on each substrate at each exposure time (*Table* 10). Three-coat systems ranked consistently first, second, or third, and two-coat systems were next. A significant exception was finish system No. 6 with one coat of alkyd primer paint and one topcoat of acrylic latex paint (*Table* 10). This system had consistently poorer performance over DFP, WB, and SP with the resultant lowering in rank when compared to the other finish systems.

The two-coat acrylic latex paint systems (Nos. 4 and 5) showed consistently good overall performance ratings (*Table* 10). These systems outperformed two-coat paint systems (Nos. 6 and 7) consisting of alkyd primer followed by acrylic latex paint. This comparison and a comparison of performance of two-topcoat application versus one-topcoat application suggest that a three-coat, all-latex finish system should give outstanding performance.

### Effect of Substrate on Coating Performance

An indication of the contribution of the substrate to finish performance can be obtained by adding all the overall performance ratings of each of the 11 finish systems into a combined rating for each substrate (*Figure* 6) as a function of exposure time. The data suggest a continuous reduction in performance for all substrates. Overall, HB appears to be the substrate that should offer the best finish performance. The poor performance of WB is readily apparent in its rapidly decreasing combined performance rating with exposure time. DFP shows an indication of an accelerating decline in performance after long exposure, apparently due to an increase in face checking on the surface of this smooth substrate.

## SUMMARY AND CONCLUSIONS

This outdoor exposure study of the performance of several finish systems on four wood-based panel products and on one solid wood substrate illustrates the enhanced protection found with two- and three-coat paint systems. A semitransparent oil stain, partially ultraviolet-light-transparent, gave the least protection to the wood substrate surface. Two-coat systems, comprised of all-latex finishes, exhibited better performance than did alkyd primer/acrylic latex paint systems. Three-coat systems gave the best overall performance and provided the greatest degree of protection for the substrate.

Variable results were found when a water-repellent preservative was used as a treatment prior to finishing with paint topcoats. The pretreatment resulted in enhanced finish and substrate performance when applied to aspen waferboard and southern pine board, but the use of this pretreatment on aspen waferboard did not prevent attack by decay fungi.

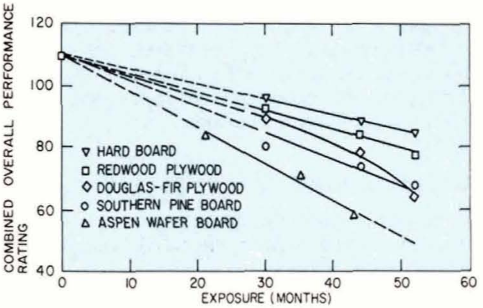

**Figure 6—Combined overall performance ratings. The overall performance ratings of each of the 11 finish systems (*Tables* 5–9) were added to yield the combined overall rating for each substrate**

Hardboard siding showed consistently good performance, especially when finished with two or more coats of paint. The all-latex finish systems showed very good overall performance on this substrate. The semitransparent oil stain and solid color oil stain gave the poorest protection for this substrate and the poorest finish performance.

Aspen waferboard panels proved the most difficult to protect of the substrates evaluated. The three-coat systems proved effective, but white-rot decay fungi were found in two panels finished with alkyd primer and latex topcoats. No decay was observed under all-latex paint systems.

Redwood plywood siding with a roughsawn texture exhibited consistently better finish and substrate performance than did smooth, sanded Douglas-fir plywood. The improved performance for roughsawn surfaces is probably related to both better mechanical adhesion of the finish and the presence of more finish, because roughsawn surfaces absorbed more finish than did smooth surfaces when the finish was brush applied.

Several more-detailed studies on the outdoor performance of finished wood substrates have been established as a result of this study. One concerns the use of several different pretreatment systems on aspen waferboard and subsequent finish and substrate performance for the three finishes at three exposure sites. A similar study involves sanded and roughsawn southern pine plywood. The role of water repellents and water-repellent preservatives as pretreatments for wood-based products is being further investigated in several studies. Finishes

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that vary from fully transparent to UV light to almost fully opaque are being evaluated on several substrates. The effectiveness of the pretreatments under several different primer and self-primer systems is also being investigated. The results of these detailed studies will be reported in future publications.

## ACKNOWLEDGMENTS

The author gratefully acknowledges the laboratory assistance of Peter G. Sotos and Jill M. Wennesheimer and the fungal identification assistance of Dr. Harold H. Burdsall.

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# Graphical Solution To CPVC Problems in Latex Paints

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Utilizing a simplified constant-volume technique for the determination of a volumetric oil absorption (OAv), it is shown how a graphical method may be used to modify the pigmentation of any flat latex paint without altering film porosity, and how the CPVC may be calculated for the resulting formulation. Much of the paper is concerned with the theory necessary to establish that this approach is consistent with earlier more complex and more time-consuming methods. Practical examples are used to illustrate the procedure for matching the dry-film porosity of a standard at both equal and improved hiding power levels. Volumetric oil absorption values are provided for a broad selection of common extenders used in latex paints.

## INTRODUCTION

It has become commonplace to refer to a paint product as having been formulated above or below its CPVC—primarily as an indication of the presence or absence of film porosity. Reference to a product as having actually been formulated *at* the CPVC is relatively rare. It is, therefore, surprising that so much of the available literature has concerned itself with how to determine the CPVC, and so little with formulating techniques designed to attain or to duplicate some desired level of film porosity.

With very few exceptions, essentially all of the methods that have been proposed for identifying the CPVC have involved the preparation of a PVC-ladder study to evaluate the changes in some selected property or properties. Since the composition of the paint occupying each "step" of the ladder is necessarily different from that which follows or precedes it, the disclosed endpoint of such studies is only the CPVC for one single step of the ladder—and in many instances it will not be the composition that the formulator would have chosen on the basis of some of those considerations that are not CPVC-related, such as hiding power, angular sheen, polishing, wet-abrasion resistance, etc.

Should the formulator try to obtain a better mix of appearance characteristics by altering the relative proportions of titanium dioxide and extender, or by substituting a different type of extender, he will also change the CPVC from that previously determined. The PVC-ladder approach then usually becomes a trial-and-error process involving incremental formula changes and numerous performance tests—all extremely time-consuming.

### Other CPVC Determinations

One of the few methods for identifying the CPVC that does not involve a PVC ladder is the CPVC Cell method proposed by Asbeck and Van Loo,[1] but it suffers from the same basic deficiency. This may be illustrated by the two paint formulations of *Table* 1—one a wall primer, the other a flat wall paint. Neither is suggested as a practical formula recommendation, but each will perform reasonably well for its indicated purpose.

Both of these paints possess the same CPVC, as determined by the CPVC Cell, because both are pigmented with the same 20:70:10 ratio (by volume) of the same three pigments. The determined CPVC of 60.5%, however, would not provide adequate sealing for a wall primer, or adequate hiding power for a flat wall paint. Furthermore, if the attempt were made to convert the composition of 60.5 PVC to a flat wall paint of adequate high dry hiding by the usual process of adding increasing

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**Table 1—Paint Formulations for CPVC-Cell Evaluation**

| | Flat Wall Paint | | Wall Primer | |
|---|---|---|---|---|
| | Pounds | Gallons | Pounds | Gallons |
| TiPure R-911 ......... | 186.0 | 5.44 | 142.0 | 4.16 |
| Snowflake ............ | 430.0 | 19.04 | 329.0 | 14.56 |
| Celite #281 ........... | 52.0 | 2.72 | 40.0 | 2.08 |
| Alkyd resin (39%) ..... | 430.0 | 42.67 | 480.0 | 64.00 |
| Mineral spirits ........ | 195.8 | 30.13 | 98.8 | 15.20 |
| | 1293.8 | 100.00 | 1089.8 | 100.00 |
| | PVC − 68.0 | | PVC − 52.0 | |

amounts of extender, the end result would bear little resemblance to the flat wall paint of *Table* 1. It would have to be significantly more porous to develop an equivalent amount of dry hiding power because of its lower titanium dioxide content. *Table* 1 thus illustrates the previous observation that the CPVC is seldom the target for paint formulation. The vast majority of paint products are formulated either above or below Van Loo's "transition point." Its value is primarily that of a reference point.

## CPVC as a Reference Point for Formulation

Stieg[2,3] has derived a number of equations that may be used to predict the relative porosity of flat latex paints based upon a CPVC calculated from pigment oil absorption, but many practical formulators appear to prefer the physical manipulations of test-batch preparation and performance testing to calculations that are moderately complicated and require some theoretical background. A few base their preference upon a professed inability to visualize any possible relationship between oil absorption and performance in a water-base paint.

Since the new graphical method for matching flat latex paint porosities, which will be the principal subject of this paper, is also based upon pigmentation oil absorption, it is important that we attempt to clarify this relationship. The oil absorption of a given pigment or combination of pigments is a convenient measure of the void volume remaining when the pigment particles are closely packed. Stieg's pigmentation CPVC, calculated from the relative volumes of oil and pigment at the driest possible endpoint of the test, is therefore a packing factor determined only by the particle-size distribution of the tested pigments.

While any other soluble binder does not significantly interfere with this packing factor, the solid dispersed particles of a latex binder are unable to fit into the smaller voids of the pigment packing, causing it to "open up." This causes the CPVC of a latex paint to be lower than that of a similarly pigmented solvent-base paint. The original packing factor still dominates, however, as evidenced by the fact that the rank order of CPVC's for different pigmentations is unchanged, regardless of the type of binder employed—the range of CPVC's is simply shifted up or down by the relative ability of the binder to form a void-free (nonporous) film with the tested pigmentation.

**Table 2—Volumetric Oil Absorption Values**

| Pigment | Lb/Gal | Sample (g) | mL Oil | $OA_V$ |
|---|---|---|---|---|
| Al-Sil-Ate® O | 22.05 | 3.31 | 2.11 | 1.688 |
| ASP-400 | 21.5 | 3.23 | 1.18 | 0.944 |
| Celite® #281 | 19.2 | 2.88 | 3.28 | 2.624 |
| Duramite® | 22.46 | 3.37 | 0.56 | 0.448 |
| Glomax LL | 21.9 | 3.28 | 2.14 | 1.712 |
| M-60 | 23.69 | 3.55 | 1.26 | 1.008 |
| Omyacarb® F | 22.53 | 3.38 | 0.87 | 0.696 |
| Omycarb® UF | 22.53 | 3.38 | 0.91 | 0.728 |
| Optiwhite® | 18.34 | 2.75 | 1.85 | 1.480 |
| Satintone #1 | 21.9 | 3.28 | 2.09 | 1.672 |
| Snowflake | 22.46 | 3.37 | 0.56 | 0.448 |
| Titanox® 2090 | 34.1 | 5.12 | 1.02 | 0.816 |

## Binding Power Index

Berardi's "binding power index"[4] is a proportionality factor with which the amount of any given latex vehicle required to produce such a void-free film with a specific pigmentation may be calculated from the amount of oil required to produce the same effect. Stieg has shown that the binding power index (his factor "x") may be experimentally determined, using Schaller's[5] procedure and the following equation:[6]

$$x = \frac{PVC_o\,(1 - CPVC)}{CPVC\,(1 - PVC_o)}$$

where CPVC = pigmentation CPVC calculated from oil absorption
$PVC_o$ = CPVC from Schaller's optical endpoint with latex vehicle
x = binding power index

He further showed that the relative porosity of any flat latex paint based upon a vehicle for which factor "x" was known, might be calculated from the following relationship:

$$L.P. = 1 - \frac{CPVC\,(1 - PVC)}{PVC\,(1 - CPVC)}\,x$$

where CPVC = pigmentation CPVC calculated from oil absorption
PVC = formula PVC of latex paint
L.P. = latex porosity as percent air in dry film, based upon total void volume

The validity of these oil-absorption-based relationships, and their use for the control of latex paint properties, has been repeatedly demonstrated by Stieg, and confirmed by a number of independent investigators, the most recent of whom being Ramig.[7]

## Volumetric Oil Absorption

The form in which the oil absorption of pigments has traditionally been expressed, pounds of linseed oil per 100 pounds of pigment, is a throwback to the early days of low-volume production in the paint industry when many formulations contained but a single pigment, and its oil absorption value was a convenient means for estimating the amount of oil to be charged into the paste mixer. Today, most paint is manufactured in large-volume, high-speed dispersers and, with the exception of low-PVC enamels, is generally pigmented with a combination of several different pigments and extenders.

Furthermore, it is widely recognized that *volume* relationships, rather than weight, are most important in the control of finished paint properties.

The classical oil-absorption test method (ASTM D 281) is, in our opinion, needlessly complicated by adherence to this earlier tradition. The oil used is measured volumetrically and then calculated to its weight in grams, which increases the possibility of error, and the weight of the sample to be tested must be estimated in advance from previous experience with similar types of pigment—again introducing possible error.

Since our primary goal was to simplify and increase the convenience of formula manipulations based upon oil-absorption relationships, considerable time was devoted to the development of a test method that would eliminate these deficiencies. The selected method was essentially the spatula rub-out procedure of ASTM D 281, modified to report oil absorption volumetrically in terms of mL of oil per mL of pigment, and specifying a uniform pigment sample having a solid volume of 1.25 mL—approximately the volume of five grams of enamel-grade rutile titanium dioxide. The abbreviation of $OA_V$ selected to identify the oil absorption value determined by this method.

The specification of a 1.25 mL pigment sample was motivated by the resulting simplification of all necessary calculations, as shown below:

(1) grams of pigment sample = lbs/gal × 0.15.

(2) volumetric oil absorption = mL of oil × 0.80.

The more precise conversion factor required to convert the density of a pigment, as commonly expressed in pounds per gallon, to the weight in grams corresponding to a volume of 1.25 mL is 0.15006, but an induced error of only 0.04% was felt to be a small price to pay for the degree of simplification obtained.

## EXPERIMENTAL

A considerable number of volumetric oil absorption ($OA_V$) determinations were made using the above method, both for single pigments and extenders, and for combinations to evaluate the effect of pigment packing. A selection of the single pigment results based upon density figures taken from the *Raw Material Index* is given in *Table* 2.

The $OA_V$ value for Titanox 2090® titanium dioxide in *Table* 2 is the average of nine determinations performed on different days by two different operators. The standard deviation for mL of added oil was ±0.03 mL, which calculates to a standard deviation for $OA_V$ of ±0.024, which is considered adequately good reproducibility. The extenders, having less surface area than titanium dioxide, might be expected to show even less variation. In any event, however, the volume of oil delivered by the dispensing burette can not be measured more closely than 0.05 mL, with intermediate points estimated.

It was found that $OA_V$ values determined for two-component systems of titanium dioxide and extender in varying proportions might be used to plot curves of $OA_V$ versus percentage composition which exhibited minima for conditions of maximum packing (see *Figure* 1), demonstrating that $OA_V$ values are no more additive than conventional oil absorption values. The absence of such minima, as in the case of the illustrated curve for the ultra-fine calcium carbonate Omyacarb® UF, is indicative of the lack of titanium dioxide packing when combined with such extenders.

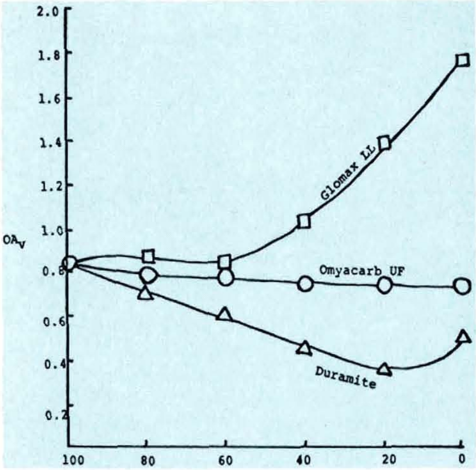

**Figure 1—Percent titanium dioxide by volume—balance extender**

## THEORETICAL

The great value of the volumetric oil absorption ($OA_V$) in paint formulation derives from its relationship to Stieg's pigmentation CPVC:

$$OA_V = \frac{(1 - CPVC)}{CPVC}$$

This will be recognized as a ratio frequently occuring in Stieg's calculations. Because of this relationship, the equation for latex porosity (L.P.) may take the following form:

$$L.P. = 1 - \left(\frac{1}{OA_V}\right)\left(\frac{1 - PVC}{PVC}\right) \quad x$$

This equation may be rearranged as follows:

$$\frac{1}{PVC} - 1 = \frac{1 - L.P.}{x} OA_V$$

The form of this equation means that if the term $1/PVC - 1$ is plotted versus $OA_V$ on rectangular graph paper, all combinations of the two terms for which $(1 - L.P.)/x$ is a constant will fall on a straight line passing through the origin of the plot. It also means, therefore, that this straight line will be the locus of equal porosity for all paints formulated with the same latex vehicle, and that the numerical value of $(1 - L.P.)/x$ will be equivalent to $1/PVC - 1$ when $OA_V = 1.0$ and may be read off the plot.

### Pigmentation Changes

To illustrate the use of this graphical approach, an experiment was designed wherein it was desired to re-pigment a flat latex paint for greater economy without

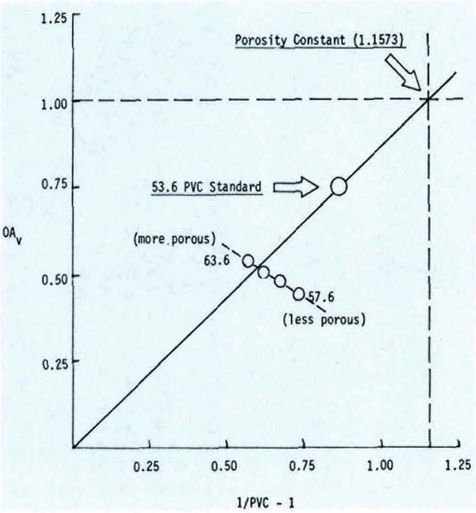

**Figure 2—Constant porosity (*Table* 3 values)**

altering dry hiding power or film porosity. The selected formulation was pigmented at 53.6 PVC and contained a latex-grade titanium pigment of relatively low titanium dioxide content (83.0%).

| | | |
|---|---|---|
| Titanox 2131 ........... | 175 lb | 5.52 gal |
| Snowflake® ............. | 240 lb | 10.63 gal |
| Celite® #281 ............ | 35 lb | 1.82 gal |
| Latex vehicle ........... | 305 lb | 34.58 gal |
| Additives + $H_2O$ ........ | 395 lb | 47.45 gal |
| | 1150 lb | 100.00 gal |

% PVC – 53.6 % Solids (v) – 33.5

The first step in repigmenting such a formula is to determine the amount of an enamel-grade titanium pigment (95% $TiO_2$) that will provide the same total amount of titanium dioxide as the 175 lb of the latex-grade pigment:

$$175 \times 83/95 = 153 \text{ pounds Titanox 2090}$$

While the surface treatment of the latex-grade pigments do not actually produce hiding power, they do provide a "spacing effect," and the difference in volume between the original and replacement titanium pigments must be replaced with a spacing extender to maintain equivalent dilution:[8]

| | | |
|---|---|---|
| Titanox 2131 ........... | 175 lb | 5.52 gal |
| Titanox 2090 ........... | 153 lb | 4.48 gal |
| | 22 lb | 1.04 gal |

An ultra-fine calcium carbonate is an ideal spacing extender for this purpose since its low oil absorption permits maximum PVC increases (and maximum savings) when making such pigmentation changes.

Because of the lower oil absorption of the Titanox 2090/spacing extender combination as compared to the original Titanox 2131, it is obvious that a sizeable PVC increase will be possible, and the next step is to determine the porosity target. This is done by determining the volumetric oil absorption ($OA_V$) for the original pigmentation. The procedure is as follows:

*Step #1*—calculate total weight (450 lb) and total volume (17.97 gal) of pigmentation

*Step #2*—calculate weight of total sample in grams:
$450/17.97 = 25.04$ lb/gal
$25.04 \times 0.15 = 3.756$ g total sample

*Step #3*—calculate weights for individual pigments in dry blend:
$175/450 \times 3.756 = 1.461$ g Titanox 2131
$240/450 \times 3.756 = 2.003$ g Snowflake
$35/450 \times 3.756 = 0.292$ g Celite #281

*Step #4*—determine mL of linseed oil required to reach driest-possible endpoint for spatula rub-out procedure (0.935 mL in actual test)

*Step #5*—calculate volumetric oil absorption:
$OA_V = 0.935 \times 0.8 = 0.748$

*Step #6*—establish the locus of equal porosity by plotting the coordinates for this pigmentation ($1/PVC - 1 = 0.866$; $OA_V = 0.748$) on a rectangular graph, as shown in *Figure* 2.

*Step #7*—draw a straight line through this point from the origin of the plot

All other combinations of $1/PVC - 1$ and $OA_V$ that fall on this line will produce the same porosity if the same vehicle is employed.

To determine the PVC to be used with the new pigmentation, it is now necessary to determine the effect upon its $OA_V$ value of adding spacing extender and removing an equal volume of latex solids to increase the formula PVC in a systematic manner that does not alter the total solids volume. A line drawn through the established points will intersect the locus of equal porosity at the value of $1/PVC - 1$ representing the required PVC.

A suggested starting point involves calculating the volume of spacing extender required to raise the formula PVC by 10 percentage points. This volume will always be equal to 10% of the total solids, which makes for a simple calculation (in this instance, $33.53 \times 0.10 = 3.35$ gal). Added to the 1.04 gal used to replace the surface treatment of the latex-grade titanium pigment, this means that the pigmentation at 63.6 PVC (53.6 + 10.0) will contain 4.39 gal of spacing extender (actually 4.40 when the third decimal place is carried in the calculations). If the other extenders are unchanged, the complete pigmentation will be as follows:

| | | |
|---|---|---|
| Titanox 2090 ........... | 153 lb | 4.48 gal |
| Omyacarb UF .......... | 99 lb | 4.40 gal |
| Snowflake .............. | 240 lb | 10.63 gal |
| Celite #281 ............ | 35 lb | 1.82 gal |
| | 527 lb | 21.33 gal |

The volumetric oil absorption for this combination is determined as before ($OA_V = 0.536$, as shown in *Table* 3), and the other coordinate calculated from the PVC of 63.6% ($1/0.636 - 1 = 0.572$). The plotted point (see *Figure* 2) falls to the left of the locus of equal porosity, indicating that a paint so formulated would be more porous than the standard to be matched.

It will therefore be necessary to reduce the PVC to obtain a porosity match. This is accomplished by a stepwise reduction in the amount of spacing extender used, each step being equivalent to a 2 PVC change, or the removal of 0.67 gal of spacing extender ($33.53 \times 0.02 =$

**Table 3—Determined $OA_V$ Values**

| PVC | 1/PVC − 1 | mL of Oil | $OA_V$ |
|---|---|---|---|
| 63.6 | 0.572 | 0.670 | 0.536 |
| 61.6 | 0.623 | 0.630 | 0.504 |
| 59.6 | 0.678 | 0.600 | 0.480 |
| 57.6 | 0.736 | 0.553 | 0.442 |

**Table 4—Determined $OA_V$ Values**

| PVC | 1/PVC − 1 | mL of Oil | $OA_V$ |
|---|---|---|---|
| 63.6 | 0.572 | 0.752 | 0.602 |
| 61.6 | 0.623 | 0.755 | 0.604 |
| 59.6 | 0.678 | 0.752 | 0.602 |
| 57.6 | 0.736 | 0.725 | 0.580 |

0.670), and $OA_V$ determined for each step. $OA_V$ values for three additional "steps" are shown on *Figure* 2 and in *Table* 3, although the plotted points show an intercept with the locus at 62.5 PVC (1/PVC − 1 = 0.60), making the two final "steps" unnecessary.

The pigmentation required at 62.5 PVC is calculated as follows:

33.53 × 0.625 = 20.96 gal of total pigment
20.96 − 17.97 = 2.99 gal spacing extender to be added (+ 1.04)
= 2.99 gal latex solids to be removed

This yields the following completed formulation:

| | | |
|---|---|---|
| Titanox 2090 | 153 lb | 4.48 gal |
| Omyacarb UF | 91 lb | 4.03 gal |
| Snowflake | 240 lb | 10.63 gal |
| Celite #281 | 35 lb | 1.82 gal |
| Latex vehicle | 246 lb | 27.94 gal |
| Additives + $H_2O$ | 426 lb | 51.10 gal |
| | 1191 lb | 100.00 gal |

% PVC − 62.5     % Solids (v) − 33.5

Due to the 22 lb reduction in titanium pigment content and the 2.99 gal reduction in latex solids, the modified formulation was approximately 25¢ a gallon less expensive than the original at the time that this work was done. Subsequent titanium pigment price increases will have increased this saving.

## Quality Improvement

Not all repigmentation problems will necessarily involve PVC increases of this magnitude, however. If, for example, it were desired to increase dry hiding power at the same time that the latex-grade titanium pigment was replaced, again without increasing film porosity, some of the saving generated by the titanium pigment change might be "ploughed back" into the formulation by replacing some of the nonfunctional coarse extender with an efficient spacer such as ultra-fine calcium carbonate. This is possible whenever the volume of coarser extender present in a formulation is greater than that required for sheen control, but the higher oil absorption of the spacing extender will tend to increase $OA_V$, reducing PVC increases. This, combined with its slightly higher cost, will tend to reduce the over-all saving.

Experience has shown that the replacement of only half the Snowflake with ultra-fine calcium carbonate spacing extender will increase dry hiding power at equal porosity by approximately 10%, but a new set of $OA_V$ determinations will have to be made to establish the new intercept with the locus of equal porosity. Since the spacing extender has the same density as the Snowflake calcium carbonate, the test samples will have the same composition as before, except for the replacement of half the Snowflake weight in grams with Omyacarb UF. The new set of $OA_V$ values are shown in *Table* 4 and *Figure* 3.

The new intercept appears to be at 59.0 PVC, although the departure of the determined $OA_V$ values from a uniformly descending series made its precise determination somewhat difficult. This might be due to a packing effect, but is more probably due to experimental error.

The calculated higher-hiding formulation at 59.0 PVC appears as follows:

| | | |
|---|---|---|
| Titanox 2090 | 153 lb | 4.48 gal |
| Omyacarb UF | 186 lb | 8.24 gal |
| Snowflake | 120 lb | 5.32 gal |
| Celite #281 | 35 lb | 1.82 gal |
| Latex vehicle | 267 lb | 30.38 gal |
| Additives + $H_2O$ | 682 lb | 49.76 gal |
| | 1176 lb | 100.00 gal |

% PVC − 59.0     % Solids (v) − 33.5

The correctness of the 59.0 PVC intercept might have been checked by determining $OA_V$ for the above pigmentation and locating it on *Figure* 3, but it was decided instead to make a direct comparison of test grinds of the 62.5 PVC and 59.0 PVC flat latex paints. The comparison of the physical properties of these two formulations in *Table* 5 suggests that the intercept should have occurred at a slightly higher PVC, since the observed porosity of the 59.0 PVC formulation is significantly lower than that of the 62.5 PVC formulation (as indicated by the lower ASTM Porosity value) and the observed hiding power increase is less than the expected 10%, although the difference is within the limit of reproducibility for the ASTM hiding power test method. Over all, however, the goal of product improvement has been achieved without time-consuming trial-and-error experimentation.

## Calculating the CPVC

It has been demonstrated that it is unnecessary to know the actual CPVC's of any of the example formulations to utilize the CPVC *concept* as a guide in matching or improving existing products. These values can be calculated, however, if the binding power index (x) of the latex vehicle is determined, using Schaller's technique, as previously described.

The vehicle system employed (including thickener, surfactants, and propylene glycol) was used to produce a PVC ladder, pigmented with Atomite,® in 5 PVC "steps" from 50 PVC to 70 PVC. Contrast ratio was determined for each step and plotted against its PVC on rectangular graph paper. The break in the plotted curve, made up of two straight-line segments, occurred at

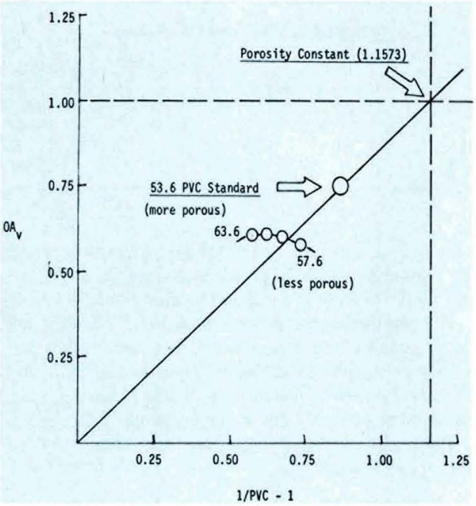

**Figure 3—Constant porosity (*Table* 4 values)**

approximately 60 PVC ($PVC_o$). The volumetric oil absorption of the Atomite calcium carbonate was determined to be 0.460 mL of oil per mL of pigment. The binding power index was then calculated as follows:

$$\begin{aligned} x &= OA_V \frac{PVC_o}{(1 - PVC_o)} \\ &= 0.460 \frac{0.60}{(1 - 0.60)} \\ &= 0.69 \end{aligned}$$

As shown on *Figure* 2, the Porosity Constant ($1/PVC - 1$ for $OA_V = 1.00$) is equal to 1.1573, and since it is by definition also equal to $(1 - L.P.)/x$:

$$\begin{aligned} L.P. &= 1 - 1.1573\,x \\ &= 0.20 \end{aligned}$$

This relatively low value for Latex Porosity, as verified by the low ASTM Porosity values in *Table* 5, and will be constant for all formulations falling on the determined locus of equal porosity in *Figure* 2 or *Figure* 3. The formula CPVC's vary, however, due to the variation of the $OA_V$ of their pigmentations.

Since film porosity is equal to zero at the formula CPVC, the equation for latex porosity (L.P.) based upon $OA_V$ takes the following form:

$$OA_V = \left(\frac{1 - CPVC}{CPVC}\right) x$$

where CPVC = formula CPVC

It will be noted that the above equation differs from the relationship between $OA_V$ and Stieg's pigmentation CPVC only by the presence of the term "x." By transposition of terms:

$$CPVC = \frac{1}{1 + OA_V/x}$$

*Table* 6 shows formula CPVC's for the three test formulations, as calculated from the determined $OA_V$ values for their pigmentations.

**Table 5—Comparison of 62.5 PVC and 59.0 Formulations**

| | 62.5 PVC | 59.0 PVC |
|---|---|---|
| Brightness | 90.9 | 91.0 |
| Contrast ratio | .953 | .963 |
| Angular sheen (85°) | 1 | 1 |
| ASTM Porosity | 7.5 | 6.2 |
| ASTM Scrub | 102 | 112 |
| Dry tint reflectance | .478 | .492 |
| Relative hiding (K-M) | 1.00 | 1.09 |

**Table 6—Formula CPVC's for Test Formulations**

| Formula PVC | $OA_V$ | Formula CPVC |
|---|---|---|
| 53.6 | 0.748 | 48.0 |
| 62.5 | 0.518 | 57.0 |
| 59.0 | 0.592 | 53.8 |

## SUMMARY

It has been demonstrated that formula manipulations involving a use of the CPVC concept may be greatly simplified by a novel, graphical solution based upon volumetric oil absorption ($OA_V$). Further simplification has been obtained through a constant-volume technique for the determination of $OA_V$ in which the weight of tested sample is established by pigment density, and the mL of oil required to reach the endpoint are converted directly to $OA_V$ by a calculation so simple that it may be performed mentally. Theoretical background has been provided to show that the graphical solution is fully consistent with published methods involving the pigmentation CPVC and the binding power index, and confirmed by practical illustrations in which both reduced cost and quality improvement were achieved.

### References

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(7) Ramig, J.R., JOURNAL OF PAINT TECHNOLOGY, *47*, No. 602, 60 (1975).
(8) Stieg, F.G., JOURNAL OF PAINT TECHNOLOGY, *49*, No. 630, 54 (1977).

### Trademark References

| | |
|---|---|
| Al-Sil-Ate O | Freeport Kaolin Co. |
| ASP-400 | Engelhard Minerals & Chemicals Corp. |
| Celite 281 | Johns-Manville Products Corp. |
| Duramite, Snowflake | Thompson-Weinman & Co., Inc. |
| Glomax LL | Georgia Kaolin Co. |
| M-60 | Smith Chemical & Color Co. |
| Omyacarb F, Omyacarb UF | Omya, Inc. |
| Satintone | Engelhard Minerals & Chemicals Corp. |
| Titanox | N L Industries, Inc. |
| TiPure R-911 | E.I. du Pont de Nemours & Co., Inc. |

# Society Meetings

## Birmingham Dec. 3

"SOLVENT SELECTION BY COMPUTER TECHNIQUES" was presented by H. Blom, of Shell Chemicals (UK) Ltd.

According to Mr. Blom, 45% of Shell's output is to the surface coatings industry. Although there have been many predictions of rapid growth in water-based and high-solids coatings, this had not happened to the extent expected, said Mr. Blom.

Pressures for development of new solvent blends come from three main sources: high solids technology where viscosity is a critical factor; control of emission of volatile components, in which evaporation is important; and systems avoiding certain exempt solvents, where solubility properties must be considered, he added.

Mr. Blom described some of the physical inter- and intra-molecular reactions which occur when polymers are dissolved in a solvent. Graphs and slides illustrated the characteristics needed for a good solvent system.

Viscosity of a material was described by Mr. Blom as its mobility or resistance to flow. It can be affected by such parameters as the degree of hydrogen bonding and polymer chain length. When solvent additions of up to 30% are involved, changes in viscosity due to variations in solvent blend can be represented by a relatively straight line graph, according to Mr. Blom.

Solubility is measured by such tests as kauri-butanol ratio, aniline point and dilution ratio, said Mr. Blom. Using points of isopolarity Mr. Blom constructed a graph which effectively determined the solubility parameters for a given resin. From this, it could be shown that a blend of nonsolvents may sometimes act as a reasonable solvent for a resin, but relative evaporation rates would be critical under such conditions. Volatility or evaporation rate was measured by evaporation numbers (i.e. total evaporation time compared with ethyl ether) or relative evaporation rate (i.e. 90% evaporation compared with normal butyl acetate).

In solvent blends, the normal, single-component interactions such as hydrogen-bonding, are disrupted and generally weaker ones are formed, according to Mr. Blom. It is this synergy which allows blends to behave differently to their components. Computer models, based on experimental data, can be used to design solvent blends which meet the requirements of a system, said Mr. Blom. An example of computer solvent selection concluded the presentation.

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*Q. Do you assume all evaporation rates are adiabatic?*

A. No. Computer results are a good guide but not perfect. There is no compensation made for cooling effects during evaporation.

*Q. Do you use optimized parameters for xylol?*

A. Yes. Ortho and para may be different as may be different fractionations.

*Q. Different media have different solvent-release effects. Does the computer model consider these?*

A. No. Only the relative effect is

considered by use of a standard form. This is only a helpful theory.

*Q. Can computer predictions be made to take polymer/resin into account?*

A. No. It would be too difficult. One can restrict various parameters, e.g., solubility characteristics can be fed into a computer, but it would only give a general view.

*Q. Does all the work have to be done in the laboratory?*

A. No. If one has a practical blend which is known to work then reformulation can be predicted by the computer.

*Q. Is it not true that molecular weight of a polymer is usually a spread and not an absolute figure?*

A. The values used are derived from practical tests on particular resins.

*Q. What would be the shift in solubility parameters for materials with high-solids?*

A. A certain minimum amount of resin is essential to produce relative disorder. Therefore the results work more closely with higher concentrations.

*Q. Can flash point functions be included in computer predictions?*

A. Usually this can only be done on the basis of excluding all solvents with flash point below a certain figure.

D.H. CLEMENT, *Secretary*

## Montreal Dec. 2

Dr. H.P. Schreiber, of Ecole Polytechnique, discussed "ABOUT SURFACES: WHAT TO MEASURE AND WHY."

Dr. Schreiber described variables governing technical demand including: energy conservation (areas of development), environmental legislation, consumerism, and raw material economics. He then discussed compatibility within polymer systems and properties such as gloss, adhesion, durability, and ease of dispersion that were good indicators as far as a coatings system was concerned.

According to Dr. Schreiber, the criteria for compatibility of polymers are as follows: (1) Optical clarity; (2) Gloss transition temperature—mixtures and effects; (3) Solubility parameter; and (4) Surface free energy or "Critical Surface Tension."

With reference to (4), he pointed out that free energy of mixtures must be less than 0 to be compatible and stable. Solubility parameters in coatings polymers can only be estimated and are of questionable value since the polymer is expected to perform as a cured film as opposed to a diluted liquid state, explained Dr. Schreiber. The critical surface tension value can be calculated from the angle of contact of a liquid on a film and is expressed as $\gamma_c$. If one still desires it, the solubility parameter can be calculated from $\gamma_c$.

The contact angle can be measured by means of a thermal gradient bar (cooled at one end and heated at the other to provide a temperature gradient). This is accomplished by placing the paint sample on a metal panel on the bar and dropping droplets of a liquid onto the paint film, explained Dr. Schreiber. The droplets are photographed, the shape or area of the droplet is determined, the angle calculated and transformed into $\gamma_c$.

Dr. Schreiber posed the question—What use is the $\gamma_c$ value? He explained the significance of $\gamma_c$ by pointing out that $\gamma_c$ is a function of $T_g$ (glass transition temperature) and provided an indication of whether a polymer reacts to a specific environment. As an example, he sited an automotive polymer requiring plasticizing where it was expected that two plasticizers would perform equally, however, over the temperature range, two quite different sets of data were obtained indicating that the polymer was compatible with one plasticizer but not the other. An important consideration in this test work is that the liquid used must not be a solvent for the polymer under evaluation.

Dr. Schreiber described a study in which the correlation between moisture penetration (permeability) and miscibility (compatibility) was used to evaluate a series of eight polymers. The polymer characteristics were reviewed including; composition, reduced viscosity, gloss, glass transition temperature, molecular weight, and $\gamma_c$ values. He noted that $\gamma_c$ varied directly as acrylic content.

The polymers were aged slightly above and slightly below their $T_g$, and the $\gamma_c$ values are redetermined versus aging time, said Dr. Schreiber. In one case, results indicated that after 10 hours of aging at 90°C that $\gamma_c$ increased drastically which suggested that the polymer surface was no longer the same.

According to Dr. Schreiber, material cannot change spontaneously to increase surface tension, thus the polymer is no longer the same chemical system. One concludes that one acrylic component must be immiscible and in this case was determined to be methacrylic acid. $\gamma_c$ plotted versus the square root of exposure time confirmed that a diffusion process was occurring with the methacrylic acid and if this component migrates to the substrate-polymer interface instead of the film surface there is risk of significant loss of adhesion.

In conclusion, Dr. Schreiber stated that a small scientific evaluation such as the above is capable of pointing out flaws in a coating's performance in a relatively short period of time compared to years of exposure to natural conditions.

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*Q. What is the size of the gradient bar?*

A. Approx. 30″ long × 10-12″ wide, and there are two commercial models available.

*Q. What is the purpose of the magnet on the gradient bar?*

A. To insure good thermal contact.

*Q. What would be the relation of critical surface tension to ink transfer?*

A. It would be essential that the surface tension of the ink is lower than that of the substrate for transfer to take place.

ERIC J. TEMPLETON, *Secretary*

## New York Nov. 10

Mike Frantz, of Daniel Products Co., spoke on "FACTORS GOVERNING TINTER PERFORMANCE."

According to Mr. Frantz, there are very few paint companies that do not buy or manufacture tint bases or colors to tint their white paints. He discussed the five prime factors governing tinter performance which included: (1) dispersing medium; (2) pigment; (3) solvent or solvents present; (4) dispersing equipment used to make tinter; and (5) interactions between various tinters used in the systems.

When using vehicles, the same vehicle should be used in both the tinter and the coating, explained Mr. Frantz. However, this does not guarantee the best film performance or color uniformity in the finished coating, maximum tint strength, good stability, or rheology.

Pigments suggested as interchangeable are not always interchangeable in different vehicle systems, and can cause viscosity problems on varying levels depending on the vehicle systems, said Mr. Frantz. At levels of 25%, there may not be problems, explained Mr. Frantz, but at levels of 45%, rheological differences will occur. A pigment that caused early excessive dilatancy problems can be assumed to be a trouble maker later on.

Mr. Frantz stressed that improper selection of solvents for tinters can cause incorporation problems.

Color development varies greatly with milling processes and milling time. Mr. Frantz explained that proper use of the correct dispersing equipment will usually provide maximum tint strength, cleaner hues, and more trouble-free incorporation. According to Mr. Frantz, the best dispersing equipment was the attriter.

Mr. Frantz discussed the interference between tinters in many systems. A tinter should never be judged by its performance by itself, but should be evaluated with others. For ideal performance, a tinter should have the following properties, said Mr. Frantz. These include: wide range of compatability; good tint uniformity; no adverse effect on the chemical or physical properties of the system; no adverse effect on the drying time of the coating; must have fine grind; maximum tintorial strength that can be developed; low stable viscosity at high pigment loadings; freedom from settling, separation, skinning; if aqueous—good freeze/thaw stability and must meet environmental restrictions.

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*Q. Have you tried different batches of pigment from the same manufacturer, especially iron oxides which give different results, such as tint strength and flocculation, etc.*

A. One could expect that with natural pigments made to a specification. It is not expected too much from pigments from manufacturers in the audience; however, one can get very extreme variations from competitive suppliers.

*Q. Can you tell us the size of the media used in the attriter?*

A. 1/3 inch.

*Q. What were they in the pebble mill by comparison?*

A. 1/2 inch to 3/4 inch, natural flint media. They were actual production batches, not lab batches.

*Q. On the three yellow oxides in retrospect, have you gone back to understand and see why they behaved differently, and (2) Do you have any explanation why the sudden change in the viscosity curve at the 45% level?*

A. They behaved differently because they are different pigments. The oil absorption may be the same on two pigments but oil absorption does not necessarily relate to the absorption of a given vehicle used in a dispersion. Oil absorption only relates to the oil used in that dispersion. (2) Why the dilatancy occurs at a given point, I really do not have any information.

*Q. Since it seems the smaller media will give a higher tint strength, what happens when you get down to the sand mill where you have more contact surfaces and you're bound to get better grinding?*

A. You have more to deal with than just the size of the media. Smaller media will give more contact area but less energy. Larger, heavier media will give you more energy and, therefore, more contact.

*Q. Is there a point of maximum efficiency and what size?*

A. There is a maximum efficiency with media, depending on the type of equipment used, e.g. 1/16 inch in a S.W. mill but not for an attriter. We have found that to get the maximum tint strength with the lowest energy and manpower input, the attriter is the most easily used equipment.

HERBERT ELLIS, JR., *Secretary*

## Northwestern Nov. 10

Robert Middlemiss, of Mooney Chemicals, presented "EFFECTS OF METAL CATALYSTS (DRIERS) IN WATER-BORNE AND HIGH SOLIDS COATINGS."

Mr. Middlemiss defined driers and discussed the types of processing and the carboxylic acids used. Natural acids are tallates and the naphthenic acids are naphthenates, according to Mr. Middlemiss. As petroleum becomes more scarce, he suggested using synthetic acid based driers. The synthetic based driers made from acids such as 2-Ethylhexoic or Neodecanoic may contain a higher metal content as these types of acids are of higher purity.

According to Mr. Middlemiss, there are three major categories of driers: oxidative—cobalt, manganese (top cure, surface dry); polymerizing—lead, zirconium, rare earth (thru cure); and auxiliary—calcium (acts synergistic with cobalt and lead to speed up the dry time of the system).

In the oxidative category, there is not a satisfactory substitute for cobalt, which is by far the most active oxidizer. The cobalt is also very important in peroxide formation and the peroxide decomposition. Cerium and iron are primarily used as a baking catalyst, however, they will discolor the film.

According to Mr. Middlemiss, in the polymerizing group, lead has been the industry standard for years. It is presently being replaced by zirconium, which is not completely satisfactory in many systems and under marginal conditions such as 50° F and 90% relative humidity, where it will not cure the film at the proper rate. The rare earth materials will perform much better under these conditions, said Mr. Middlemiss.

In the auxiliary category, calcium aids in the thru dry and in dispersion. Zinc is a cobalt modifier which actually retards the cobalt to some degree and allows the coating to stay open a little more and allows the oxygen to penetrate deeper into the film and give a better dry. It is effective in correcting wrinkling if too much cobalt has been used, said Mr. Middlemiss.

Mr. Middlemiss showed typical drier levels to be used. As an example, cobalt should be used in the range of 0.02-0.1% based on metal. He suggested that you start at a lower level and then work up the ladder to the proper percentage.

The drying process contains basically five categories, said Mr. Middlemiss. They are: (1) Induction period—primarily the solvent flashes out of the system. They could be the organic solvents, water, butyl cellosolve, etc.; (2) Peroxide formation; (3) Peroxide decomposition—initiates the polymerization; (4) Polymerization reaction—rapid increase in viscosity; and (5) Degradation phase—this can be from several months to several years depending on how long the film is on the substrate.

The metal carboxylate groups significantly shorten the induction period, increase the rate of oxygen absorption, promote peroxide formation and also peroxide decomposition, and reduces the amount of oxygen required in the entire system. Slides illustrated various examples of cobalt used as the primary metal drier.

Mr. Middlemiss pointed out that if you have any free phenol in the system it will have a tendency to stabilize the lower oxidation state which will reduce the ability of the cobalt to resonate between the higher and lower state resulting in a very poor dry time. Zirconium, lead, and rare earth metals break the oxygen across the polymeric chain.

In high solids and water-based systems it is very important to maximize the efficiency of the cobalt material initially and especially on aging, said Mr. Middlemiss. It was found important to chelate the drier to some degree. Chelating will significantly increase the activity of the drier, minimize the drier absorption via pigments, and stabilize the drier against hydrolysis. In a water reducible system this becomes extremely important, according to Mr. Middlemiss. Also it will increase film hardness, increase rate of electron transfer, and change the electron distribution in the system.

Slides were shown showing the effects of chelated and nonchelated systems that have been aged for eight months, using a scrub resistant test. The chelated system showed no loss of dry after eight months while the nonchelated system showed a significant loss of dry. Minimal loss of dry is extremely important in the water reducibles, explained Mr. Middlemiss.

Some drier related problems to high solids formulation and water reducibles are: (1) Drier incompatibility with the resin; (2) Resin viscosity build; and (3) In high solids (80% or greater) some resins are loaded with reactive monomers or just linseed oil to come up to a high solids system—you must use the proper drier system for these systems in order to get the proper cure.

Dispersion of the driers in the high solids systems can be done by premixing the driers in a solvent and then adding the premix to the high solids system, said Mr. Middlemiss. You also may be able to use a surfacant type drier.

Mr. Middlemiss recommended a calcium, zirconium, and cobalt system as the ultimate combination for curing a high solids system. He suggested a combination consisting of 0.1% cobalt, 0.2% calcium, and 0.2% zirconium as a good starting point.

Some problems encountered with water-borne formulations are drier incompatibility, seeding, resin discoloration, poor initial dry, critical recoat time, and loss of dry with time, said Mr. Middlemiss. Chelated driers help stabilize the driers. Data was shown using a drier premix consisting of cobalt, calcium, and zirconium in butyl cellosolve which was then added to the water reducible resin. Shown was the improved drytime of the system both initially and after aging.

Some reasons for loss of dry were explained by Mr. Middlemiss as: (1) Resin hydrolysis; (2) High pH (greater than eight) causes resin to rapidly hydrolize and degrade the resin; (3) Drier hydrolysis—cobalt adverse coordination with water or ammonia. Refluxing with water or ammonia it becomes totally inactive. Therefore chelating is important in order to prevent this from occurring; and (4) Drier absorption by the pigments—chelating will help but you will still have some loss of dry.

Not all the problems have been solved, said Mr. Middlemiss, but when the suppliers and paint manufacturers work together they will solve more of them.

HERBERT DAVIDSON, *Secretary*

### Pacific Northwest Nov. 19

Edward Antonucci, of Drew Chemicals Corp., presented "FLASH RUST INHIBITION IN WATER-BASED PAINTS."

Mr. Antonucci defined flash rust as the growth of nail rusting in latex paints. Corrosion was discussed as the difference in electro-potential in cells. The extent of corrosion is the ability of ions to migrate, explained Mr. Antonucci.

Numerous inhibitors were discussed such as chelates, amines, sulphites, and sodium nitrates; all are water soluble. Mr. Antonucci described the effects of these products but concluded by suggesting good surface preparation as the best cure.

O. SCHMIDT, *Secretary*

### Philadelphia Dec. 10

"EXPERIMENTAL OPAQUE POLYMERS" was presented by Dr. Nyi, of Rohm and Haas Co.

Dr. Nyi explained that experimental opaque polymer is an additive which aids in reducing RMC's of trade sales coatings by contributing directly to hiding, improving the hiding efficiency of $TiO_2$ (spacing), and allowing paints to be formulated with equal resistance properties at higher PVC's. The basic principles, formulating methodology, and model formulations of the new technology were reviewed.

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*Q. Can these particles be added to the dispersion phase?*

A. They usually are not but can be and should give no problems.

*Q. Do these particles cause any change in drying character or time?*

A. These particles do dry somewhat differently since the spheres must lose their water. Under good drying conditions (50% or less R.H.), the time is typical of trade sales paints. At high R.H. (70%) the spheres do not lose their water quickly.

*Q. What is the nature of the process that permits the sphere to dry initially but then not take up water into its air void with subsequent exposure to wet conditions?*

A. We consider the answer to this question proprietary at this time. The diffusion out is vapor pressure related. The process that prevents reabsorption we cannot divulge.

*Q. Can you use coalescing agents with this polymer and do they cause any problems?*

A. Yes, we use them and recommend slightly higher levels than with conventional formulas. There is no adverse effect on the polymer by coalescents.

*Q. What is the direct comparison of scattering of this polymer vs. titanium dioxide?*

A. In terms of PVC, a titanium dioxide PVC of 10 is probably close to the hiding of an opaque polymer PVC of 30. The comparison is not linear or fair since the hiding of titanium dioxide can be effected by crowding while the opaque polymer cannot be crowded.

RALPH MYERS, *Secretary*

### Piedmont Dec. 16

Al Heitkamp, of Cargill, Inc., spoke on "FILM SURPRISES OR IRREGULARITIES IN WATER-BORNE AND HIGHER SOLIDS INDUSTRIAL SYSTEMS."

The development and use of aqueous and high solids paint systems are exposing formulators to film failures not often seen with conventional solvent systems, said Mr. Heitkamp. Film "surprises" i.e., failures that are common to all three paint systems are: (1) fisheyes, cratering and pinholes; (2) flooding, floating; (3) blistering, solvent popping; (4) microscopic wrinkling; (5) flow leveling, orangepeeling; and (6) sagging, runs. Making the corrections to these film failures are common practice to formulators, explained Mr. Heitkamp. However, in the aqueous and high solids systems several other types of film failures do exist: (1) application variation from temperature and humidity; (2) picture framing; (3) telegraphing, show through; (4) foam; and (5) air entrapment. The solutions to these surprises afford new challenges to the formulators, through formula modifications and additive selection, said Mr. Heitkamp.

J.E. HUSTED, *Secretary*

### Pittsburgh Dec. 7

"COMPUTER PREDICTION OF EVAPORATION OF AQUEOUS SOLVENT BLENDS WITH ANY NUMBER OF COSOLVENTS AT ANY HUMIDITY" was discussed by Dr. Albert L. Rocklin, of the Shell Development Co.

Selection of cosolvents for water-reducible coatings can be simplified, according to Dr. Rocklin, by a computer program which predicts solvent balance and evaporation time of multicomponent water/solvent blends. The solvents must be chosen for satisfactory application, drying, film quality, and cost.

According to Dr. Rocklin, the Evaporometer complies with the ASTM-D 3539 method. The solvent blend evaporation rate was explained as the sum of the individual solvent contributors. The contribution of each solvent is proportional to the concentration, evaporation rate of the pure solvent, temperature, and activity coefficient (UNIFAC), said Dr. Rocklin. Computer programming comes close to actual rates.

MICHAEL GILLEN, *Secretary*

### Rocky Mountain Dec. 7

Joan Ringle, of the Colorado Business Regulatory Reform Project, discussed the efforts of the Regulatory Business Reform Project to assist small businesses with regulatory procedures and to develop a procedure manual for regulatory reform.

DONALD M. SHILLINGBURG, *Sectretary*

# Future Society Meetings

### Birmingham

(Apr. 1)—"COPING WITH UNCERTAINTY IN BUSINESS"—L.N. Sneddon, Sundridge Park Management Center.

(May 6)—"COMPARISON OF EXPOSURE TEST METHODS"—Speaker from Hoechst UK Ltd.

### Chicago

(Apr. 5)—"TECHNICAL EEFFECTIVENESS"—E.B. Euchner, SCM Corp., and "STRESS MANAGEMENT"—Mel Clapp, Cities Service.

### Cleveland

(Mar. 16)—MINI-SYMPOSIUM on High Solids. "VERSATILITY OF HIGH SOLIDS INDUSTRIAL COATINGS"—Rich Johnson, Cargill, Inc. "DESIGN CONSIDERATIONS FOR HIGH SOLIDS REACTIVE COATINGS"—Dr. Loren W. Hill, Monsanto Plastics and Resins Co.

(Mar. 23-24)—25th SYMPOSIUM ON ADVANCES IN COATINGS TECHNOLOGY.

(Apr. 20)—PLANT TOUR.

(May 18)—60th ANNIVERSARY OF FEDERATION MEMBERSHIP. PAST PRESIDENTS AND SPOUSES' NIGHT.

### Dallas

(May 13)—"ANATOMY OF AN EMULSION POLYMER"—Benjamin Kine, Rohm and Haas Co.

### Detroit

(Mar. 23)—"USE OF SILICONES IN HIGH SOLIDS COATINGS"—William Saad, General Electric Co.

(Apr. 27)—"FUMED SILICA FOR RHEOLOGY CONTROL OF HIGH SOLIDS COATINGS"—Speaker from Cabot Corp.

(May 4)—FOCUS—"NEW FRONTIERS IN APPLICATION TECHNIQUES"—Michigan State University, Education Center.

(May 25)—JOINT MEETING with Detroit Paint & Coatings Association.

(Sept. 28)—Presentation by Cargill Corp.

(Oct. 19)—EDUCATION COMMITTEE'S PRESENTATION/PAST PRESIDENTS' NIGHT.

(Dec. 14)—"HIGH SOLIDS COATINGS"—Dick Hong, Spencer Kellogg Div., Textron, Inc.

### Golden Gate

(Mar. 15)—"THE UNIQUE PROPERTIES OF ULTRA-FINE SILICA"—John C. Becker, Jr., Omya, Inc.

(Apr. 19)—"HAZARDOUS WASTE DISPOSAL"—Michael L. Markowitz, Rollins Environmental Services of Texas, Inc.

(May 17)—"NEW DEVELOPMENTS IN SANDMILL DISPERSIONS TECHNOLOGY"—Roland F. Swett, Moorehouse Industries, Inc.

(June 14)—"COMPLIANCE SOLVENTS FOR INDUSTRIAL COATINGS"—Violete Stevens, Dow Chemical Corp.

### Houston

(May 12)—"ANATOMY OF AN EMULSION POLYMER"—Benjamin Kine, Rohm and Haas Co.

### Los Angeles

(Apr. 14)—"HAZARDOUS WASTE DISPOSAL"—Michael L. Markowitz, Rollins Environmental Services of Texas, Inc.

## Constituent Society Meetings and Secretaries

BALTIMORE (Third Thursday—Eudowood Gardens, Towson). JOSEPH D. GUISTO; Lenmar, Inc., 150 S. Calverton Rd., Baltimore, MD 21223.

BIRMINGHAM (First Thursday—Calthorpe Suite, Edgbaston). D. H. CLEMENT, Holden Surface Ctgs. Ltd., Bordesley Green Rd., Birmingham B9 4TQ, England.

CHICAGO (First Monday—meeting sites in various suburban locations). JOHN R. INGRAM, DeSoto, Inc., 1700 S. Mt. Prospect Rd., Des Plaines, IL 60018.

C-D-I-C (Second Monday—Sept., Jan., Apr., June in Columbus; Oct., Dec., Mar., May in Cincinnati; Nov., Feb., in Dayton). ROBERT A. BURTZLAFF, Potter Paint Co. of Ind., P.O. Box 265, Cambridge City, IN 47327.

CLEVELAND (Third Tuesday—meeting sites vary). DONALD C. DENISON, JR., Hilton Davis Chemical Co., 5254 Berkshire Dr., N. Olmsted, OH 44070.

DALLAS (Thursday following second Wednesday—Steak & Ale Restaurant). T. LEON EVERETT, Dan-Tex Paint & Ctg. Mfg., Inc., P.O. Box 18045, Dallas, TX 75218.

DETROIT (Fourth Tuesday—meeting sites vary). PETER BURNETT, Wyandotte Paint Products, Inc., 650 Stephenson Hwy., Troy, MI 48084.

GOLDEN GATE (Monday before third Wednesday—Alternate between Sabella's Restaurant on Fisherman's Wharf and the Sea Wolf at Jack London Square, San Francisco). KEN E. TRAUTWEIN, Sherwin-Williams Co., P.O. Box 23505, Oakland, CA 94623.

HOUSTON (Second Wednesday—Sonny Look's, South Main). GEORGE SCHWARTZ, Cook Paint & Varnish Co., P.O. Box 3088, Houston, TX 77001.

KANSAS CITY (Second Thursday—Cascone's Restaurant). MEL BOYER, Patco Coatings Products, 3947 Broadway, Kansas City, MO 64111.

LOS ANGELES (Second Wednesday—Steven's Steak House). EARL SMITH, Spencer Kellogg Div., Textron, Inc., P.O. Box 7205, Long Beach, CA 90807.

LOUISVILLE (Third Wednesday—Hasenour's Restaurant). E. D. THOMASSON, Louisville Varnish Co., 1400 Maple St., Louisville, KY 40207.

MEXICO (Fourth Thursday—meeting sites vary). TERESA SUAREZ, Sherwin-Williams Co., Mexico, D.F., Mexico.

MONTREAL (First Wednesday—Bill Wong's Restaurant). ERIC TEMPLETON, NL Chemicals Can., Inc., 2140 Sun Life Bldg., Montreal, Que., Can., H3B 2X8.

NEW ENGLAND (Third Thursday—Fantasia Restaurant, Cambridge). N. BRADFORD BRAKKE, Lilly Chemical Products, P.O. Box 188, Templeton, MA 01458.

NEW YORK (Second Tuesday—Landmark II, East Rutherford, NJ). H. ELLIS, D. H. Litter Co., Inc., 116 E. 16th St., New York, NY 10003.

NORTHWESTERN (Tuesday after first Monday—Edgewater East Restaurant). HERBERT DAVIDSON, Spencer-Kellogg Div., Textron, Inc., 525-25th Ave. S.E., Minneapolis, MN 55414.

PACIFIC NORTHWEST (Portland Section—Tuesday following second Wednesday; Seattle Section—the day after Portland; British Columbia Section—the day after Seattle). WILLIAM SHACKELFORD, Gaco-Western, Inc., P.O. Box 88698, Seattle, WA 98188.

PHILADELPHIA (Second Thursday—Valle's Steak House). RALPH MYERS, Del Vac Ink & Color Co., 1301 Taylors Ln., Riverton, NJ 08077.

PIEDMONT (Third Wednesday—Howard Johnson's Coliseum, Greensboro, NC). JAMES E. HUSTED, Mobil Chemical Co., P.O. Box 2438, High Point, NC 27261.

PITTSBURGH (First Monday—Skibo Hall, Carnegie Mellon Univ.). MICHAEL GILLEN, Van Horn, Metz & Co., Inc., 400 Keystone Dr., Carnegie, PA 15106.

ROCKY MOUNTAIN (Monday following first Wednesday—Gusthaus Ridgeview, Lakewood, CO). DONALD SHILLINGBURG, Union Chemical Div. of Union Oil, 1535 W. 13th Ave., Denver, CO 80204.

ST. LOUIS (Third Tuesday—Salad Bowl Restaurant). ROBERT J. GIERY, Spatz Paint Industries, Inc., 1601 N. Broadway, St. Louis, MO 63102.

SOUTHERN (Gulf Coast Section—Various Dates; Central Florida Section—Third Thursday after first Monday; Atlanta Section—Third Thursday; Memphis Section—Second Tuesday; Miami Section—Tuesday prior to Central Florida Section). J.E. GEIGER, Sun Coatings, Inc., 12295 75th St., N., Largo, FL 33540.

TORONTO (Second Monday—Mayfair Restaurant). R. KUHNEN, Tioxide Canada, Inc., 1 Eva Rd., Etobicoke, Ontario, Canada M9C 425.

WESTERN NEW YORK (Third Tuesday—Lord Amherst Restaurant, Williamsville, NY). MICHAEL C. KAUFMAN, Bisonite Co., Inc., P.O. Box 84, Kenmore St., Buffalo, NY 14217.

(May 12)—"NEW DEVELOPMENTS IN SANDMILL DISPERSION TECHNOLOGY"—Ronald E. Swett, Moorehouse Industries.

(June 9)—"COMPLIANCE SOLVENTS FOR INDUSTRIAL COATINGS"—Violete Stevens, Dow Chemical Corp.

### Montreal

(Apr. 7)—Manufacturing Committee Presentation.

(May 5)—"THE PURCHASING, SALES INTERFACE"—John Humfreys, Sherwin-Williams Co., and Paul Rheaume, NL Chemicals, Canada, Inc.

### Piedmont

(Mar. 17)—"COMPLIANCE—SOLVENT OPTIONS"—Speaker from Dow Chemical Corp.

(Apr.)—JOINT MEETING with Virginia Section.

(May 20)—"COMPUTER SELECTION OF SOLVENT BLENDS"—Dr. Albert Rocklin, Shell Development Co.

(June 16)—"ECONOMIC RECOVERY OF SOLVENT VAPORS"—Larry J. Durr, DCI Corp.

### Pittsburgh

(Apr. 5)—"ENVIRONMENTAL UPDATE"—Dr. Hugh M. Smith, Sun Chemical Co.

(May 3)—"DESIGN CONSIDERATION FOR HIGH SOLIDS REACTIVE COATINGS"—Dr. Loren W. Hill, Monsanto Plastics and Resins Co.

### Rocky Mountain

(Apr. 12)—"HAZARDOUS WASTE DISPOSAL"—Michael L. Markowitz, Rollins Environmental Services of Texas, Inc.

(May 10)—"NEW DEVELOPMENTS IN SANDMILL DISPERSIONS TECHNOLOGY"—Ronald E. Swett, Morehouse Industries.

(June 7)—"COMPLIANCE SOLVENTS FOR INDUSTRIAL COATINGS"—Violete Stevens, Dow Chemical Co.

### St. Louis

(Mar. 16)—"MICROBIOLOGICAL SPOILAGE OF LATEX EMULSIONS, CAUSES, AND PREVENTION"—John A. Jakubowski, Merck and Co.

(Apr. 20)—"PIGMENT SELECTION AND EVALUATION"—David Wisnewski, Industrial Finishes Laboratory.

(May 18)—"THE WHYS AND WHEREFORES OF CARTRIDGE FILTRATION IN THE COATINGS INDUSTRY"—Donald S. Onnen, AMF Cuno Div. "EFFECTIVE PAINT WASTE TREATMENT"—Edward M. Antonucci, Drew Chemical Corp. "DISPERSION EQUIPMENT"—Speaker to be announced.

# Elections

### BIRMINGHAM

*Active*

Dobell, R.K.—NL Chemicals UK Ltd., Brixworth, England.
Fowler, B.A.—Grilon UK Ltd., Stafford, England.
Harwood, Maurice G.—Croda Paints Ltd., Middlesex, England.

### CLEVELAND

*Active*

Banks, Brian Michael—Benjamin Moore & Co., Cleveland, OH.
Eichhorn, Thomas—Cambridge Ctgs. Co., Cleveland.
Howard, Dennis C.—Lord Corp., Erie, PA.
Kuschnir, Pamela A.—Glidden Coatings & Resins, Strongsville, OH.
Lemke, Chris—Pioneer Manufacturing Co., Cleveland, OH.
Rauls, Thomas—Glidden Ctgs. & Resins Div. SCM Corp., Strongsville, OH.
Spector, Richard J.—Morgan Adhesives Co., Stow, OH.
Woebkenberg, James N.—Glidden Coatings & Resins, Strongsville, OH.

*Associate*

Allen, Hope—Ferro Corp., Cleveland, OH.
Christman, Gregg—Schabel Products Corp., Cleveland, OH.
Schabel, Norman G., Jr.—Schabel Products Corp., Cleveland.

*Educator and Student*

Chuu, Shean Ren—Kent State University, Kent, OH.
Rickert, Scott E.—Case Western Reserve University, Cleveland, OH.

*Retired*

Tomc, William M.—Cleveland, OH.

### HOUSTON

*Active*

Baker, Herbert H. Jr.—Imperial Coatings, Inc., Alvin, TX.
Barnes, Richard C.—Negley & Co., Inc., San Antonio, TX.
Farrow, Thomas—Souther Clay Products, Gonzales, TX.
Grannell, R.A.—Shell Development Co., Houston, TX.
Hollingshead, Gary J.—Isothermal Protective Ctgs., Inc., Pearland, TX.
Kaiser, C.E.—C.E. Kaiser Co., Houston.

*Associate*

Dunn, Glenn—Union Chemical Div., Houston, TX.
Flaming, Mel—Henley & Co., Houston.
Jones, Robert L.—Chemcentral, Houston.
Kaufmann, Elaine—Union Chemical Div., Houston.
Marmaduke, Bennett—Union Carbide Corp., Dallas, TX.
Schory, Bob—Union Chemicals Div., Houston.
Shreves, Douglas—Union Chemicals Div., Houston.

*Retired*

McSherry, William—Houston, TX.

### PIEDMONT

*Active*

DuPont, Steve M.—Ashland Chemical Co., Charlotte, NC.
Mills, John—Reliance Universal, Inc., High Point, NC.

Perkins, Lew—Reliance Universal, Inc., High Point.

Quinlan, George L.—Prillaman Co., Martinsville, VA.

Smith, Jerry L.—Thiele-Engdahl Inc., Winston-Salem, NC.

Wasson, Shirley J.—Rutland Fire Clay Co., Gastonia, NC.

*Associate*

Austin, Sarah A.—Moreland McKesson Chemical Co., Greensboro, NC.

Brown, Kenneth W.—Worth Chemical Corp., Greensboro, NC.

Cassel, Michael D.—Union Chemicals Div., Charlotte, NC.

### SOUTHERN

*Active*

Augustine, Roseann—Imperial Prof. Coating, New Orleans, LA.

Beam, Rickey L.—Midland Div., Dexter Corp., Birmingham, AL.

Blake, D. Willson—American Cyanamid, Savannah, GA.

Bryant, Daniel M.—Aladdin Paint Mfg., Orlando, FL.

Burke, Barry E.—Sigma Ctgs, Inc., Harvey, LA.

Byrd, C.R.—Ameron, Inc., Enmar Finishes, Little Rock, AR.

Byrd, Richard R.—Ameron-Enmar Industrial Finishes, Little Rock, AR.

Caramello, Peter—Davies Can Co., Tampa, FL.

Carneal, Charles D.—Safety Coatings, Inc., Foley, AL.

Caviness, Gary W.—Wyandotte Paint Inc., Norcross, GA.

Culp, Michael B.—Ameron Inc., Enmar Finishes, Little Rock.

Davis, M. Kenneth—Glidden Coatings & Resins, Atlanta, GA.

DeLuca, Frank—Armor Paint Inc., Clearwater, FL.

Drexel, Richard J., Jr.,—Freeport Kaolin, Gordon, GA.

Espeut, Kenneth W.—ITD Industries, St. Petersburg, FL.

Gill, Debra E.—Glidden Coatings & Resins, Atlanta, GA.

Griffin, John L.—Al Hendry Co., Tampa, FL.

Horton, Howard J.—Glidden Coatings, Oakwood, GA.

Johnson, Charles G.—Mobile Paint Mfg., Theodore, AL.

Lakatos, Stephen J.—Kohl P. Madden Ink Co., Doraville, GA.

MacRae, John—International Paint Co., New Orleans.

Martyn, John G.—Sinnett Lacquer, Dotham, AL.

Moes, Philip—Glidden, Atlanta, GA.

Page, Bevester—Buckman Laboratories, Memphis, TN.

Rawle, Richard—Var Tung Coatings, Picayune, MS.

Reece, David S.—Glidden Coatings & Resins, Atlanta, GA.

Robinson, Russ—The O'Brien Corp., Brunswick, GA.

Schrier, Bruce H.—ITD Industries, St. Petersburg.

Shipp, Peter W.—Glidden Coatings & Resins, Atlanta.

Slate, Joseph—Benjamin Moore & Co., Jacksonville, FL.

Stanley, Keith—Glidden Coatings & Resins, Atlanta, GA.

Waters, C. Donald—Savannah Paint Co., Savannah.

Wayne, Jack, Jr.—Aladdin Paint Mfg., Orlando.

Wayne, Jack, Sr.—Aladdin Paint Mfg., Orlando.

*Associate*

Alkins, Edward R.—Polyvinyl Chem. Ind., Lilburn, GA.

Barber, Truman J., Jr.—Ribelin Sales, Inc., Jefferson, LA.

Cantrell, Lester—Georgia Marble Co., Atlanta, GA.

Cousin, Constant J.—Ribelin Sales, Inc., Jefferson, LA.

Dillingham, John T.—J.R. Hall, Inc., Hot Springs, AR.

Golden, Haschal—Delta Foremost Chem., Memphis, TN.

Goldson, Wayne M.—Miami Epoxy Resin Supply, Miami, FL.

Hart, Larry R.—Air Products & Chemicals, Stone Mountain, GA.

Jellico, Ruby L.—Standard Container, Tampa, FL.

Jones, John H.—Inland Steel Container, Atlanta.

Jones, Roger M.—Roger Jones Asso., Inc., Roswell, GA.

Kraniak, Lynn—Kerr-McGee Chemical, Decauter, GA.

Matienzo, Peter J.—MAT Chemicals, Inc., Miami, FL.

Messer, Ed—Sun Chemical Corp., Sharpsburg, FL.

Millhof, David W.—Summit Chemical, Inc., Stone Mountain, GA.

Taylor, Harold F.—Reliance Universal, Inc., Oakwood, GA.

Tucker, Wayne M.—Canariis Corp., Tampa, FL.

Volz, Robert C.—MAT Chemicals, Inc., Miami.

Wilson, Les—Cargill, Inc., Forest Park, GA.

Woolf, Ralph B., Jr.—Apperson Chemical, W. Palm Beach, FL.

Wrobel, Joseph J., Jr.—Ciba-Geigy Corp., St. Louis, MO.

*Educator/Student*

Engelhardt, Kenneth—Univ. of Southern Mississippi, Hattiesburg, MS.

### WESTERN NEW YORK

*Active*

MacLauchlan, John C.—Pratt & Lambert, Buffalo, NY.

Proctor, Malcolm—Spencer Kellogg Div., Buffalo.

## Southern Society to Hold 46th Annual Meeting, March 10–12

"Coating Technology—Strategies for the Eighties" will be the theme of the 46th annual meeting of the Southern Society for Coatings Technology when it meets at the Hyatt Regency Hotel in Savannah, GA, on March 10–12.

The theme emphasizes strategies that will be used by paint manufacturers to survive and profit in the upcoming decade.

The Keynote Address will be given by William A. Bours, III, Past-President and member of the Board of Directors of the National Paint and Coatings Association. Mr. Bour's address, entitled "How's Our Visibility," will examine the low profile of the paint industry and the benefits of better understanding of the industry's contributions to society.

Following the Keynote Address, Violete Stevens, Technology Coordinator for Dow Chemical, will discuss the forces of change in the 80's which require innovations in resins and solvents. Fred Schulenberg, Special Projects Editor of the *American Paint and Coatings Journal*, will explain how to enhance a paint company's image in his presentation, "Your Product, Your Plant, Your People: They Build Your Public Image."

Two panel discussions will be featured in the program. One panel will examine "Present and Future Trends" in paint application, while the other panel, entitled "Paint Production-Design for Profit," will evaluate how changes in the 80's effect production management and plant design.

"Coatings Opportunities in the Eighties—They Are Disguised as Problems" will be presented by John C. Dean, Vice-President, Chemical Marketing Services.

Preceding the formal program, "Past Presidents' Paint Seminar" symposium will be offered on Wednesday, March 10. This special session will be presented by the Past-Presidents of the Southern Society and will discuss exterior clear coatings—trade sales and industrials.

Members of the Planning Committee are: *Chairman*—John R. Lawson, Kerr McGee Chemical; *President-Elect*—Dan M. Dixon, Freeport Kaolin Co.; *Program*—William G. Early, Piedmont Paint Mfg. Co.; *Operations*—Frank Kaulakis, Freeport Kaolin Co.; *Registration*—Jim Gieger, Sun Coatings, Inc.; *Golf/Tennis*—Robert Link, R.T. Vanderbilt Co.; *Printed Materials*—Ron R. Nelson, Kelco Corp.; *Spouses' Program*—Bobby Moore, Interstate Paint Corp.; and *Publicity*—Terrence J. Walsh, Kinsmen Corp.

Fee for the meeting is $55 which includes the full formal program on Thursday and Friday, the Thursday night reception, and the Friday awards luncheon. With registration, the cost of the Wednesday symposium is $10.

For additional information, contact Terrence J. Walsh, Kinsmen Corp., 214 Permalume Pl., N.W., Atlanta, GA 30318, (404) 355-9550.

## FATIPEC Congress Discussion Reports In Netherlands Publication

Discussion reports of papers presented at the XVth FATIPEC Congress (June 1980, Amsterdam, Netherlands) have been published in *Verf Kroniek*, a publication of the Dutch Association member of FATIPEC, the Nederlandse Vereniging Van Verftechnici.

These reports, published in the author's language, supplement the published proceedings in the FATIPEC Congress Book. The discussions center on a variety of subjects including energy savings, environmental issues, waterborne, high-solids, and powder coatings, corrosion protection; R&D efficiency, and printing inks.

The reports have been published in 1981 issues of *Verf Kroniek*. For further information write to the publication's editors at: Berkenrode, Groot Haesebroekseweg, Postbus 71, 2240 AB Wassenaar, Netherlands.

## AFP/SME To Sponsor Workshops On Industrial Paints and Methods

The Association for Finishing Processes of the Society of Manufacturing Engineers (AFP/SME) will sponsor one-day workshops on "Industrial Paints and Painting Methods" on April 13 in Detroit, MI; April 15 in Hartford, CT; and May 18 in Philadelphia, PA.

These workshops are designed to provide an understanding of the character and performance factors of paint applied to products and to give a broad view of the various paints and methods of application that are available to achieve a quality finish. Designed for management and engineering companies using paint as a finishing method for their product, these workshops will give special emphasis to meeting air quality standards for paint emissions.

The following topics have been outlined for the program: basic paint concepts; basic application steps; components of paint; wet and dry properties; the painting process; and paint quality.

Horace H. Homer, Finishing Consultant based in North Falmouth, MA, is the instructor for these workshops. He is a graduate of Massachusetts Institute of Technology and holds a Bachelor of Science Degree in Chemical Engineering. Mr. Homer holds 22 patents in the finishing equipment field and has handled the installation of numerous powder coatings systems.

Fee for the program is $135 for members and $155 for nonmembers.

For additional information, contact Susan Buhr, Technical Activities Dept., SME, One SME Dr., P.O. Box 930, Dearborn, MI 48128.

## "A Batch Operated Mini-Media Mill" Added to Federation A/V Training Series

Addition of "A Batch Operated Mini-Media Mill" to its series of audio/visual training programs has been announced by the Federation.

Prepared by the Manufacturing Subcommittee of the New York Society for Coatings Technology, the program describes the design and operation of a batch operated mini-media mill, and was developed to assist in the training of plant personnel to operate such equipment.

The program, which runs approximately 8½ minutes, includes a cassette tape, 51 slides, and accompanying script, packaged in a vinyl album. Price is $60, plus shipping charges.

Orders and inquiries should be directed to Federation of Societies for Coatings Technology, 1315 Walnut St., Suite 832, Philadelphia, PA 19107.

# XVIth FATIPEC Congress To Be Held In Belgium, May 9–14

The XVIth Congress of FATIPEC (Federation of Associations of Technicians in the Paint, Varnish, Lacquer and Printing Ink Industries of Continental Europe) will be held in Liege, Belgium, May 9-14, at the Palais des Congres. The host organization is the ATIPIC, the Belgian Association member of FATIPEC.

## Theme

The theme of the Congress will be "Evaluation and Foresight of Film Properties of Organic Coatings by the Use of Modern Analytical Methods."

Present-day economical, ecological, and energy requirements place the paint industry in an accelerated evolution period regarding its technology. The Congress will examine this situation and discuss the difficult task faced by the manufacturer and formulator to create new products having the equivalent, if not better, properties than conventional coatings.

Lecturers will discuss how the problem might be solved or facilitated and many tests spared by a mastery and precise knowledge of: (1) the materials to be used and how to use them; (2) the interaction between pigments/binders (solvents)/substrates; and (3) the relationship between the physico-chemical properties of the formed film, both at short and long term, and the nature of the materials in the coating.

## Program

The program features section lectures accepted by the Scientific Committee of the XVIth FATIPEC Congress which have been classified in seven sections, taking account of the theme.

The scheduled program includes the following:

*Monday, May 10*

PLENARY LECTURES:

"Mechanical Properties of Weathered Paint Films"—Dr. L.A. Simpson, B.T.P. Tioxide Ltd. (U.K.)

"Automation in Analysis and Testing of Coatings"—Dr. J. de Wit, Kunstharsfabriek Synthese (Netherlands).

SHORT LECTURES:

Section 1: Films Formation

"Solvent History Effects and Multivalued Surface Properties of Poly(methyl methacrylate) Coatings"—H.P. Schreiber, Ecole Polytechnique (Canada).

"Pigmentation of Water-Soluble Resins: Correlation Between Application Properties and Dispersion Variables"—G. Cerruti (Italy).

"Thermoplastic Paints—Kinetics of Film Formation"—G. Torriano, Universita de Trieste, (Italy).

Section 2: Analysis of Binders

"Methods to Determine the Diffusion of Formaldehyde Through Coatings on Particle Board"—Ch. Korf, Center of Surface Technology (Netherlands).

"Analysis of Coatings Additives and Free Monomers Using Liquid and Capillary Gas Chromatography"—L.G.J. van der Ven, AKZO Research (Netherlands).

Section 3: Physico-Chemical Properties Analysis

"Group Contribution Methods for the Prediction of the Behavior of Polymer Solutions in the Paint Industry—P. Alessi, Universita de Trieste (Italy).

"Performance Optimization of Ambient Temperature Cured Epoxy Systems Using Statistical Techniques"—N. de Vries, Koninklijke Shell Laboratory (Netherlands).

"Acetylenic Glycols in Water-Based Coating"—J.H. Kasperma, Air Products & Chemicals, Inc. (U.S.A.).

*Tuesday, May 11*

PLENARY LECTURES:

"Computer Prediction of Latex Paints Properties"—Dr. G.P. Bierwagen, The Sherwin-Williams Co. (U.S.A.).

SHORT LECTURES:

Section 1: Film Formation

"Associative Thickeners and Their Rheological Behavior in Trade-Sales Formulations"—J.E. Glass, North Dakota State University (U.S.A.).

"Measurement of Formaldehyde Emission From Paint Films"—A. Tickelenberg, (Netherlands).

"Absorption of Paint Driers by Titanium Dioxide Pigments and Its Influence on the Hardening Process of Alkyd Paint Films"—S. Wilska (Finland).

Section 3: Physico-Chemical Properties Analysis

"Differential Scanning Calorimetry of the Curing of Polyester Powder Coatings With Epoxies"—R. van der Linde (Netherlands).

"Estimation of the Properties of a Reactive Three Components System Related to the Reaction Kinetics of the Components, With the Aid of I.R. Spectrophotometry, Thermal-Viscosity and Tensile Measurements"—T.T. Dekker.

"Cross-Linked Binders—Transition Temperatures"—G. Torriano, Universita de Trieste (Italy).

Section 5: Surface Characterization Methods

"Study of Interfacial Interactions Between Paint Systems and Various Metals Using Surface Analytical Techniques" —W.J. van Ooije, AKZO Research (Netherlands).

"X-Ray Photoelectron Study of the Surface Properties of Chromium Yellow and Molybdenum Red and Orange Pigments"—P.G. Rouxhet, University Catholique de Louvain (Belgium).

"Investigation of the Coatings Degradation by Auger Electron Spectroscopy" —S. Skledar, Institute of Chemistry (Yugoslavia).

"Use of the Scanning Electron Microscope (SEM) in the Development of 'Clear Over Base' Metallic Coatings"—R.W. Mahar, Eastman Chemical (U.K.).

*Thursday, May 13*

PLENARY LECTURES:

"Suitable Method to Determine the Low Shear Behavior. An Application to the Evaluation of Paint Levelling"—Dr. Lapasin (Italy).

SHORT LECTURES:

Section 6: Durability

"Electrochemical Methods to Predict the Corrosion Protecting Properties of Paints"—A. Koopmans (Netherlands).

"Wood Surface Degradation and Consequences for the Durability of Coating Systems"—K. Kleive (Norway).

Section 7: Analysis of Pigments

"Study About Stability of Titanium Dioxide Dispersions by Means of Measurement of the Polymer Adsorption of the Pigment Surface"—F. Biglieri (Italy).

"Design and Use of a Simple Flocculation Gradient Apparatus"—L.A. Simpson, B.T.P. Tioxide Ltd. (U.K.).

*Friday, May 14*

PLENARY CONFERENCES:

"Storage Stability of Some Oxygenated Raw Materials"—G. Christensen (Scandinavia).

COMMUNICATIONS:

Section 3: Analysis of Physico-Chemical Properties

"Dispersibility of Pigments as Criterion for Determining Optimal Mill Base Formulations"—J. Oyarzun (Germany).

Section 6: Durability

"Evaluation of Weather Durability of Paint Films"—B. Lindberg, Scandi-

*(Continued on page 67)*

# Rolla Announces 1982 Coatings Short Course Schedule

The Continuing Education Department of the University of Missouri-Rolla will sponsor its 1982 series of Coatings Short Courses, scheduled from March 15 to December 3.

Included are courses on basic composition and formulation, testing, advanced coatings technology and new management techniques and also workshops and conferences for the finishing and application industry.

According to John A. Gordon, Professor of Chemistry and Director of Coatings Continuing Education at UMR, additional programs may be developed as needs become apparent. Also, scheduled courses may be presented or special programs developed in-plant for industries with 10 or more employees to train.

The schedule of courses is as follows:

(Mar. 15-17—Villa Hotel, San Mateo, CA; May 4-6—Raphael Hotel, Chicago, IL)—"Industrial Market Research for the Chemical Industry"—Designed for marketing and sales managers and sales staff and trainees, the course will provide a general overview of market research with emphasis on an in-class case study. Featured will be a market research assignment, data gathering, estimating variables, forecasting, and developing information. Fee for the course is $495.

(Mar. 22-26, Aug. 9-13)—"Introductory Short Course on Composition of Coatings"—Through lectures, audiovisual presentations, and classroom demonstrations, participants will be introduced to the history of paint, the materials used in coatings manufacture, and some simple formulating techniques. Designed for newcomers, this course will offer explanations of the equipment used to make and test modern protective coatings. Fee for the class is $375 and will be held on the UMR campus.

(Apr. 5-9, Sept. 13-17)—"Introduction to Paint Formulation"—This lecture and laboratory course will feature sessions on calculating coating formulas for performance, economics, method of manufacture, and compliance with government regulation. It is designed for coatings and raw material manufacturers' laboratory staff who have a basic understanding and experience of coatings technology and want to learn and practice formulating techniques. Cost of the class is $400 and will be held on the UMR campus.

(Apr. 12-16)—"Advanced Paint Formulation—Trade Sales"—Designed for laboratory staff who have a basic understanding of formulation methods, and wish to broaden their skills. Emphasis of this course will be on proper formulation to achieve specific goals of cost, profit, performance, and ease of manufacture. The course will be held on the UMR campus, for a fee of $400.

(May 18-20—Villa Hotel, San Mateo, CA; Nov. 16-18, Sheraton St. Louis Hotel, St. Louis, MO)—"Job Estimating Workshop for Painting Contractors"—Study will include blueprint reading, specifications, quantity take-offs, and pricing structures. The class will work with actual plans in as near a real-life situation as possible. Class cost is $400.

(Aug. 16-20)—"Physical Testing of Paints and Coatings"—The course, designed for those working in quality assurance for coatings or raw materials, will illustrate how to measure the quality of paint from the standpoint of the coating manufacture. Lectures will present the purpose, theory, and techniques of quality assurance while laboratory sessions will feature actual performance of tests on equipment discussed in the lectures. The course will be held at the UMR campus for a fee of $400.

(Sept. 20-24)—"Advanced Paint Formulation—Industrial"—Designed for those with a basic understanding of industrial coatings, and formulation methods, the course will emphasize proper formulations to achieve specific goals of cost, profit, performance, and ease of manufacture of trade sales coatings. Fee for the course is $400 and will be held on the UMR campus.

(Oct. 26-27)—"World Congress—New Coatings Systems for Bridges and Steel Structures"—Safeguarding bridges against deterioration is the subject of this international two-day meeting designed for engineers, architects, contractors, and federal, state, and municipal highway personnel. Current practice and new technology will be presented by authorities from the United States and Europe. The congress will be held at the Holiday Inn LaGuardia, New York, NY for a fee of $215.

(Oct. 31-Nov. 2)—"Women in Coatings—Meeting the Challenges"—Designed for women and men in sales, management, and technology, the seminar will discuss the opportunities and challenges that industry offers women. A session will deal with skills to assure leadership situations while contributing more fully to company success. Fee for the seminar is $395 and will be held in Washington, D.C.

(Nov. 9-11)—"Refresher for Painting Contractors, Maintenance Engineers, and Inspectors"—Designed to introduce the newest techniques, equipment, and products for preparing surfaces for coatings, the course will discuss paint composition, preparation of wood, metal, and cement surfaces, application methods, drywall installation, and new restrictive government regulations. The course will be held at the Sheraton St. Louis Hotel, St. Louis, MO for a fee of $400.

(Nov. 29-Dec. 3)—"Principles of Industrial Coatings"—The course will evaluate coatings systems from the point of surface preparation and efficient application while maintaining quality and complying with government regulations. Designed for the industrial finisher, the course will feature lecturers from the finishing industry. Fee for the course is $495 and will be held at the Sheraton St. Louis Hotel, St. Louis, MO.

For additional information, or to register, contact Norma Fleming, Senior Coordinator, Arts and Sciences Continuing Education, G7A Humanities—Social Sciences Bldg., UMR, Rolla, MO 65401, (314) 341-4202.

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*(Continued from page 66)*

navian Paint & Printing Ink Research Institute (Denmark).

Section 7: Analysis of Pigments

"Measurement of the Degree of Dispersion of Pigments in Water-Based Flexographic Inks Using Chromatographic Methods"—PH. Huwart (Belgium).

The program also includes various social activities and a special program for spouses.

### Exhibition

An exhibition of coatings raw materials and manufacturing equipment, under the name FATIPEXPO, will run concurrently with the Congress in the Palais des Congres.

For additional information regarding registration, contact Destree-Congres, 10 rue du Coggege St. Michael, 1150 Brussels, Belgium.

## Paint Research Institute Programs Supported by 1981 Contributors

The list of Corporations/Organizations/Individuals which made financial contributions to the Federation's Paint Research Institute in 1981 (in addition to the annual grant from the Federation and the continuing Leo Roon Endowment Fund) is as follows:

### 1981 Contributors to PRI Societies

C-D-I-C; Dallas; Detroit; Golden Gate; Houston; Kansas City; Louisville; New England; St. Louis; Southern; and Toronto.

### Corporations and Foundations

C-I-L Paints Inc.; The M. F. Cachat Co.; Canada Colors & Chem. Ltd.; Canadian General Electric; Celanese Canada, Inc.; Chemcentral; Cook Paint & Varnish Co.; Daniel Products Co.; Dar-Tech., Inc.; Devoe and Raynolds Co.; D/L Labs.; Dominion Colour Co. Ltd.; Dow Chemical Co.; Drew Chemical Corp.; Dundas & Keele; Ferro Corp.; Flood Co.; Inmont Canada, Inc.; Jamestown Paint & Varish Co.; Kalcor Coatings Co.; L.V. Lomas Chem. Co. Ltd.; Mameco Int'l.; Midland Div., Dexter Corp.; Mobil Chem. Canada, Ltd.; Monsanto Co.; Mooney Chemicals, Inc.; N L Industries Foundation; Nacan Products Ltd.; Q-Panel Co.; Henry Reichhold Foundation; Reichhold Chemicals Ltd.; Rohm & Haas Co.; SCM, Glidden C&R Div.; Seegott, Inc.; Shell Chemical Co.; Sherwin Williams Foundation; Silberline Mfg. Co.; Donald McKay Smith, Inc.; Tioxide Canada Ltd.; Union Carbide Corp.; and Whirlpool Corp.

### Corporations Comprising The Mildew Consortium

Buckman Labs, Inc.; E. I. duPont de Nemours & Co.; Merck & Co., Inc. (Calgon); National Paint & Coatings Assn.; PPG Industries, Inc.; Rohm and Haas Co.; SCM, Glidden C&R Div.; and Troy Chemical Group.

### Individuals

H. Bender; G.D. Cheever; Raymond R. Myers (in memory of Herbert L. Fenburr); Joseph M. Walton; J. Wojtkowiak; and Anonymous.

## R&D Management Program Sponsored by Battelle

Battelle's International Program in productive research and development management will be held August 2–20 in Columbus, OH.

The intensive program is designed to train middle-level managers, who are responsible for R&D activities in industry, government, and academia, to more effectively carry out their jobs. Participants will gain an understanding of the principles and techniques encompassed in a productive R&D management system. In addition, they will be able to identify the strengths and limitations of their present management systems and to develop strategies for improving those systems.

Topics to be covered include: philosophy of management; planning; organizing; staffing and staff development; directing and leading; and evaluating and controlling. To help participants apply the concepts presented, a comprehensive case study will be used throughout the three-week program.

Instructors for the program include senior management from Battelle and experts in organization development, human resources, economics, policy analysis, and information systems.

Enrollment is limited to 30 participants. Additional information can be obtained from Dr. William D. Hitt, Battelle's Columbus Laboratories, 505 King Ave., Columbus, OH 43201.

## Printing Inks Short Course Offered by Lehigh, Apr. 19–23

The third annual short course, "Printing Inks and Printing Processes," will be offered at Lehigh University, Bethlehem, PA, April 19–23.

Designed for engineers, chemists, other scientists, and managers, the course will feature lectures and laboratory demonstrations presented by the faculty and staff of the National Printing Ink Research Institute. Emphasized will be a description of the different printing processes and the fundamentals and composition of printing inks.

Further information can be obtained from Dr. Mohamed S. El-Aasser, Dept. of Chemical Engineering, Sinclair Lab #7, Lehigh University, Bethlehem, PA 18015.

# People

Drew Chemical Corp., Boonton, NJ, has made three appointments in the reorganization of the Specialty Chemicals division. **Edward M. Antonucci** and **Raymond C. Montani** have been promoted to the positions of Marketing Managers for Chemical Additives and Process Chemicals, respectively. Mr. Antonucci is a member of the New York Society. Appointed Technical Manager of the division was **Bjorn Mattsson**, responsible for product development and qualification of technical investment opportunities.

Polychrome Corp., Yonkers, NY, has announced the appointment of **Dr. Kenneth A. Kun** as Vice-President, Chief Technical Officer. Based at corporate headquarters, Yonkers, he is responsible for guiding all of the firm's technical activities, including research and development, engineering, technical services, and special projects.

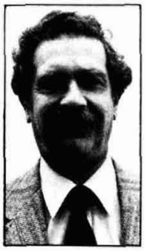
The Dexter Corp., Midland Division, has promoted **Lawrence Wasowski** to the position of Senior Project Chemist in the Resin Laboratory. A Midland employee since 1974, Mr. Wasowski has made notable contributions to research efforts in the areas of epoxy emulsions for inside spray applications and development of melamine resins.

Ultra Adhesives, Paterson, NJ, has named **John D'Amico**, President, succeeding **Mike Zecchin**, who has retired. Mr. D'Amico is the architect of the Ultra Adhesive technology used in the development of water-borne systems. As Chief Executive Officer, he brings a broad managerial background to his new position. Mr. D'Amico is also President of the Glazed Cement Corp. Both Mr. D'Amico and Mr. Zecchin are members of the New York Society.

**Dale W. Blewett** has been named International Technical Coordinator for the Container Coatings Group of Inmont Corp., Cincinnati, OH. In his new position, he will be responsible for technical coordination between the domestic container coating group and all affiliated companies outside North America. Mr. Blewett is a member of the C-D-I-C Society.


E.M. Antonucci


Dr. K.A. Kun


Dr. N.N. Schwartz


Dr. F.R. Huege

**Dr. Nelson N. Schwartz** has joined Thibaut & Walker, Inc., Newark, NJ, as Technical Director, reponsible for the development of emulsion and polymers. Also joing the staff is **Andy Romano**, responsible for the firm's Quality Control department.

**Dr. Seymore Hochberg**, recently retired from du Pont, was presented with the 4th Annual Golden Impeller Award from Morehouse Industries in recognition of his contributions to dispersion technology. The presentation was made at the FSCT Annual Meeting in Detroit.

**Dr. Frederick W. Von Rein** has been transferred to the Hilton-Davis Chemical Group as Director of Commerical Development. Previously, Dr. Von Rein was Director of Manufacturing for Sterling Organics.

**David Elkei** has joined Bee Chemical Co., Lansing, IL, as a Sales Representative serving North and South Dakota, Minnesota, Wisconsin, and Chicago.

**J. Marvin Quin** has been named administrative Vice-President for Ashland Chemical Co., Columbus, OH. Mr. Quin is responsible for the firm's controller's office, computer science and services, logistics, planning and analysis, and business development departments.

Also announced by the firm were the additional responsibilities assigned to **Harold J. Lincks** and **John K. Drake**. Mr. Lincks, Ashland Chemical's Controller, has been assigned responsibility for the credit and central coding departments along with the previous accounting function assignment. Mr. Drake, Director of Logistics, has been assigned additional responsibility for the office and building services department.

**Dr. Fred R. Huege** has been appointed Director of Research and Development, Pigments and Extenders Group of Engelhard Corporation's Minerals & Chemicals Division.

**Henry W. Levison** will receive the Inter-Society Color Council Macbeth Award for 1982 for outstanding achievements in color for the visual arts. The presentation will be made at the Awards Luncheon of the 51st ISCC Annual Meeting, April 19, in Charlotte, NC.

The Macbeth Award, established in 1972, was awarded to Mr. Levison for his lifetime contributions to the art material industry and his concentrated work since 1971 on new ASTM standards for artists' paints.

Trained as a chemist at the University of Cincinnati, Mr. Levison began his career working with commercial varnishes and inks. In 1933, he established the Permanent Pigments Co. and in 1954 formulated and marketed the first complete line of acrylic polymer emulsion artists' paints. He later formulated and introduced an innovative set of paints called the Modular Colors.

Mr. Levison has been a member of the Federation of Societies for Coatings Technology since 1936 and has been a 52-year member of the American Chemical Society. He is a past Fellow of the American Institute of Chemists, was elected to the Art Material Hall of Fame by the Art Material Trade Association, and has been an active member of the ISCC serving on several committees. Mr. Levison has also served on a National Bureau of Standards Standing Committee which in 1942 established the first voluntary standard for artists' paints.

Upon his retirement in 1971, Mr. Levison established Colorlab in Hallandale, FL, where he serves as a consultant.

**Dr. Umberto "Bert" Ancona** has joined the C.J. Osborn Chemicals, Inc., Research and Technical Group. He brings to his new position 31 years of experience in the field of coating and printing ink vehicles.

After receiving his doctorate in industrial chemistry from the University of Milana, Dr. Ancona came to the United States for additional studies at Columbia University. He was employed by McCloskey Varnish, Co., Philadelphia, PA, in 1950 and rose through the positions of assistant chief chemist, chief chemist, technical director, and more recently, vice-president and member of the board of directors.

Dr. Ancona has served the coatings industry at the local and national levels in various capacities. In 1965, he was elected President of the Philadelphia Society for Coatings Technology. Continuing his service, he was presented with the Liberty Bell Award in 1970 and the Technical Award in 1974. At the national level, he has chaired the Roon, Trigg, and the American Paint Journal awards committees of the Federation of Societies for Coatings Technology. Dr. Ancona has also chaired the Raw Materials Committee of the National Paint and Coatings Association.

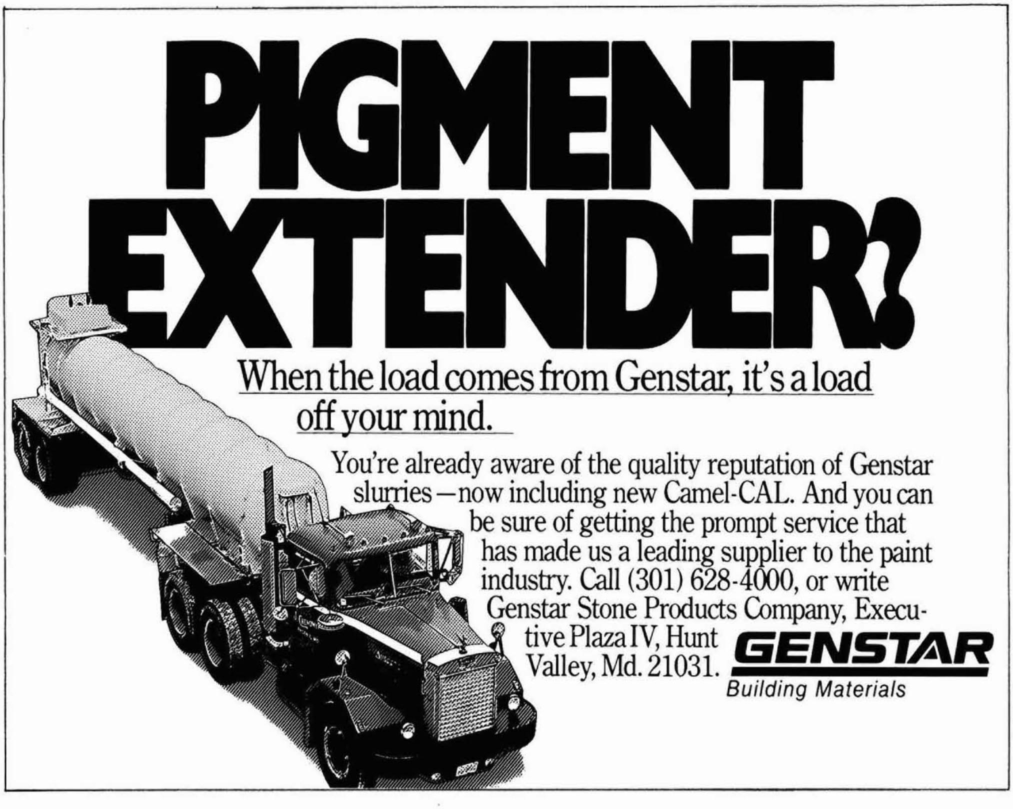
Ferro Corporation's Chemical Division, Bedford, OH, has announced several marketing organization changes. **Robert L. Iverson** has been promoted to Senior Marketing Manager responsible for flame retardants, UV stabilizers, and antioxidants. **Charles Draucker** has joined as Market Specialist, flame retardants, and **Thomas J. Slam** has been named Market Specialist for the application and marketing of UV stabilizers and antioxidants. **Derk Gauw** was named Marketing Manager, Rigid PVC. Promoted to the position of Technical Service Manager, Vinyl Products was **Lawrence J. Verbiar**. Also, **Thomas P. Kelley** has been appointed Technical Service Engineer.

**Walter K. Boyd**, a Senior Research Leader at Battelle's Houston Operations, has been elected President of the National Association of Corrosion Engineers (NACE). Mr. Boyd has been involved in NACE activities since 1955, serving as the Association's Vice-President and Treasurer, as well as on the Board of Directors and on various committees. In 1977, he received the Frank Newman Speller Award, the highest recognition given by the Society.

**Alexander A. Chasan** has been named Coatings Specialist at the David W. Taylor Naval Ship Research and Development Center, of the U.S. Navy in Annapolis, MD. He was previously employed by the Federal Supply Service of the General Services Administration as Specifications Manager. Mr. Chasan is a Past-President of both the Baltimore Society and the Washington Paint Technical Group, and is the current Society Representative for Baltimore to the Federation Board of Directors.

**James G. Aslaksen** has been named National Sales Manager of the Container Coatings Division of The O'Brien Corp. Based at the firm's Oakbrook, IL offices, he will be responsible for the marketing, sales, and product-service functions.

Nalco Chemical Co. has announced the promotions of **Robert B. Brower** to Group Vice-President and **Dr. Ronald J. Allain** to Vice-President, Research and Development. Also, **Dr. Alvin J. Frisque** was appointed to the newly-created position of Director, Corporate Science and Technology.



**Keith Hendrick,** President of Noranda Sales Corp., Ltd., Toronto, Canada, was elected Chairman of International Lead Zinc Research Organization, Inc. (ILZRO), the cooperative research arm for lead and zinc producers.

**Peter King**, of Australian Mining & Smelting Co., Ltd., Melbourne, and **Dr. William P. Roe**, of Asarco Inc., were elected Vice-Chairmen of the board of directors.

Re-elected President was **Dr. S.F. Radtke**, and **Dr. J.F. Cole,** formerly Vice-President, was named Executive Vice-President. Other officers re-elected were: Treasurer—**Vincent E. Dorman**, of AMAX Lead & Zinc Co.; Secretary—**Cynthia Noelle**; and Assistant Treasurer—**Helen McMullin**.

Sinnett Industrial Paints, St. Louis, MO, has appointed **Stephen Sinnett**, Vice-President of Sales; **Richard W. Storm**, Technical Director; and **Gordon B. Prough**, Controller.

The Valspar Corp. has announced the appointment of **James N. Edward** to the position of Technical Director, Consumer Coatings laboratory. As technical director, Mr. Edwards will be responsible for the consumer development laboratories in Minneapolis, MN and Kansas City, MO, the liquid powder development laboratory in Kansas City, and the technical services laboratory in Minneapolis. Mr. Edwards is a member of the Kansas City Society.

Hercules Incorporated, Wilmington, DE, has made two assignments in its Southern region. **R.G. Hoffman** has been promoted to Account Supervisor for Resin Products based at Norcross, GA headquarters. **Henry K. Graves** has been transferred to the Atlanta District as District Sales Manager for Polypropylene film from the Green Bay, WI office of the Midwestern Region.

The firm has also announced appointments in its Northeastern Region. **Donna S. Descheemaeker** was named Field Marketing Assistant, Water Soluble Polymers, Coatings, and PFW Products. **Robert R. Kirr** was promoted to Senior Technical Sales Representative for Polypropylene Film. Ms. Descheemaeker and Mr. Kirr are based at the firm's Wilmington headquarters.

Hunterlab has announced the appointment of **William C. Gasper** to the position of Director of Sales responsible for the worldwide sales of all the firm's products. Also announced was the appointment of **E. Kenneth Koos** as Manager of Marketing Services responsible for corporate communication functions.

**William S. Gilman** has been appointed Vice-President for Operations, Chemical Services Division of United States Testing, Co., Inc., Hoboken, NJ.

**Dr. Kenneth Abate** has been appointed Manager of the Chemical Department at the Building Products Technical Center of H.H. Robertson Co. He will assume responsibilities for all chemical research, development, and technical service.

The operations of BASF Wyandotte Corp., Parsippany, NJ, have been restructured into five business groups resulting in several promotions. Appointed to the positions of Vice-President were **David J. Buchner**—Chemicals; **K. Guenter Koenen**—Colors and Auxiliaries; **S. Paul Malchick**—Pigments and Organic Specialities; **Ingo Kroeger**—Agricultural Chemicals; and **Manfred Buller**—Polymers.

**John T. Yeager** was appointed Technical Director—Trade Sales by Pratt & Lambert, Inc., succeeding William G. Ringle, who has retired. Both are members of the Western New York Society.

# Obituary

**Robert Francis McTague**, 64, died November 28. He had been Technical Director of Glidden Corporation's Tintas Ypiranga, S.A., Rio de Janeiro, Brazil. He was an affiliated member of the Federation of Societies for Coatings Technology.

**David G. Braithwaite**, 68, formerly President and Board Chairman of Nalco Chemical Co. who retired in 1971, died on December 17 in Tyler, TX. Since 1935 when Mr. Braithwaite joined the firm as chemist, he had held the positions of Production Manager, Assistant Vice-President, and Vice-President and General Manager of the Catalyst Division. He was elected a Director in 1957, became Executive Vice-President in 1959, and held the positions of President, Chief Executive Officer, and Board Chairman.

**Leo Pesola**, 72, died in Pymouth, MI. He had been a long-time member of the Detroit Society and was most recently employed as a consultant with Wyandotte Paint Products.

# Literature

### Viscometer

A new, six-page, two color brochure is available describing various models of viscometers. Information is given to aid in selecting the proper model of viscometer to ensure maximum sensitivity and accuracy in the range of viscosities to be measured. Contact Brookfield Engineering Laboratories, Inc., Dept. NR 38, 240 Cushing St., Stoughton, MA 02072.

### Laboratory Stir-Tester

A new laboratory stir-tester has been introduced in literature which has 1/8 HP permanent magnet DC motor capable of turning a paddle or propeller type agitator in thick, high-viscosity mixtures. Capabilities of the stir-tester are featured which include generating data such as rate of shear and shear stress at various stirring speeds, the best speed for arriving at a specified viscosity in the least time with the lowest power consumption, and starting and breakdown torques for thixotropic and semi-solid materials. Literature and detailed specifications are available from G.K. Heller Corp., 7 Mayflower Place, Floral Park, L.I., NY 11001.

### Fire Red Pigment

A newly developed pigment which produces very bright, pure shades, particularly in the mass tone range, is featured in recent literature. Advantages are described such as: offers a very high covering power; perfect fastness to overspraying; good resistance to solvents and heat; and outstanding rheological properties. Uses and formulations with paint are also featured. For information, contact Sandoz Colors & Chemicals, East Hanover, NJ 07936.

### Bird Applicator

A new leaflet describes a complete line of Bird type wet film applicators, now available in nickel chrome and steel. Specification references are cited. Write Paul N. Gardner Co., Inc., 218 Commercial Blvd., Suite 205, Lauderdale By-The-Sea, FL 33308.

### Gauge

Literature describing a new coating thickness gauge, which measures the coating thickness of any nonmagnetic coating both in mils and metric values, is available. Write Elektro-Physik, Inc., 5700 Thurston Ave., Suite 224, Virginia Beach, VA 23455.

### Water-Soluble Resins

A 30-page booklet describing Polyox water-soluble resins for a wide range of applications has been published. The general properties of the poly(ethylene oxide) homopolymers are described, including solubility, stability, moisture sorption, and characteristics of the two basic product types. Additional information is given on shipping, storage and handling, toxicological studies, and the FDA and EPA status of Polyox resins. An appendix contains test methods. Copies of the booklet (F-44029C) are available from Union Carbide Corp., Water-Soluble Polymers, Specialty Chemicals and Plastics Div., Dept. M1552, Danbury, CT 06817.

### Fumed Silica

A new brochure showing the effectiveness of Cab-O-Sil® fumed silica for rheology control of high solids coatings is available. The performance is demonstrated versus competitive thixotropes as an antisag, antisettling agent, and is shown to be cost effective and to cause less loss of gloss than the competitive products. For the brochure, contact Cabot Corp., Cab-O-Sil Div., Box 188, Tuscola, IL 61953.

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# Book Review

## FIFTH INTERNATIONAL CONFERENCE IN ORGANIC SCIENCE AND TECHNOLOGY

Edited by
G.D. Parfitt and A.V. Patsis
Technomic Publishing Co.
Westport, CT
1981
$55.00

Reviewed by
Dr. Joseph B. Zicherman
University of California
Berkeley, CA

This volume contains nineteen papers which either review particular subject matter areas or present experimental work related to coatings technology. Excluding the rather poor and brief introductory paper entitled, "New Developments in Polymers for Coatings—a Review," the first four papers deal specifically with particular types of resin systems (polyurethenes, high-solids polyesters, epoxy resins, organo-silicon resins). These are both interesting and (one would hope) timely. Also, of particular note for the American reader is the fact that the bulk of the papers are by European authors, and while some suffer from problems in translation they do present a reasonably up-to-date view of most of the technological areas presented as they exist in Europe.

The next six papers deal with interactions between pigments and resin systems from a variety of viewpoints. One of these papers, "Pigment Vehicle Interactions and Their Effect on Pigment Performance," is an extensive review of previously published information. The others deal with pigments and vehicle systems from a research standpoint. Areas discussed include pigment flocculation, pigment dispersion quality as related to properties of printing inks, methods to characterize the durability of $TiO_2$ pigment, mechanical properties of pigmented paint films and insights in structure and behavior of polymers and pigmented paint films.

The remaining papers deal with rather specific individual subject areas including industrially-significant coatings systems such as powder coatings, high-solids paints and UV-curable systems. Other technological areas dealt with include how oxidation reactions affect films, vacuole formation in high-built coatings films, and glycerophthalic paints and color-matching technology. The two final papers deal with the coating of metal powder surfaces with polymers and a description of experience with X-ray techniques in plant use for quality control of lead.

As one can see from the foregoing, the breadth of papers presented is quite wide and there is "something for everyone" in this particular volume. As such, I feel it would be a useful addition to a company or University library. However, unless a reader has a very specific interest in one or more of the subject areas in the papers, it might not be a useful addition to a personal library. In a general way, it is my opinion that the publication of non-peer reviewed technical articles which have been proliferating in this type of publication may be doing our technical literature a disservice. This volume, given the wide range of quality between presentations is, I think, typical of this.

### Media Mills

A new six-page brochure describing the "Red Head" small media mill is now available. The brochure provides a complete description of the operation of the light weight mills and gives complete technical information on six industrial models and five laboratory models. A special section provides the information necessary for the user to determine the mill size best adapted to his application. Copies of the new brochure are available from Dept. RN, Chicago Boiler Co., 1965 Clyborn Ave., Chicago, IL 60614.

### Mixer/Disperser

A new four-color, six-page brochure describes, illustrates, and gives specifications for the Daymax mixer/disperser. Listed are the product advantages, including high quality dispersion, faster processing time, and versatility. For a copy of the brochure, contact Day Mixing, 4932 Beech St., Cincinnati, OH 45212.

### Inorganic Zinc; Phenolic Coatings

Two, new four-page brochures describing a series of inorganic zinc and modified phenolic coatings have been released. The Carbo Zinc® series is described in bulletin 400R which lists the performance, advantages, and cost comparison of the self-curing inorganic zinc coating. Bulletin 600R describes the chemical resistance, physical properties, abrasion resistance, and application properties of the Phenoline® series. For a copy of either brochure, contact Carboline Co., 350 Hanley Industrial Ct., St. Louis, MO 63144.

### Water-Reducible Resins

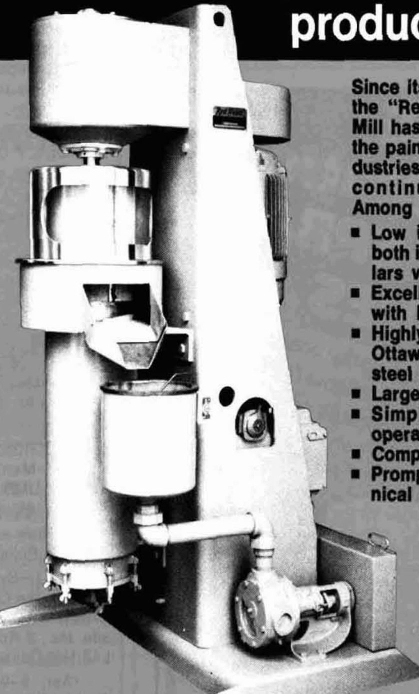
Two, new water-reducible chain-stopped alkyds are described in recently published literature. The brochures report that Type 7448 alkyd based coatings exhibit early water resistance and good salt spray and humidity resistance, along with outstanding gloss and fast dry rates. Coatings based on Type 7445 alkyd have the above properties plus superior exterior durability, adhesion, and hardness. Suggested applications are for heavy equipment and automotive parts. For specifications and formulating information contact Marketing Dept., Cargill, Inc., P.O. Box 5630, Minneapolis, MN.

## CLASSIFIED ADVERTISING

CHAIRPERSON, POLYMER SCIENCE. UNIVERSITY OF SOUTHERN MISSISSIPPI. Anticipated opening July 1, 1982, at full or associate professor level for individual with demonstrated research capability. Expertise in polymer physical chemistry, coatings and/or plastics preferred. However, exceptional candidates in any polymer science discipline are invited to apply. This position provides a unique opportunity to interact with vigorous young faculty and quality students in our B.S., M.S., and Ph.D. degree programs. Experience in academia, industry, or a combination of both acceptable. Department recently occupied new facilities with excellent teaching and research equipment. Salary and benefits competitive. Forward resumé and names of three references to : Polymer Search Committee, Southern Station, Box 5165, Hattiesburg, MS. 39406-5165. The University of Southern Mississippi is an Equal Opportunity/Affirmative Action Employer.

### PAINT TECHNICIAN

Chemist with experience in screen process ink formulation or related fields. Nationally known company producing quality decal transfers. Durochrome Products, Inc., 2475 W. La Palma, Anaheim, Calif. 92801 (714) 527-1213 Mr. John Morris.



# Coming Events

## FEDERATION MEETINGS

(Apr. 29–30)—Spring Meetings. Society Officers on 29th; Board of Directors on 30th. Lenox Hotel, Boston, MA. (FSCT, 1315 Walnut St., Suite 832, Philadelphia, PA 19107).

(Nov. 3–5)—60th Annual Meeting and 47th Paint Industries' Show. Sheraton Washington Hotel, Washington, D.C. (FSCT, 1315 Walnut St., Suite 832, Philadelphia, PA 19107).

### 1983

(Oct. 12–14)—61st Annual Meeting and 48th Paint Industries' Show. Queen Elizabeth Hotel, Montreal, Quebec, Canada. (FSCT, 1315 Walnut St., Suite 832, Philadelphia, PA 19107).

## SPECIAL SOCIETY MEETINGS

(Mar. 23–24)—25th Annual Technical Conference of the Cleveland Society for Coatings Technology. Baldwin-Wallace College, Berea, OH.

(Apr. 20–21)—Chicago Society. SYMCO '82. "Back to Basics." Fountain Blue Restaurant, Des Plaines, IL. (Ray Cziczo, Glidden Coatings & Resins, 1855 N. LeClaire Ave., Chicago, IL 60639).

(Apr. 21–23)—Southwestern Paint Convention. Shamrock Hilton Hotel, Houston, TX.

(May 6–8)—Pacific Northwest Society. Annual Symposium. Bayshore Inn, Vancouver, B.C. (Barry Lamb, Harrisons & Crosfield, Ltd., 810 Derwent Way, New Westminster, B.C. V3M 5R1).

(May 19–20)—New England Society Coatings Tech Expo '82. Sheraton Inn, Boxborough, MA. (Robert Marderosian, Chairman, c/o Dame Assoc., Inc., 51 Church St., Boston, MA 02116).

(June 11–12)—Joint meeting of Kansas City and St. Louis Societies. Hilton Plaza Hotel, Kansas City, MO.

(Oct. 5)—Cleveland Society for Coatings Technology Manufacturing Committee Symposium on "The Use of Computers in the Manufacture of Coatings." Cleveland Engineering and Scientific Societies Bldg., Cleveland, OH. (Chairman Charles K. Beck, Premier Industrial Corp., 4415 Evelid Ave., Cleveland, OH 44103).

### 1983

(Feb. 23–25)—16th Biennial Western Coatings Societies' Symposium and Show. Hyatt Regency, San Francisco, CA. (Ted Favata, Chairman, Triangle Coatings Co., 2222 Third St., Berkeley, CA 94710).

## OTHER ORGANIZATIONS

(Mar. 15–17)—"Industrial Market Research for the Chemical Industry" Short Course. Villa Hotel, San Mateo, CA. (Norma Fleming, Senior Coordinator, Arts & Sciences Continuing Education, University of Missouri-Rolla, Rolla, MO 65401).

Mar. 15–19)—"Principles of Color Technology" Workshop. Philadelphia College of Textiles and Science. Philadelphia, PA. (PCT&S, Department of Chemistry & Physical Science, School House Lane and Henry Ave., Phila., PA 19144).

(Mar. 22–26)—CORROSION/82. Albert Thomas Convention Center, Houston, TX. (National Association of Corrosion Engineers, P.O. Box 2183430, Houston, TX 77218).

(Mar. 22–26)—"Introductory Short Course on Composition of Coatings." University of Missouri-Rolla, Rolla, MO. (Norma R. Fleming, Arts & Sciences Continuing Education, UMR, Rolla, MO 65401).

(Mar. 22–26)—Semi-Annual "Spray Finishing Technology" Workshop. Bowling Green State University and the DeVilbiss Co. Headquarters, Toledo, OH. (Dr. Richard A. Kruppa, School of Technology, Bowling Green State University, Bowling Green, OH 43403).

(Mar. 28-Apr. 2)—American Chemical Society's 183rd National Meeting. Las Vegas, NV. (A. T. Winstead, ACS, 1155 Sixteenth St., N.W. Washington, D.C. 20036).

(Mar. 29–30).—"Fundamentals and Technology of Computerized Robots" Seminar. University of Missouri-Rolla, Rolla, MO and Marriott Pavillion Hotel, St. Louis, MO. (Norma R. Fleming, UMR, Rolla, MO 65401).

(Mar. 29–Apr. 1)—National Plant Engineering & Maintenance Show and Conference. McCormick Place, Chicago, IL. (Clapp & Poliak, Inc., 245 Park Ave., New York, NY 10167).

(Apr.)—Symposium on Color in Protective Coatings sponsored by the Chemical Institute of Canada, Protective Coatings Division. Montreal and Toronto. (D.S. Wiersma, Celanese Canada, Inc., 2 Robert Speck Pkwy., Suite 900, Mississauga, Ont., L4Z 1H8 Canada).

(Apr. 5–9)—"Introduction to Paint Formulation" Short Course. University of Missouri-Rolla, Rolla, MO. (Norma R. Fleming, UMR, Rolla, MO 65401).

(Apr. 12–16)—"Advanced Paint Formulation—Trade Sales" Short Course. University of Missouri-Rolla, Rolla, MO. (Norma R. Fleming, UMR, Rolla, MO 65401).

(Apr. 13)—"Industrial Paints and Painting Methods" Workshop. Cobo Hall, Detroit, MI. (Susan Buhr, Technical Activities Dept., Society of Manufacturing Engineers, One SME Dr., P.O. Box 930, Dearborn, MI 48128).

(Apr. 15)—"Industrial Paints and Painting Methods" Workshop. Hartford Civic Center, Hartford, CT. (Susan Buhr, Technical Activities Dept., Society of Manufacturing Engineers, One SME Dr., P.O. Box 930, Dearborn, MI 48128).

(Apr. 19-20)—Inter-Society Color Council. Annual meeting. Sheraton Center Hotel, Charlotte, N.C. (Fred Billmeyer, Jr., Rensselaer Polytechnic Institute, Troy, NY 12181).

(Apr. 19-20)—22nd Annual Symposium of the Washington Paint Technical Group. Marriott Twin Bridges Motel, Washington, D.C. (John Montgomery, Secretary, Washington Paint Technical Group, P.O. Box 12025, Washington, D.C. 20005).

(Apr. 19-23)—"Printing Inks and Printing Processes" Short Course. Lehigh University, Bethlehem, PA. (Dr. Mohamed S. El-Aasser, Dept. of Chemical Engineering, Sinclair Lab #7, Lehigh University, Bethlehem, PA 18015).

(Apr. 21-28)—Hanover Fair '82 for Surface Treatment and Coatings Technology Equipment and Materials. Hanover, West Germany. (The Hanover Fairs Information Center, P.O. Box 338, Whitehouse, NJ 08888).

(Apr. 27-29)—Oil & Colour Chemists' Association's 34th Annual Exhibition, "International Forum for the Surface Coatings Industries." Cunard International Hotel, Hammersmith, London, England. (R.H. Hamblin, OCCA, Priory House, 967 Harrow Rd., Wembley, Middlesex, HAO 2SF).

(May 2-5)—National Coil Coaters Association's Annual Meeting. Marriott's Camelback Inn, Scottsdale, AZ. (Don White, NCCA, 1900 Arch St., Philadelphia, PA 19103).

(May 2-6)—American Oil Chemists' Society 73rd Annual Meeting. Sheraton Centre, Toronto, Canada. (James Lyon, Executive Director, AOCS, 508 S. Sixth St., Champaign, IL 61820).

(May 4-6)—"Industrial Market Research for the Chemical Industry" Short Course. Raphael Hotel, Chicago, IL. (Norma Fleming, Senior Coordinator, Arts & Sciences Continuing Education, University of Missouri-Rolla, Rolla, MO 65401).

(May 9-14)—XVIth Congress of FATIPEC, Palais des Congres, Liege, Belgium. (Destree-Congres, 10 Rue du Coggege St. Michael, 1150 Brussels, Belgium).

(May 11-13)—Powder & Bulk Solids Conference/Exhibition. O'Hare Exposition Center, Rosemont, IL. (Cahners Exposition Group, 22 W. Adams St., Chicago, IL 60606).

(May 17-21)—"Dispersion of Pigments and Resins in Fluid Media" Short Course. Kent State University, Kent, OH. (Carl J. Knauss, Chemistry Dept., Kent State University, Kent, OH 44242).

(May 18)—"Industrial Paints and Painting Methods" Workshop. Philadelphia Civic Center, Philadelphia, PA. (Susan Buhr, Technical Activities Dept., Society of Manufacturing Engineers, One SME Dr., P.O. Box 930, Dearborn, MI 48128).

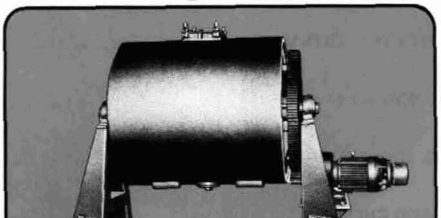
(May 18-20)—"Estimating Workshop for Painting Contractors." University of Missouri-Rolla, Rolla, MO. (Norma R. Fleming, UMR, Rolla, MO 65401).

(May 25-28)—"Basic Microcomputer Programming for Coatings Manufacturers" Short Course. University of Missouri-Rolla, Rolla, MO. (Norma R. Fleming, UMR, Rolla, MO 65401).

(June 7-11)—"Adhesion Principles and Practice for Coatings and Polymer Scientists" Short Course. Kent State University, Kent, OH. (Carl J. Knauss, Chemistry Dept., Kent State University, Kent, OH 44242).

(June 7-11)—"Advances in Emulsion Polymerization and Latex Technology" Short Course. Lehigh University, Bethlehem, PA. (Dr. Mohamed S. El-Aasser, Dept. of Chemical Engineering, Sinclair Lab #7, Lehigh University, Bethlehem, PA 18015).

(June 13-16)—Dry Color Manufacturers' Association Annual Meeting. The Greenbrier, White Sulphur Springs, WV. (P.J. Lehr, DCMA, Suite 100, 1117 N. 19th St., Arlington, VA 22209).



(June 20-23)—American Society for Testing and Matrerials Committee D-1 Meeting on Paint and Related Coatings and Materials. Sheraton Center, Toronto, Canada. (Jane M. Turner, ASTM, 1916 Race St., Philadelphia, PA 19103).

(June 20-25)—75th Air Pollution Control Association's Annual Meeting and Exhibition. The Rivergate Convention Center, New Orleans, LA. (APCA, P.O. Box 2861, Pittsburgh, PA 15230).

(June 21-25)—"Applied Rheology for Industrial Chemists" Short Course. Kent State University, Kent, OH. (Carl J. Knauss, Chemistry Dept., Kent State University, Kent, OH 44242).

(June 28-30)—"Organic Coatings Technology" Short Course. Center for Professional Advancement's Academic Center, East Brunswick, NJ. (Center for Professional Advancement, Dept. NR., P.O. Box H, East Brunswick, NJ 08816).

(July 12-16)—8th International Conference on Organic Coatings, Science and Technology. Athens, Greece. (Angelos V. Patsis, Coykeydall Science Bldg., State University of New York, New Platz, NY 12561).

(July 12-16)—International Union of Pure and Applied Chemists' Macromolecular Symposium. Amherst, MA. (James C.W. Chien, Dept. of Polymer Science & Engineering, University of Massachusetts, Amherst, MA 01003).

(Aug. 2-20)—Battelle's International Program in Productive R&D Management. Columbus, OH. (Dr. William D. Hitt, Battalle's Columbus Laboratories, 505 King Ave., Columbus, OH 43201).

(Aug. 9-13)—"Introductory Short Course on Composition of Coatings." University of Missouri-Rolla, Rolla, MO. (Norma Fleming, Senior Coordinator, Arts & Sciences Continuing Education, UMR, Rolla, MO 65401).

(Aug. 16-20)—"Physical Testing of Paints and Coatings" Short Course. University of Missouri-Rolla, Rolla, MO. (Norma R. Fleming, UMR, Rolla, MO 65401).

(Sept. 12-17)—American Chemical Society's 184th National Meeting. Kansas City, MO. (A.T. Winstead, ACS, 1155 Sixteenth St., N.W. Washington, D.C. 20036).

(Sept. 13-17)—"Introduction to Paint Formulation" Short Course. University of Missouri-Rolla, Rolla, MO. (Norma Fleming, Senior Coordinator, Arts & Sciences Continuing Education, UMR, Rolla, MO 65401).

(Sept. 18-21)—Canadian Paint and Coatings Association. 70th Annual Convention. Four Seasons Hotel, Toronto, Ont. (R. Murry, CPCA, 515 St. Catherine St. W., Montreal, Que., Canada H3B 1B4).

(Sept. 20-24)—"Advanced Paint Formulation—Industrial" Short Course. University of Missouri-Rolla, Rolla, MO. (Norma Fleming, Senior Coordinator, Arts & Sciences Continuing Education, UMR, Rolla, MO 65401).

(Sept. 21-23)—"Radiation Curing VI" Conference and Exhibition sponsored by the Association for Finishing Processes of the Society of Manufacturing Engineers. Ramada O'Hare Inn, Des Plaines, IL. (Susan Buhr, Technical Activities Dept., SME, One SME Dr., P.O. Box 930, Dearborn, MI 48128).

(Oct. 11-13)—10th Congress of the Federation of Scandinavian Paint and Varnish Technologists. Copenhagen, Denmark. (G. Christensen, Sadolin & Holmblad Ltd., Holmbladsgade 70, DK-2300, Copenhagen S, Denmark).

(Oct. 18)—"Fire Resistant Coatings: The Need for Standards" Symposium. Philadelphia, PA. (Symposium Chairman Dr. Morris Lieff, County College of Morris, Dover, NJ 07801).

(Oct. 26-27)—"New Coatings Systems for Bridges" World Congress. Holiday Inn LaGuardia, New York, NY. (Norma Fleming, Senior Coordinator, Arts & Sciences Continuing Education, University of Missouri-Rolla, Rolla, MO 65401).

(Oct. 31-Nov. 2)—"Women in Coatings—Meeting the Challenges" Seminar. Washington, D.C. (Norma Fleming, Senior Coordinator, Arts & Sciences Continuing Education, University of Missouri-Rolla, Rolla, MO 65401).

(Nov. 1-3)—National Paint and Coatings Association. 95th Annual Meeting. Washington Hilton Hotel, D.C. (Karen Bradley-Welch, NPCA, 1500 Rhode Island Ave. N.W.; Washington, D.C. 20005).

(Nov. 9-11)—"Refresher for Painting Contractors, Maintenance Engineers and Inspectors" Short Course. Sheraton St. Louis Hotel, St. Louis, MO. (Norma Fleming, Senior Coordinator, Arts & Sciences Continuing Education, University of Missouri-Rolla, Rolla, MO 65401).

(Nov. 12-14)—National Decorating Products Association 35th Annual Show. Superdome, New Orleans, LA. (Lillian Smysor, NDPA, 9334 Dielman Industrial Dr., St. Louis, MO 63132).

(Nov. 16-18)—"Estimating Workshop for Painting Contractors" Short Course. Sheraton St. Louis Hotel, St. Louis, MO. (Norma Fleming, Senior Coordinator, Arts & Sciences Continuing Education, University of Missouri-Rolla, Rolla, MO 65401).

(Nov. 29-Dec. 3)—"Principles of Industrial Coatings" Short Course. Sheraton St. Louis Hotel, St. Louis, MO. (Norma Fleming, Senior Coordinator, Arts & Sciences Continuing Education, University of Missouri-Rolla, Rolla, MO 65401).

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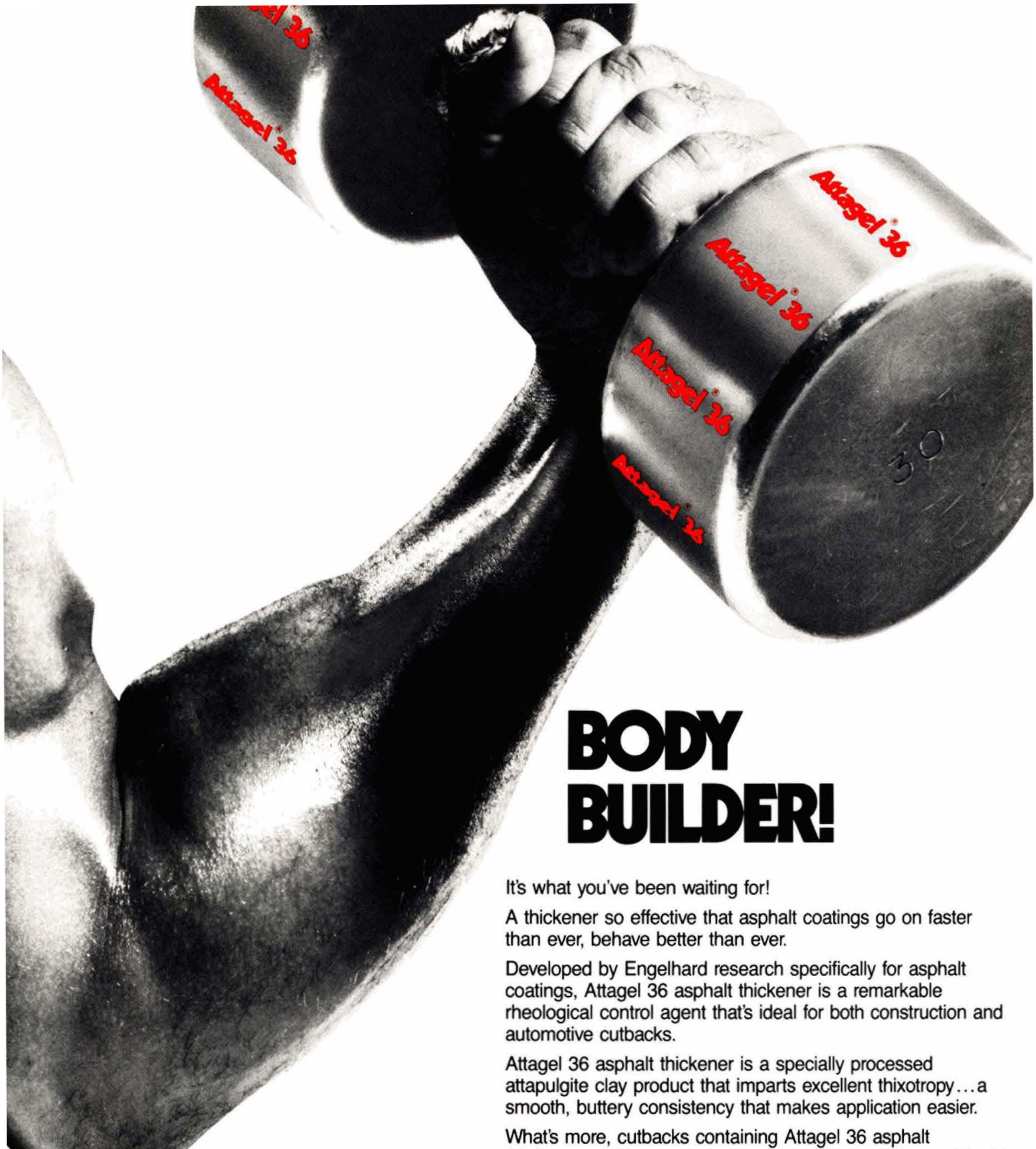
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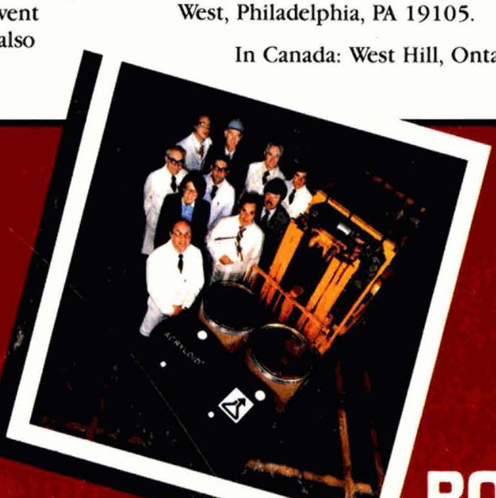

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