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July 1986

64th Annual Meeting & 51st Paint Industries Show
FSCT
1986
Georgia World Congress Center
• Atlanta •
November 5, 6, 7, 1986

Accelerated Corrosion Testing

APPARENTLY THE COMPETITION IS GETTING READY TO DEAL WITH THE COMPETITION.

We knew the day would come.

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Now that we've proven to over 140 paint makers that UCAR Acrylics really can increase profits without sacrificing performance, the competition is finally beginning to make some strategic moves of their own.

That's just fine, we say, because healthy competition can only benefit the customer.

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We'll be glad to show you how to spot the winner in spite of the noise and dust of the battlefield.

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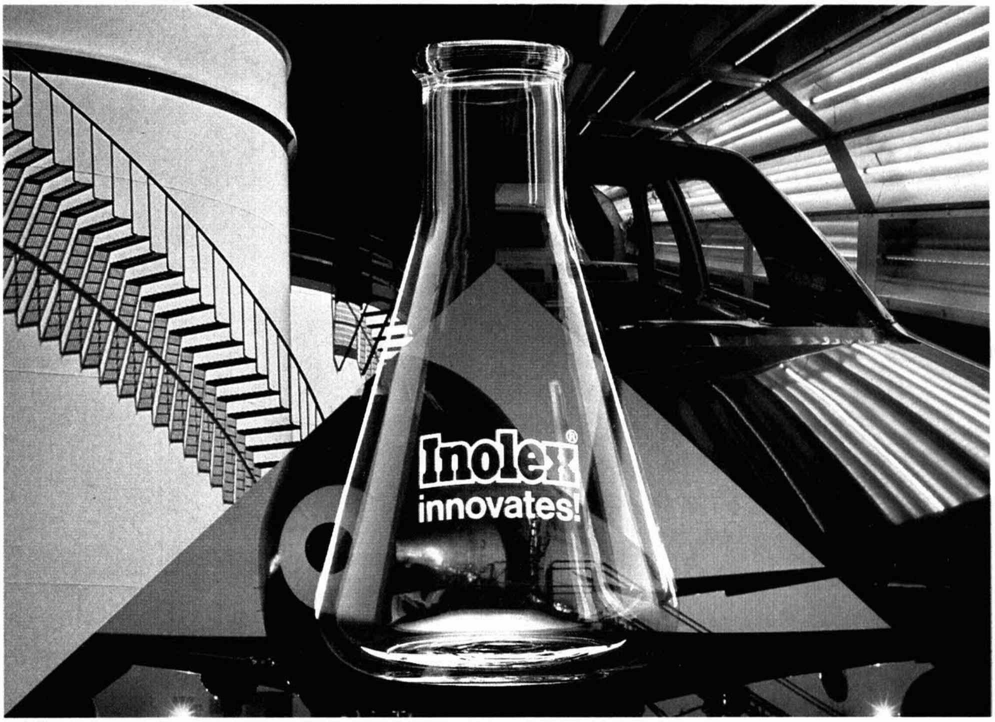
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JULY 1986

jct JOURNAL OF COATINGS TECHNOLOGY

VOLUME 58 NUMBER 738

Federation of Societies for Coatings Technology

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Open Forum

Federation News

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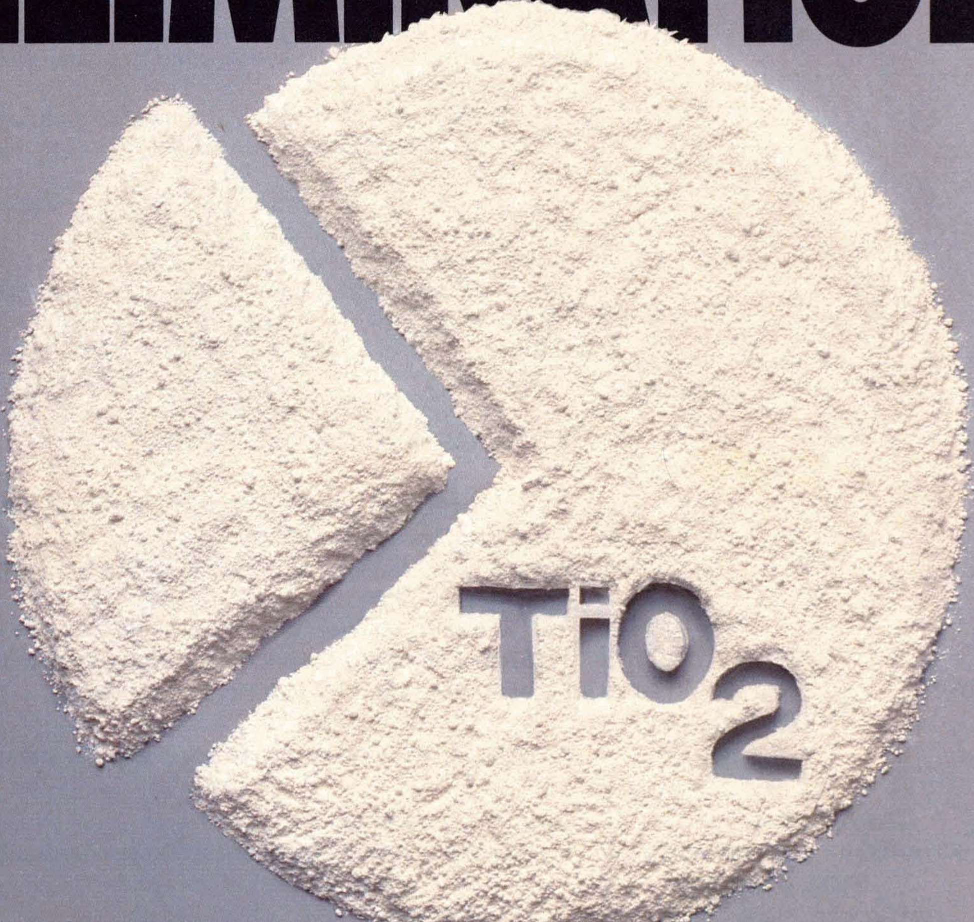
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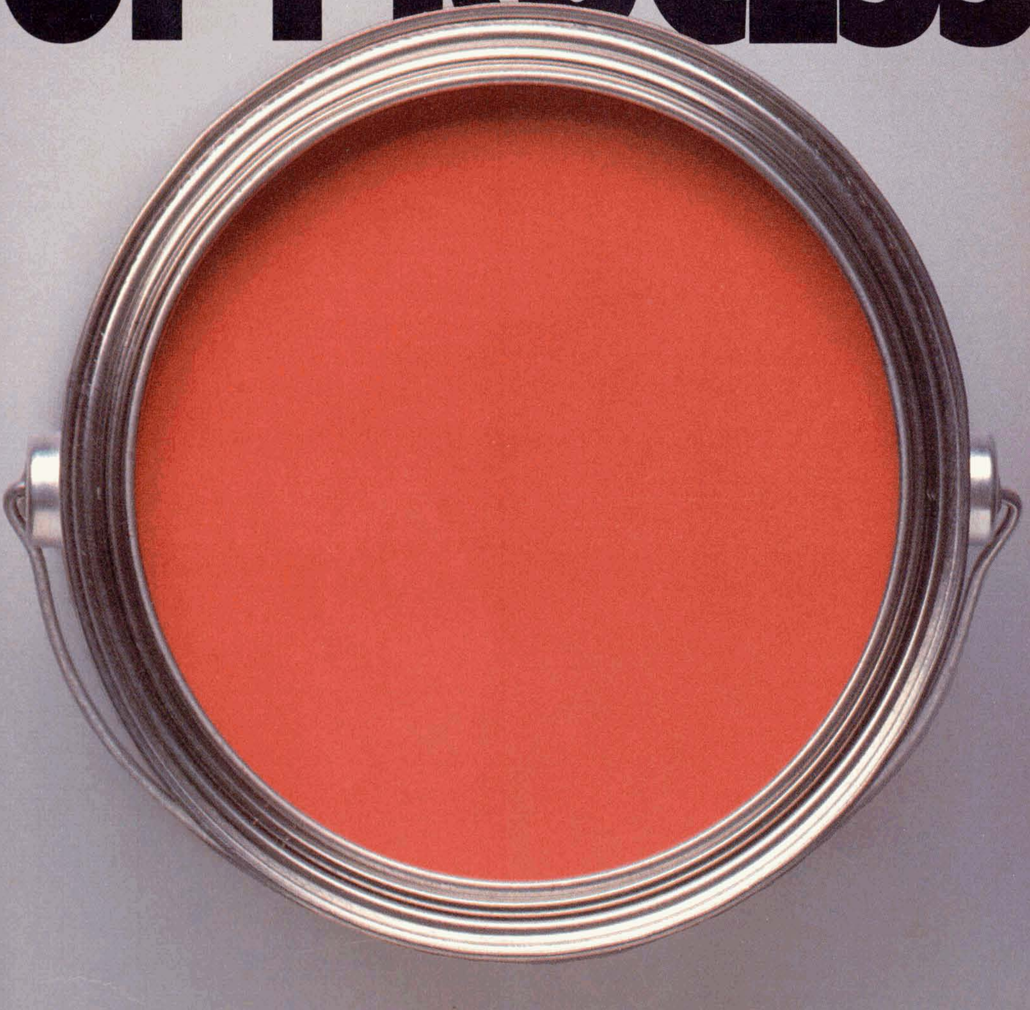

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Comment

A Challenge From the Board; An Appeal to the Membership

At its May 16th meeting, the Federation Board of Directors approved a Golden Gate/Los Angeles recommendation that the Federation direct either a new or a current staff member to coordinate the dissemination of information and developments in environmental and hazardous waste matters to the Societies and the Federation membership.

The West Coasters feel that governmental regulations which impact upon the coatings industry travel from west to east. Whatever the results in California, they will move to other parts of the country sooner or later. The Board indicated that it wants the membership to be aware of what is happening in all areas.

Such a collection, filtration, and distribution of information from a variety of sources is a formidable task for one person, or two, or even three. It cannot and will not be accomplished without the help of the Federation's biggest strength and asset—its membership.

The Federation has an Environmental Control Committee. And we know of 17 Society EC Committees. All names and addresses are shown on page 20 in this issue.

What we would like to do is ''networkize'' these committees so that summaries of key issues and up-to-date developments (at the local, state, and federal levels) can be forwarded to a central source—the Federation office. The material will be screened by the Federation's EC Committee and released to Society committees by mail and to the membership in the JCT.

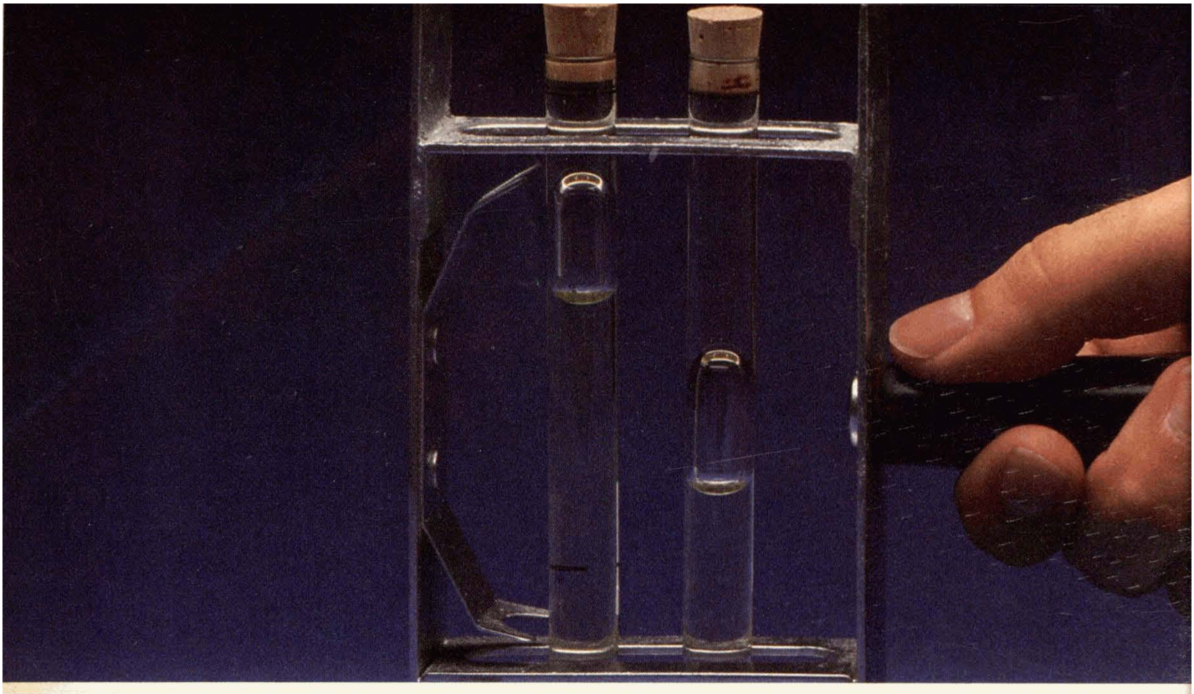
The Federation is willing to support a national meeting of Society EC Chairmen with the Federation committee (with transportation and meeting expenses paid by the Federation) if such a gathering will start the ball rolling and the net working.

We appeal to our Societies and our members to help each other for the common industry good. Will those so involved in environmental matters let us have their suggestions for the successful and continued implementation of this plan—and—a brief update as to what is happening of general interest in their area.

We are charged to start someplace, sometime. The place is here. The time is now.

Frank J. Borrelle

Frank J. Borrelle,
Executive Vice-President



CIBA-GEIGY epoxy resins and the winning battle against VOC's.

With their lower viscosity, these two unique epoxy resins significantly decrease your need for solvent or diluent.

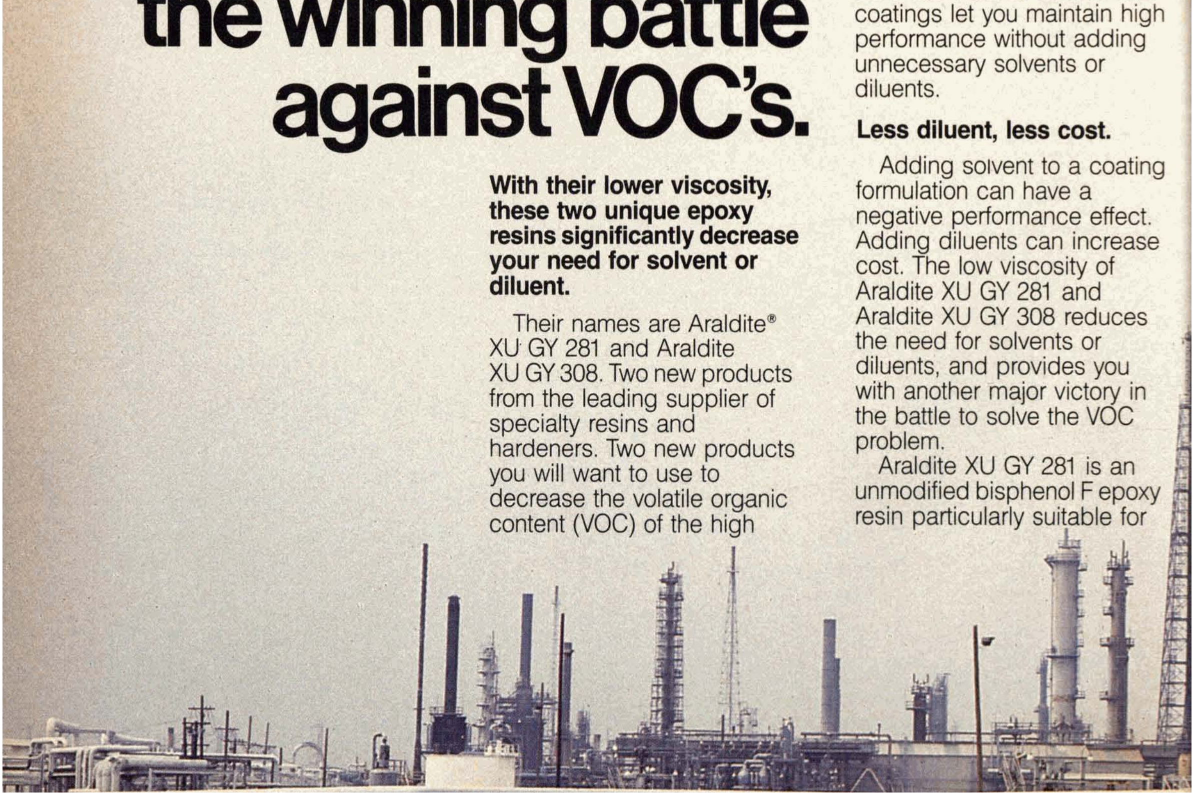
Their names are Araldite® XU GY 281 and Araldite XU GY 308. Two new products from the leading supplier of specialty resins and hardeners. Two new products you will want to use to decrease the volatile organic content (VOC) of the high performance coatings you formulate for heavy duty service in such applications as petroleum refineries, tank linings, pulp and paper mills, industrial plants and the like.

These new epoxy resins from CIBA-GEIGY for low VOC coatings let you maintain high performance without adding unnecessary solvents or diluents.

Less diluent, less cost.

Adding solvent to a coating formulation can have a negative performance effect. Adding diluents can increase cost. The low viscosity of Araldite XU GY 281 and Araldite XU GY 308 reduces the need for solvents or diluents, and provides you with another major victory in the battle to solve the VOC problem.

Araldite XU GY 281 is an unmodified bisphenol F epoxy resin particularly suitable for



Gardner Bubble Tube Viscosity Test. On left: diglycidyl ether of bisphenol F resin (CIBA-GEIGY Araldite® XU GY 281). On right: diglycidyl ether of bisphenol A resin.

solventless and high solids coatings and linings requiring superior chemical and corrosion resistance. It also has outstanding resistance to solvents, excellent mechanical properties and conforms to 175.300 of the FDA Register.

XU GY 281 Typical Properties

Visual Appearance	Clear
Color, Gardner	3 max.
Viscosity, cP @ 25°C	5,000-7,000
Weight per Epoxide	159-172
Hydrolyzable Chlorine	0.2 max.
Volatile Content, %	0.2 max.
Pounds per gallon	10

An extra added attraction.

Araldite XU GY 308 is our second new low viscosity liquid epoxy resin. It has all the major properties of Araldite XU GY 281. And one that's unique. That uniqueness is its resistance to crystallization under normal conditions, making it easy to handle and process. As you are well aware, most low viscosity, pure epoxy resins change to a waxy white solid if left unused at low temperatures. That means heat must be applied before using. And heating a 55-gallon drum or a whole tank car is no easy task. Araldite XU GY 308's resistance to crystallization can, therefore, save you time, energy and money.

Clear epoxy resin (right), Araldite XU GY 308, resists crystallization at low temperatures.

Special solutions for special problems.

At CIBA-GEIGY, we have built a reputation as the leading supplier of specialty resins and hardeners. And we can offer the technological skill required to meet and solve the special problems that arise in formulating high performance coatings. One problem is the adverse impact of the VOC from coatings based on traditional epoxy resins. And our new products, Araldite XU GY 281 and Araldite XU GY 308, can help alleviate that problem by reducing the use of solvents and diluents in coatings. Both products, of course, come with the technical support for which we are also widely regarded. Call Rob Crespi at 800-431-1900 (in New York 914-347-4700). Or write
Plastics Department,
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Three Skyline Drive,
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Abstracts of Papers in This Issue

MECHANISM OF CORROSION AND DELAMINATION OF PAINTED PHOSPHATED STEEL DURING ACCELERATED CORROSION TESTING—M. Knaster and J. Parks

Journal of Coatings Technology, 58, No. 738, 31 (July 1986)

A theoretical model for the delamination of organic coatings from zinc-phosphated steel surfaces is presented. It is shown that under ambient conditions and in neutral NaCl, media delamination occurs as a result of the formation of a surface-tension gradient during oxygen depolarization and, subsequently, the disruption of adhesion at the coating-phosphate interface. Dissolution of the phosphate coating occurs only after adhesion is lost. An accelerated cathodic delamination test showing good correlation with the long-term scab blistering test also is introduced.

DEVELOPMENT AND APPLICATION OF NETWORK STRUCTURE MODELS TO OPTIMIZATION OF BAKE CONDITIONS FOR THERMOSET COATINGS—D.R. Bauer and R.A. Dickie

Journal of Coatings Technology, 58, No. 738, 41 (July 1986)

A physico-chemical model of crosslinked network formation has been applied to the evaluation and optimization of cure conditions for thermoset acrylic copolymer/melamine formaldehyde coatings in automotive assembly plant ovens. Cure response has been characterized in terms of an elastically effective crosslink density (C_{el}) calculated from a network structure model, a kinetic model of cure, and measured car body temperature profiles. Acceptability of cure has been assessed by comparing the calculated value of C_{el} with the range of values of C_{el} known to result in acceptable paint physical properties. Relationships between oven and paint parameters have been quantified using the model together with an optimization program. It has been found that the minimum bake time to achieve acceptable uniformity of paint cure is principally a function of the cure response (or "cure window") of the paint, the maximum allowed air temperature in the oven, and the minimum value of a heat transfer parameter on the car body. At constant bake time, more uniform paint cure can be achieved either by broadening the cure response of the paint or by increasing the minimum heat transfer parameter.

AQUEOUS DISPERSIONS OF CROSSLINKED POLYURETHANES—R.E. Tirpak and P.H. Markusch

Journal of Coatings Technology, 58, No. 738, 49 (July 1986)

The importance of aqueous polyurethane dispersions to the coating industry has grown steadily since their introduction into the marketplace. The development of these aqueous coating systems has been motivated primarily by environmental considerations. A variety of polyurethane dispersions have found acceptance in applications such as textile and non-textile coatings, leather finishing, adhesives, and glass fiber sizings. These commercial products are predominantly linear thermoplastic polyurethanes dispersed in water.

In the past, the development of aqueous dispersions of crosslinked polyurethanes has been complicated by problems related to high-viscosity intermediates and poor coalescence. Recently, however, this type of water-borne coating has been successfully prepared in a manner which overcomes these difficulties. The resulting aqueous dispersions of crosslinked polyurethanes form films and coatings with outstanding properties. The performance of these coatings is comparable in many ways to that obtained from two-component solvent-borne polyurethane coatings.

Unpredictable painting conditions demand a predictable emulsion.

Rhoplex® AC-829 performs consistently, weather or not.

It's amazing the strain less-than-ideal painting conditions can place on some paints. Even an unexpected change in the elements, such as a sudden shower or drop in temperature, could cause them to blister, crack, peel or flake.

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Abstracts of Papers in This Issue

SYNTHESIS AND CHARACTERIZATION OF WATER-SOLUBLE PHENOLIC RESINS AND ESTERS BASED ON CARDANOL—G.S. Srinivasa Rao, et al.

Journal of Coatings Technology, 58, No. 738, 55 (July 1986)

Water-soluble phenolic resins have been prepared from maleinized cardanol, the active phenolic constituent of cashew nut shell liquid (CNSL) by reaction with formaldehyde using acidic and basic catalysts. Phenolic esters and varnishes were prepared by reacting these phenolic resins with maleinized linseed oil fatty acids and maleinized linseed oil, respectively. The reaction product of resol from maleinized cardanol and maleinized linseed oil fatty acids was characterized by IR spectroscopy. The physical characteristics of the resins, esters, and varnishes were determined and the film properties of brush, spin-coated, and electrodeposited coatings were evaluated. The effect of variation of electrodeposition parameters such as voltage, pH, bath solids, time, and temperature on dry film thickness obtained have been studied. Iron oxide paints based on the above resins at 20 and 35% pigment volume concentration were prepared and evaluated for their anticorrosive properties.

INFLUENCE OF RHEOLOGY MODIFIERS ON THE PERFORMANCE CHARACTERISTICS OF LATEX PAINTS—Montreal Society for Coatings Technology

Journal of Coatings Technology, 58, No. 738, 65 (July 1986)

A series of latex paints was prepared based on a range of commercially available rheology modifiers, including cellulose derivatives, alkali-soluble and polyurethane associative thickeners. An extensive range of rheological, optical, and physical properties was determined to evaluate the relative performance characteristics of each system.

It was found that the associative thickeners offered superior application properties, together with increased flow and leveling, compared with systems based on cellulosic polymers. However, some deficiencies in sag resistance were observed. When polyurethane associative thickener/cellulose combinations were used, the overall performance of the system was found to be inferior relative to an associative thickened system, with application properties in particular being adversely affected.

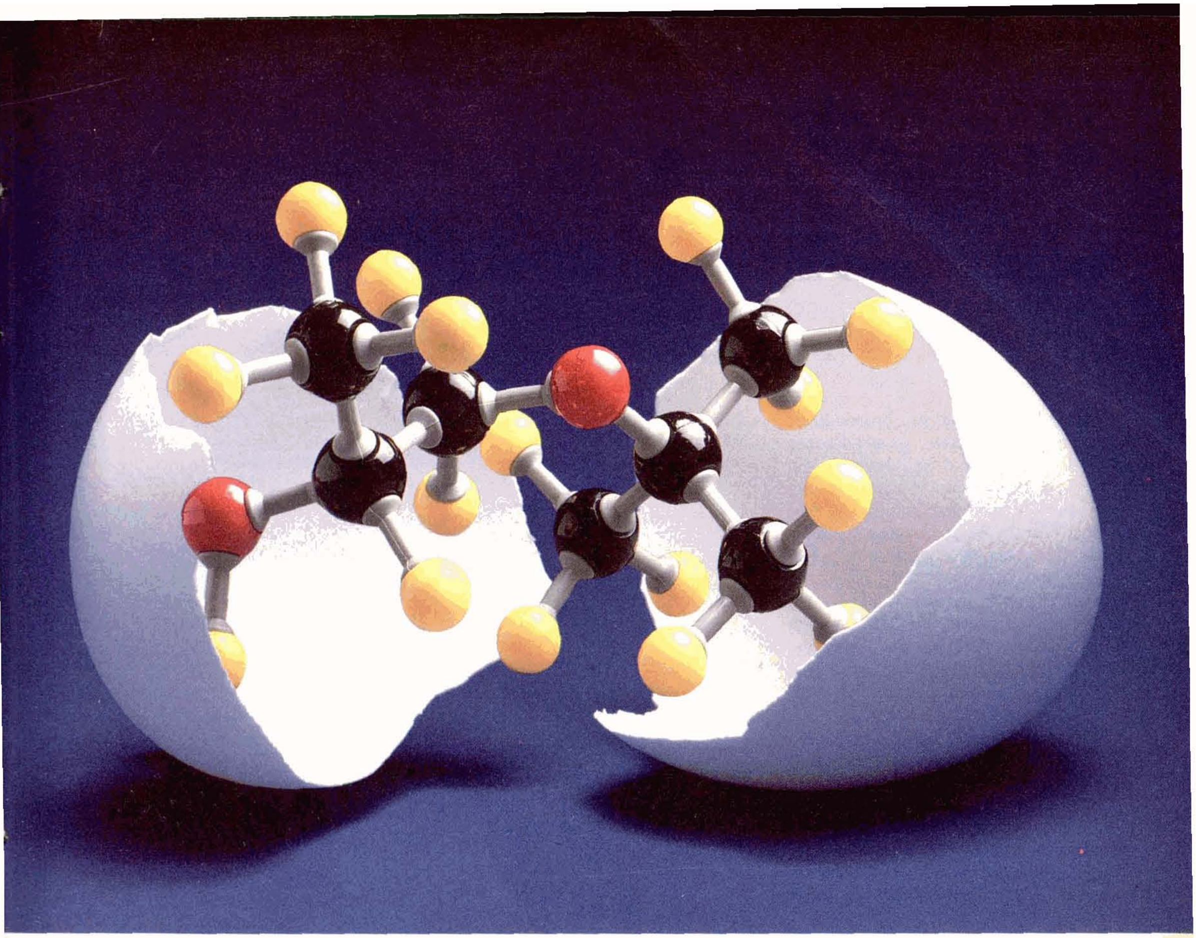
Papers to Be Featured in the August Issue

''Correlation of Results from Color Matching Aptitude Test Scores''—Birmingham Paint, Varnish and Lacquer Club.

''Influence of the Design of Instruments on the Accuracy of Color-Difference and Color-Matching Calculations—H. Schmelzer, Hoechst A.G.

''Polyester Resin Synthesis Techniques for Achieving Lower VOC and Improved Coatings Performance''—J.D. Hood, W. Blount, and W. Sade, Eastman Chemical Products, Inc.

''Hiding Power and the Cost-Effectiveness of Titanium Dioxide''—F.B. Stieg, Pigmentech Consulting.



Introducing ARCOSOLV® PTB ether, the high-performance/lower-toxicity butyl ether.

Improved performance in water-based coatings.
ARCOSOLV PTB (propylene glycol monotertiary butyl ether) offers formulators a unique structural blend of hydrophobicity and hydrophilicity, moderate evaporation rate, low surface tension, excellent coupling ability, and solvency power for a wide range of resins, oils and waxes. It can improve product performance versus formulations using conventional glycol ethers, such as ethylene glycol butyl ether (EB) and propylene glycol propyl ether (PP).

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ARCOSOLV PTB ether is essentially (99%) secondary in structure. It does not react with water-reducible alkyd or polyester resins as conventional EO-based glycol ethers like EB and EP do. Stable molecular weight means retention of production quality, and can provide higher customer satisfaction.

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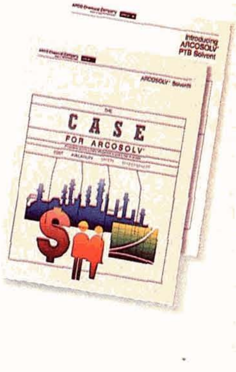
The CASE for formulation with ARCOSOLV P series ethers keeps getting stronger.
When you consider cost, availability, safety and effectiveness, ARCOSOLV PTB ether is the new product of choice in water-based systems. Add this to ARCO Chemical's complete line of PO-based ethers and acetates, and formulators now have a full range of low toxicity, high-quality products to choose from.



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Federation News

Annual Federation Lunch to Feature Haywood Hale Broun as Guest Speaker; Airline Tickets to Be Awarded as Door Prize

Haywood Hale Broun, broadcaster, commentator, author, actor, and lecturer will be the speaker at the Awards Lunch during the Federation's Annual Meeting and Paint Show in Atlanta, Friday, November 7, at the World Congress Center.

Mr. Broun has covered more than 600 sporting and news events for CBS News. Drawing material from his multi-faceted career, he will enliven the audience with clever anecdotes on sports, the theatre, the literary world, and society in general. True to his spirit, he specializes in the "offbeat."

A special door prize will be added to the lunch this year: a pair of first-class round-trip tickets on Delta Airlines. The tickets will be valid for travel within one year on Delta's domestic services (excluding Hawaii) and including Bermuda, San Juan, Nassau, and Montreal. Certain restrictions apply, especially during peak travel periods.

During the Luncheon, presentations will be made to the recipients of the George Baugh Heckel Award (outstanding individual who has contributed to the advancement of the Federation), the Flynn Awards (firms judged to have the best exhibit booths in the 1986 Paint Industries' Show), the Roon Foundation Awards, and other Annual Meeting awards.

Tickets are $20.00 each and can be purchased in advance or at the registration area during the Annual Meeting.

Keynote Speaker

Lee Sherman Dreyfus, former Governor of the state of Wisconsin, will present the Keynote Address at Wednesday's Opening Session at the Federation's 64th Annual Meeting in Atlanta, November 5. The topic of his address will be "The American Mission."

Mr. Dreyfus, who served as Governor from 1979-1983, is currently President of Lee Sherman Dreyfus, Inc., which he started in 1984. Prior to his term in public office, Mr. Dreyfus was President of Sentry Insurance Co., Chancellor of the University of Wisconsin-Stevens Point, and Professor at the University of Wisconsin-Madison.

He presently serves on the Board of Directors for Marcus Corp., the Wisconsin Mental Health Society, and American Energy Week, Inc.

Listed in *Who's Who in the World* and *Who's Who in America,* Mr. Dreyfus received the President's Gold Medal through the Association of U.S. Army and the Distinguished Public Service Medal from the U.S. Secretary of Defense, plus numerous honorary degrees.

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The Annual Meeting will open on Wednesday morning, November 5, at the Georgia World Congress Center, and Program Chairman Percy E. Pierce, of PPG Industries, Inc., Allison Park, PA, has announced the theme, "Compliance and Quality: Recognizing the Opportunities."

Program Highlights

- Mattiello Lecture by Dr. Zeno W. Wicks, Jr., former Chairman of the Dept. of Polymers and Coatings, North Dakota State University, "Free Volume and the Coatings Formulator." (See May 1986 JCT)
- Manufacturing Committee-sponsored session on "Productive Alternatives for Improving Materials Flow"
- "Powder Coatings" session
- "Color" session
- Constituent Society Papers
- Roon Award Competition Papers
- Overseas papers from OCCA and FATIPEC.

Paint Industries' Show

The 51st Paint Industries' Show of the Federation will be held in conjunction with the Annual Meeting at the Georgia World Congress Center, and will feature the products and services of over 225 supplier companies to the coatings industry. Exhibit hours have been expanded to: 11:00 am-5:30 pm, on Wednesday, November 5; 9:00 am-5:30 pm, on Thursday, November 6; and 9:00 am-3:00 pm, on Friday, November 7.

Registration Fees

Advance registration is available for $50 for members and $65 for non-members. Fee for spouses' activities is $35 in advance.

Also, there will be a special advance registration fee of $25 for retired members and their spouses.

On-site registration for members will be $60 full-time and $40 one-day. Non-members fees will be $75 full-time and $50 one-day. Spouses activities will be $45 on-site.

Registration forms were mailed in April and are included in this issue (see pages 21-26).

Hotels and Reservations

The Federation headquarters hotel will be the Altanta Marriott Marquis. Other hotels which have reserved blocks of rooms are: Atlanta Hilton, Atlanta Marriott Downtown, Holiday Inn-Downtown, Hyatt Regency, Omni International, Ritz Carlton, and Westin Peachtree Plaza. All requests for housing must be made on the official housing form, which is available from Federation headquarters, and is included in this issue (see pages 21-26).

Special Air Fare

Delta Airlines, in cooperation with the Federation, is offering a special discount fare which affords passengers a 40% mini-

(Continued on page 19)

Pittsburgh Hosts Successful FSCT "Spring Week"

The Federation's third "Spring Week" was as successful as its predecessors. There were three major events: (1) Seminar; (2) Society Officers Meeting; and (3) Board of Directors Meeting.

The Pittsburgh Society was a super host and the Federation extends its thanks to Ray and Gloria Uhlig and all the members and spouses who worked with them on arrangements, such as spouses programs, special restaurant guides, and the evening receptions. The latter were sponsored by Mobay Corp. and Eastman Chemical Products, to whom the Federation is also grateful. Thank you very much, Pittsburgh!!

Seminar

This seminar, on "Special Purpose Coatings," programmed by Technical Advisor Roy Brown, drew an attendance of 101, of which 88 were paid. Among the various coatings systems discussed were: Traffic Marking. . .Aerosol. . .High Solids Maintenance. . .Auto Refinish . . .Fire-Retardant. . .Elastomeric . . .Heavy Duty Maintenance. . .Highway Bridge Maintenance. . .Marine. . . and High Performance for Pulp/Paper Mills and Petroleum Refineries. With three lively Q&A sessions, it was an interesting and informative experience for the attendees.

Society Officers Meeting

This was the 10th annual meeting of this group. Attendance was 31 (26 Society Officers from 22 Societies, and five new Society Representatives to the Federation Board).

Board of Directors Meeting

Major business from this meeting at the Sheraton Hotel at Station Square on May 16 was:

Attendance (64): Thirty-five members of the Board, plus 29 guests (including five Past-Presidents, 13 Society Officers, and Larry Thomas, Executive Director of the NPCA).

Federation Membership: It was reported that membership has reached a new milestone—the 7,000 mark. Biggest percentage gains in 1986 were made by the Dallas, Northwestern, and St. Louis Societies. Their Membership Chairpersons will receive a Certificate of Appreciation.

Nominations: The slate for 1986-87, presented by the Nominating Committee, is:

President-Elect—Deryk Pawsey, of Pacific Northwest
Treasurer—Jim Geiger, of Southern
Executive Committee—Kurt Weitz, of Toronto (3 years)
Board (At-Large)—Ronnie Brown, of Southern (2 years)
Lloyd Haanstra, of Los Angeles (2 years)
Board (Past-President)—Terryl Johnson, of Kansas City (2 years)
Carlos Dorris, of Dallas, was already elected to assume the Presidency

There were no nominations from the floor.

Amendments of By-Laws: Approval was given to Article VIII (Dues), setting the annual dues for Society Honorary Members at one-half the Active Member rate—$10.00. The amendments to Article I re Federation Honorary Membership were also passed.

Insurance Program for Federation Members: A proposal for a Federation-sponsored insurance program for members was mailed to the Board well in advance of the meeting. It was reviewed at the meeting by Bob Carron, of Financial Design Consultants, St. Louis. Basics of the plan provide four types of coverage: (1) Term Life; (2) Accidental Death and Dismemberment; (3) Hospital Indemnity; and (4) Disability. Federation's only involvement will be the association of its name and mail and print promotion. The Board approved the concept of this new membership service and authorized the Executive Committee to continue discussions with Mr. Carron toward implementation. (Mr. Carron advised that all states involved must approve the program).

Staff Member on Environmental Matters: Continuing discussions which began at the October 6, 1985 meeting, the Board approved a motion (by the Golden Gate and Los Angeles Societies) that the Federation direct either a new or a current staff member to coordinate the dissemination of information and developments re coatings industry environmental and hazardous waste matters, for the benefit of the Societies and their individual members.

(At a session following the meeting, the Executive Committee indicated that a current staffer will begin to assist in the areas indicated, in close cooperation with the Federation's Environmental Control Committee. The staffer will also be available to attend significant meetings upon request. One of the first steps will be to query and "networkize" the Society Environmental Control Committees, of which there are a reported 17).

Actions of Executive Committee: Committee actions of October 10, 1985 and January 31, 1986 were approved by the Board.

(Continued on page 16)

Kathryn Ferko, Assistant to Treasurer, Retires from FSCT Headquarters Staff

Kathryn A. Ferko, Assistant to the Treasurer of the Federation of Societies for Coatings Technology, retired on June 30, 1986. She joined the staff in February 1974.

She was honored at the Board of Directors meeting on May 16 with a Scroll of Appreciation and a gold bracelet presented by Federation President William Mirick (right) and Executive Vice-President Frank J. Borrelle.

Ms. Ferko will move to the New Jersey seashore.

Successful Seminar on "Special Purpose Coatings" Sponsored by FSCT in Pittsburgh on May 13-14

The fourth Federation Spring Seminar was presented on May 13 and 14 at the Sheraton Hotel at Station Square in Pittsburgh, PA, in conjunction with the Incoming Society Officers Meeting and the Board of Directors Meeting, as part of Federation "Spring Week."

This successful 1½ day event featured presentations by knowledgeable industry speakers on the application, inspection, performance, and generic composition of special purpose coatings.

A total of 101 attendees included participants from across the U.S., as well as Canada and England.

President William Mirick delivered welcoming remarks on behalf of the Federation, and FSCT Technical Advisor Roy Brown, (who developed the programming) served as Moderator.

The following papers were presented:

"Traffic Paints"—David R. Miller, Redland-Prismo Corp., Canton, GA.

"Aerosol Paints and Coatings"—Robert M. Hall, Rust-Oleum Corp., Evanston, IL.

"Performance and Cost Effectiveness of High Solids Maintenance Coatings"—J.P. Weinberg, DuPont Co., Philadelphia, PA.

"Automotive Refinish Coatings"—Robert Allinder, BASF Inmont, Whitehall, OH.

"Fire-Retardant Paints"—William A. Rains, Albi Div. of Stan Chem, Inc., East Berlin, CT.

"Introduction to Elastomerics"—Thomas De Pippo, The Neogard Corp., Dallas, TX.

"Evaluating and Predicting Performance of Heavy-Duty Maintenance Coatings"—Bernard R. Appleman, Steel Structures Painting Council, Pittsburgh, PA.

"Problems of Bridge Maintenance"—David Spagnoli, Pennsylvania Department of Transportation, Pittsburgh, PA.

"High-Performance Corrosion-Resistant Coating Systems"—J.J. Bracco, Mobay Chemical Corp., Pittsburgh, PA.

"Conducting an Inspection of the Paint Job"—Kenneth Trimber, KTA-Tator Associates, Pittsburgh, PA.

"Marine Coatings for Ships and Off-Shore Structures"—John White, Devoe Marine Coatings Co., Div. of Grow Group, Inc., Louisville, KY.

"Coating Systems for Petroleum Refineries and Petrochemical Plants"—Gilbert Repka, PPG Industries, Inc., Houston, TX.

"Special Purpose Coatings for Pulp and Paper Mills"—Douglas Jones, Southern Coatings and Chemicals Co., Sumter, SC.

"Spring Week" Held in Pittsburgh *(From page 15)*

The following from the May 15 meeting of the Exec were also okayed by the Board:

(1) That the Executive Committee supports a clearer delineation of the respective duties of the Educational and Professional Development Committees.

Educational should concern itself with attracting new people into the industry and their basic orientation in coatings technology through short courses at the local or Society level.

Professional Development should devote its efforts to the continuing education and professionalism of those with experience in the industry, through special seminars or courses of a more extended and advanced nature.

As a start toward the clarification of duties, paragraph (2) should be deleted from the present PD duties, as listed on page 71 of the 1986 *Year Book*.

The Chairmen of the two committees will be contacted, the duties rewritten, and submitted to the Executive Committee in time for the September meeting.

(2) That the Executive Committee supports the concept of Federation-sponsored insurance programs as an additional service for members, provided that the Federation's involvement is minimal.

(3) That the Birmingham Club's representation at Federation meetings be changed by substituting attendance at the annual Educational Committee meeting with attendance at the annual Society Officers meeting. The new policy thus provides for transportation cost reimbursement of: The Club's Board member to both the Spring and Fall meetings; the Technical Committee Chairman to the annual Technical Committee Chairmen's meeting; and an Officer to the annual Society Officers meeting.

(4) That thanks be extended to the Baltimore Society for its invitation to hold either the 1994 or 1995 AM&PS in Baltimore. The invitation will be given full consideration.

(5) That committee approval be given to the CDIC Society's nomination of Lewis P. Larson for Federation Honorary Membership. The nomination will now be referred to the CDIC membership. Following their confirmation, it will then be referred to the Societies and the Federation Board of Directors. Election will take place at the AM&PS in November.

(6) That there be no Union Carbide Award (for extraordinary achievement) this year.

(7) That retirees from Federation Staff be permitted to continue their enrollment with the Staff Blue Cross/Shield plan, at their own expense.

(8) That the Pittsburgh Society's request for matching funds—to provide modest cash grants to students in smaller colleges in the Pittsburgh area—be referred to the Coatings Industry Education Fund.

(9) That the two requests of the Manufacturing Committee be approved: (1) to request Morehouse Industries to again involve the Federation Manufacturing Committee in the selection of the recipient of the annual Golden Impeller Award and (2) to permit the committee to study the concept of making available to interested members a collection of reprints of meaningful manufacturing-related articles from various publications, most likely in binder form.

Coatings Industry Education Fund

Chairman Neil Estrada reported that the Trustees will propose a change in the objectives of CIEF, by de-emphasizing research activities. CIEF will also review the Pittsburgh proposal re grants to small colleges and is also thinking of sponsoring a Workshop on Motivation at a future Annual Meeting.

PD Committee Questionnaire

A questionnaire from the Professional Development Committee was mailed to Federation members in April. The returns have been phenomenal—somewhere around 4,000—or—60%. A summary will be published.

Spring Week 1987

The Federation and the Pacific Northwest Society will present Spring Week 1987 from April 28-May 2, at the Westin Hotel in Seattle.

Frank J. Borrelle
Executive Vice-President

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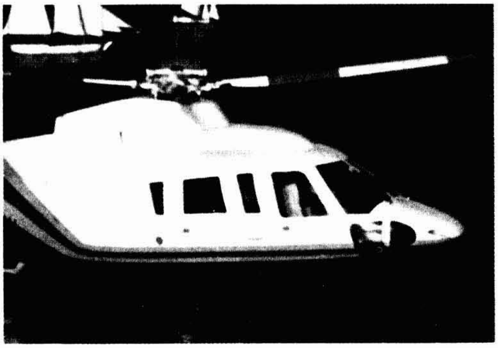

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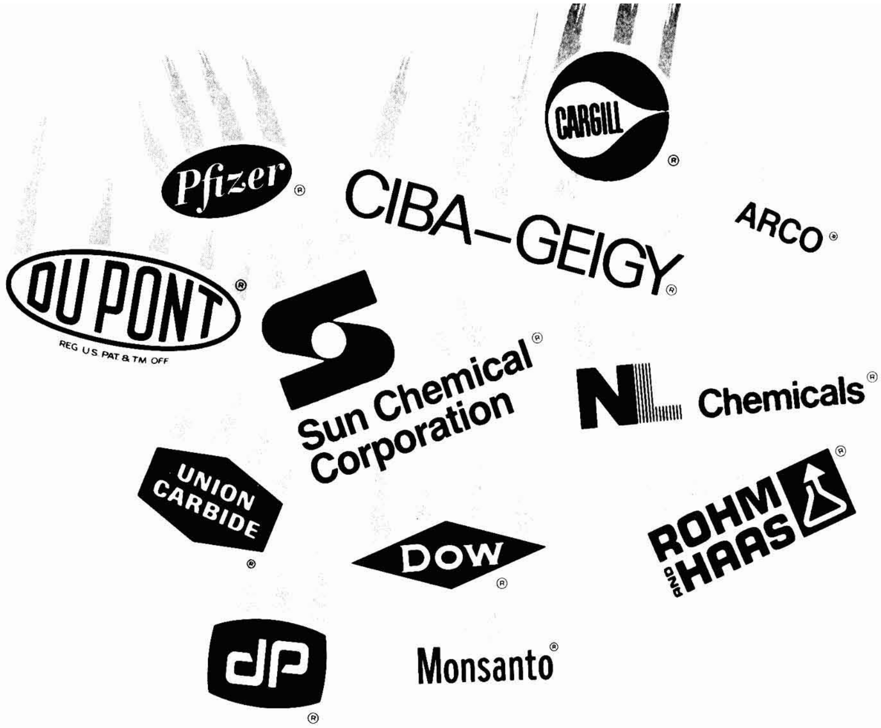
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ENVIRONMENTAL CONTROL

EPA Says Certain Glycol Ethers Pose Unreasonable Risk to Health

In the May 20, 1986 issue of *The Federal Register* (pp. 18488-18497), the Environmental Protection Agency presents public notice of its intended actions concerning the manufacture and use of 2-methoxyethanol (CAS # 109-86-4), 2-ethoxyethanol (CAS # 101-80-5), 2-methoxyethanol acetate (CAS # 110-49-6), and 2-ethoxyethanol acetate (CAS # 111-15-9). The EPA states that (there is) "a reasonable basis to conclude that the risk of injury to worker health from exposure to these glycol ethers during their manufacture and during processing and use is unreasonable and that this risk may be prevented or reduced to a sufficient extent by action to be taken by OSHA under the Occupational Safety and Health Act." Based upon this, EPA is using the May 20 FR notice as a report to OSHA under Section 9 (a) of the Toxic Substances Control Act (TSCA), 15 U.S.C. 2608(a). By filing the information in this manner, Federal OSHA is required to respond to the EPA within 180 days of the publication of the May 20 issue of *The Federal Register*.

These four glycol ethers have been used in commerce for over 50 years. Glycol ethers, as a family, are unique chemicals because they contain both the alcohol (–OH) and ether (–O–) moiety in the same molecule. This combination makes the glycol ethers useful in formulations containing organic and inorganic materials. Glycol ethers are useful solvents for a host of commonly used resins in the paint and coatings industry. The EPA estimates total domestic consumption of these glycol ethers as approximately 320 million pounds. The Agency divides consumption of the glycol ethers into industrial uses that include chemical intermediates, industrial coatings, industrial solvents, and jet fuel additives and trade uses that include coatings and solvents used in trade industries.

2-Methoxyethanol, 2-ethoxyethanol and 2-ethoxyethanol acetate have been shown to produce adverse reproductive and developmental effects in a number of animal species at levels of exposure well below current OSHA standards. These adverse effects include effects on adult male testicular tissue, effects on the embryo or fetus, and effects on the pregnant female. 2-Methoxyethanol acetate has been shown to produce adverse testicular effects at relatively high doses. The EPA says that "the fact that the great number of studies that have been conducted by many investigators in many countries, in several animal species, are in agreement in terms of the nature of the developmental and reproductive effects that these glycol ethers." In addition, EPA "has confidence in its conclusion that current exposure to these chemicals may pose a significant hazard to humans."

In the industrial sector (manufacturing, processing and use), the EPA says that there are approximately 200,000 industrial workers exposed to these glycol ethers and as many as 4,000 of those workers are exposed to concentration levels that afford little or no margin of safety from incurring effects similar to those observed in test animals. A larger number—32,000 to 36,000—are exposed to concentration levels that EPA believes do not afford a sufficient margin of safety. EPA has also concluded that reasonable methods such as reduced workplace PELs, controlled work practices and protective equipment could be used to control exposure. The cost of instituting new PELs, for example, for all industrial workers is approximately $61 million annually.

For trade uses, the EPA says that as many as 43,000 trade workers are exposed to concentration levels that afford little or no margin of safety from incurring effects similar to those observed in test animals. Between 159,000 and 272,000 are exposed to concentration levels that EPA believes do not afford a sufficient margin of safety.

Because of the high costs of engineering controls, work practices, and personal protective equipment, occupational control standards that would substantially reduce trade worker risk from glycol ether exposure may result in trade users complying by substituting other products. The cost of complete substitution would be about $22 million annually. To put this in perspective, a typical glycol ethers-containing paint costing $35 per gallon might increase eight to nine cents per gallon as the result of switching to a substitute. Reduced PELs, assuming compliance using engineering controls, and personal protective equipment, on the other hand, might result in an increase of many dollars per gallon.

Based on the entire record developed during EPA's regulatory investigation, the Agency has determined that a reasonable basis exists to conclude that the current conditions of manufacture and use of glycol ethers present an unreasonable risk of injury to human health, and that the risk to workers can be prevented or reduced to a sufficient extent by actions taken by OSHA, by 9(a) of TSCA.

The reader is directed to the May 20 issue of *The Federal Register* for a more detailed reading.

Joyce S. St. Clair,
Chairperson

Annual Meeting *(From page 14)*

mum savings off Delta's round trip, undiscounted day coach fares for those who travel to the Annual Meeting on Delta's domestic system. (For travel from Canada the discount minimum is 30%.)

To take advantage of this discount, you must:

(1) Leave for Atlanta between November 1-6, 1986;

(2) Stay no longer than 15 days;

(3) Purchase tickets at least seven days prior to departure;

(4) Phone 1-800-241-6760 for reservations. Immediately reference the FSCT file number: **U0235**. (The special discount fares are available only through this number.)

If a travel agent is used, they should place the reservations through the toll-free number to obtain the same fare advantages.

Federation's Environmental Control Committee

Joyce Specht-St. Clair, Chairperson
Porter Paint Co.
400 S. 13th St.
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Yvonne D'Arcy
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Sidney Rubin
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Wilmington, DE 19899

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Allison Park, PA 15101

ROCKY MOUNTAIN
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Union Chemical Div.
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Denver, CO 80204

ST. LOUIS
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Walsh & Associates, Inc.
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St. Louis, MO 63144

SOUTHERN
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DuPont Co.
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Longwood, FL 32779

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64th Annual Meeting & 51st Paint Industries' Show

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November 5, 6, 7, 1986

FSCT 1986 ANNUAL MEETING AND PAINT INDUSTRIES' SHOW
GEORGIA WORLD CONGRESS CENTER, ATLANTA, GEORGIA
WEDNESDAY, THURSDAY, AND FRIDAY, NOVEMBER 5, 6, 7

APPLICATION FOR HOTEL ACCOMMODATIONS

MAIL TO:
FSCT Housing Bureau
233 Peachtree St. NE #2000
Atlanta, GA 30043

Please indicate below the type of accommodations requested and choice of hotels. All reservations will be processed by the Housing Bureau of the Atlanta Convention & Visitors Bureau. Hotel assignments will be made in accordance with prevailing availability. The confirmation of your reservation will come to you directly from the hotel to which you have been assigned. Changes and cancellations—prior to October 5—must be submitted in writing to the Housing Bureau at the above address. After October 5, please direct all inquiries to the hotel (phone numbers in this brochure).

All reservations will be held until 6:00 p.m. and none can be guaranteed after October 5.

TYPE OF ACCOMMODATION	NUMBER	RATE REQUESTED
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Double (2 persons)		
Twin (2 persons)		
Suite (parlor and 1 bedroom)		
Suite (parlor and 2 bedrooms)		

CHOICE OF HOTELS:
1st
2nd
3rd
4th

NAMES OF ROOM OCCUPANTS AND DATES OF ARRIVAL/DEPARTURE

Type of Room	Name	Dates Arrive	Depart

Please Type Additional Reservations on a Separate Sheet and Attach to This Form

SEND CONFIRMATION FOR ALL RESERVATIONS TO:

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Note: Requests for accommodations at the Marriott Marquis will be limited to six rooms per company. A parlor counts as one room. Reservations for the Atlanta Hilton will be accepted for arrival beginning Wednesday, November 5, only.

HOTEL ROOM AND SUITE RATES[1]

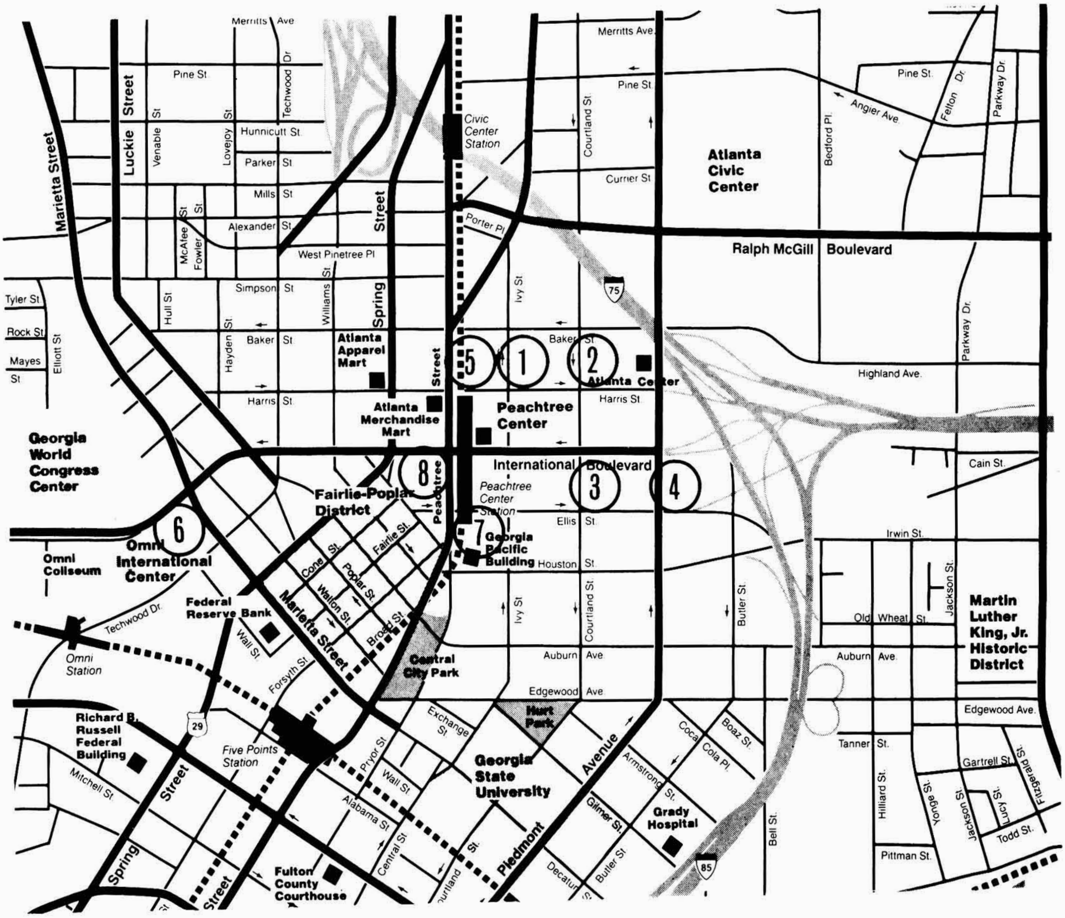
No. on Map	Hotel	Singles	Doubles	Suites
1.	**Marriott Marquis[2]** **(FSCT Headquarters)**	88/98/108 150 Concierge	108/118/128 170 Concierge	$275 & up
2.	**Hilton & Towers[3]**	82/92/102 135 Towers	102/112/122 155 Towers	250 & up
3.	**Marriott Downtown**	79	90	225 & up
4.	**Holiday Inn**	68	68	—
5.	**Hyatt Regency**	82/92/102	104/108/116	225 & up
6.	**Omni International**	88/98/108	108/118/128	250 & up
7.	**Ritz Carlton**	99/109	119/129	350 & up
8.	**Westin Peachtree Plaza**	80/90/100	90/100/110	250 & up

(1) All room rates are subject to an 8% City and Occupancy Tax.

(2) Requests for accommodations at the Marriott Marquis will be limited to six rooms per company. A parlor counts as one room.

(3) Reservations for the Atlanta Hilton will be accepted for arrival beginning Wednesday, November 5, only.

Note: Most hotels require deposits. Please read your confirmation carefully. If a deposit is required, please mail directly to the hotel.



EXHIBITORS SIGNED UP FOR 1986 PAINT INDUSTRIES' SHOW

(As of June 1, 1986)

Aceto Chemical Co., Inc.
Advanced Coating Technologies
Advanced Software Designs
Air Products & Chemicals, Inc.
Alcan Powders & Pigments
C. M. Ambrose Co.
American Cyanamid Co.
American Hoechst Corp.
American Society for Testing and Materials
Analect Instruments
Angus Chemical Co.
Anker Labelers Corp.
Applied Color Systems, Inc.
Arco Chemical Co.
Aries Software Corp.
Ashland Chemical Co.
Atlas Electric Devices Co.
AZS Corporation

B&P Environmental Resources
B.A.G. Corp.
BASF Corporation Chemicals Div.
Beltron Corp.
Berol Chemicals, Inc.
Blackmer Pump Div., Dover Corp.
C.W. Brabender Instruments, Inc.
Brinkmann Instruments
Brockway Standard, Inc.
Brookfield Eng. Labs., Inc.
BTL Specialty Resins Corp.
Buckman Laboratories, Inc.
Bulk Lift International, Inc.
Burgess Pigment Co.
Byk-Chemie USA

Cabot Corp., Cab-O-Sil Div.
Calgon Corp., Div. of Merck & Co., Inc.
Canada Talc Ltd.
Cargill, Inc.
Caschem, Inc.
Celanese Specialty Resins
CEM Corp.
Chemical & Engineering News
  American Chemical Society
Chicago Boiler Co.
CIBA-GEIGY Corp.
Clawson Tank Co.
Coatings Magazine
Color Corp. of America
Colorgen, Inc.
Columbian Chemicals Co.
Commercial Filters
Consolidated Packaging Machine
Continental Fibre Drum Co.
Cook Resins & Additives
Cosan Chemical Corp.
Coulter Electronics, Inc.
Cray Valley Products, Inc.
Crosfield Chemicals
Cuno Industrial Products
Custom Fibers International
Custom Metalcraft, Inc.
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Dow Chemical USA
Dow Corning Corp.
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Drew Chemical Corp.
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Hunter Associates Laboratory

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1986 ADVANCE REGISTRATION

FEDERATION OF SOCIETIES FOR COATINGS TECHNOLOGY

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- CC ☐ Manufacturers of Equipment and Containers
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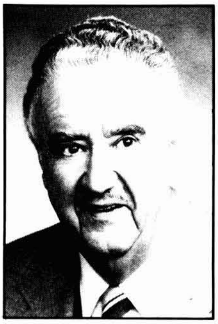
1986 Annual Meeting
Paint Industries' Show
November 5, 6, 7
Georgia World Congress Center
Atlanta, GA

OPENING SESSION
Wednesday, November 5

Keynote Address

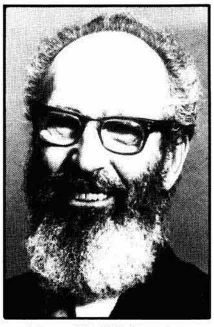
"The American Mission"

Lee Sherman Dreyfus


Lee Sherman Dreyfus

Lee Sherman Dreyfus served as Governor of the state of Wisconsin from 1979 to 1983. Currently, he is President of Lee Sherman Dreyfus, Inc., which he started in 1984. Career highlights include serving as President of Sentry Insurance Co., Chancellor of the University of Wisconsin-Stevens Point, and Professor at the University of Wisconsin-Madison. Listed in *Who's Who in the World* and *Who's Who in America,* Mr. Dreyfus was the recipient of the President's Gold Medal through the Association of U.S. Army and the Distinguished Public Service Medal from the Secretary of Defense, plus numerous honorary degrees.

MATTIELLO LECTURE
Friday, November 7


Zeno W. Wicks, Jr.

"Free Volume and the Coatings Formulator"

Zeno W. Wicks, Jr.

Zeno W. Wicks, Jr., former Department Chairman of Polymers and Coatings at North Dakota State University, has conducted or directed industrial research projects in the areas of coatings, polymers, coated fabrics, printing inks, textile colorants, plastics, and sealants. In addition, he has served as a consultant to a number of governmental agencies with regard to environmental regulations in the coatings industry. Author of over 35 technical articles, Dr. Wicks has taught numerous courses in the U.S. as well as China, England, and France. Four of his research papers were awarded Roon prizes as the best technical papers offered for presentation at the Annual Meetings of the Federation of Societies for Coatings Technology.

Coil Coating Industry Experiences Drop from Previous Levels

After a record-shattering 1984, the coil coating industry readjusted in 1985 to shifting market demands and actually dropped just under five percent from previous year heights.

Coil coated steel slid from an estimated 3,448,000 tons shipped from North American coil coaters in 1984 to 3,238,000 tons in 1985. At the same time, coil coated aluminum increased by 1.4%, from 720,000 tons in 1984 to 730,000 tons in 1985.

The National Coil Coaters Association estimates total shipments from United States, Canadian, and Mexican coil coaters from actual shipment tonnages reported to the association by both member and non-member companies.

Specific end-use markets cannot be estimated as accurately and NCCA can report only actual tonnages supplied from reporting companies.

It became apparent in 1985 that the largest single market for coated coil—weldable zinc-rich primed steel for corrosion-resistant body parts on autos, vans, and light trucks—is shifting to other materials. This market has represented more than one-quarter of all coated coil over the past several years. Shipments reported to NCCA dropped by 10.7% in 1985, from 1,415,681 tons in 1984 to 1,278,598 tons.

Other major markets for coil coated steel were off only slightly from their record 1984 levels. Building products dipped from 807,540 tons to 778,394 tons. Appliances remained at the same record level of 118,000 tons. Furniture, fixtures, and equipment dropped from 68,735 tons to 65,889 tons. Containers and packaging, which many predict will become a major "new" market for coated coil, slipped in 1985 from 67,000 tons to 65,500 tons.

Conversely to the trend in coil coated steel, the aluminum shipments demonstrated slight gains in almost all the major markets. Building products jumped more than 14%, from 200,249 tons to 229,038 tons.

The next largest market for coil coated aluminum, containers and packaging, stayed level at 161,500 tons.

The rest of the market uses showed increases. Transportation was up from 20,665 tons to 23,739 tons; furniture, fixtures, and equipment from 4,841 tons to 6,988 tons; and, appliances from 3,281 tons to 3,838 tons.

Metal cans, ends and tabs remained the most dominant use of coil coated aluminum at 154,756 tons with residential siding and roofing coming in at 63,643 tons.

Coated coil is sheet steel or aluminum that is prepared and coated with organic paints or other liquid of film laminates while still in coil form on automated, high-speed continuous lines. Liquid coatings are applied to cleaned, prepared and primed metals at speeds up to 900 ft. per minute by rolls revolving in the reverse direction to the strip being coated. The thickness of coatings is controlled to a high degree of accuracy, then in the same continuous operation, it is cured and recoiled ready for further processing. Many metal fabricating industries find that coated coil offers them significant economies in quality control of the finish prior to expensive fabrication. Also, eliminating their own post-painting facilities saves costs, space, and concerns about pollution control.

Hercules and Henkel KGaA Plan Joint Venture

A new water-soluble polymers joint venture is being planned by Hercules Incorporated, Wilmington, DE, and Henkel KGaA, Dusseldorf, Federal Republic of Germany.

The two companies intend to form a 50/50 worldwide joint-venture company that would combine substantially all of their respective water-soluble polymers businesses and assets. The joint venture will operate as an independent entity. Both firms cautioned that an undertaking of this complexity requires resolutions of a number of issues in the final agreements, which must then be submitted to the boards of both companies for approval. Final agreements should be submitted by September of this year and a closing should be accomplished in early 1987.

Hercules intends to contribute or dedicate its water-soluble polymers plants at Hopewell, VA; Parlin, NJ; Brunswick, GA; Zwijndrecht, The Netherlands; Alizay, France; Bergamo, Italy; and Ceratonia, Spain. Henkel intends to contribute or dedicate its plants at Dusseldorf, Germany; Doel, Belgium; Kennedy, TX; and Sao Paulo, Brazil. Net value of the contributed or allocated assets would be approximately $250 million.

Alcoa Aluminum Pigment Div. Acquired by Silberline

Silberline Manufacturing Co., Inc., Lansford, PA, has purchased the Alcoa Aluminum Pigment and Flake Division. Both Silberline and the Alcoa division are manufacturers of pigments used to formulate metallic finishes in paints, plastics, and inks. According to Ernest Scheller, Jr., President of Silberline, all Alcoa grades and products will continue to be manufactured.

Silberline recently completed a multimillion dollar aluminum pigment manufacturing center in Hometown, PA, which includes a research and development laboratory devoted exclusively to aluminum pigments and their application.

Fine Particle Characterization Definitions To Be Developed by ASTM Task Group

Participants are sought for a new ASTM task group on definitions relating to fine particle characterization. The goal of this group is to produce a standards definition document to benefit those in the latex, pigments, and fillers industries.

This task group is part of ASTM Subcommittee E29.02 on Subsieve Testing, a branch of Committee E-29 on Particle Size Measurement.

Additional information is available from Task Group Chairman Roger L. Blaine, Du Pont Company, Quillen Building/Concord Plaza, Wilmington, DE 19898.

William Emmons to Receive 1986 Tess Award

The Officers and Award Committee members of the Division of Polymeric Materials: Science and Engineering of the American Chemical Society have announced that Dr. William D. Emmons, of the Rohm and Haas Co., Spring House, PA, is the recipient of the first Roy W. Tess Award in Coatings.

The award, established to recognize outstanding contributors in the field of coatings science, technology and engineering, is given to Dr. Emmons in acknowledgment of his significant enrichment of the patent literature, with over 80 patents in areas as diverse as adhesion promotion, ambient-curing systems, associative thickeners, reactive diluents, radiation-curable monomers, and others.

In his 35-year career, Dr. Emmons has proven to be a key innovator in the coatings industry. He received the B.S. Degree from the University of Minnesota and a Ph.D. Degree from the University of Illinois. In addition, he has served on the editorial boards of various ACS journals, including the *Journal of Organic Chemistry* and *Organic Syntheses*. He is currently a member of the Board of Directors of *Organic Syntheses*, and has also served on the Advisory Board of *Chemical and Engineering News*.

Dr. Emmons will be presented the Tess Award at the 192nd Meeting of the ACS on Sept. 7-12 in Anaheim, CA.

—Call for Nominees—
1987 Roy W. Tess Award in Coatings

The American Chemical Society's Division of Polymeric Materials: Science and Engineering (PMSE) seeks nominations for the "Roy W. Tess Award in Coatings." This award, made possible through a grant from Dr. Tess, will be for $1,000, and will be presented at the 194th meeting of the ACS, August 30 to September 4, 1987, in New Orleans.

The Executive Committee and membership of PMSE support this award, which recognizes outstanding individual achievements and noteworthy contributions to coatings science, technology, and engineering, and which confirms PMSE's long-standing support and dedication to excellence in the coatings field.

Nominations are welcomed from all sections of industry and academia. Upon receipt of names, the chairman will submit a documentation form requesting information on the nominee relevant to patents, publications, etc. All nominations for the *1987 Tess Award* should be sent in prior to September 1, 1986, although nominations received after that date will be considered for the succeeding year's award.

Members of the Nominating Committee are: *Chairman*—George R. Pilcher, Hanna Chemical Coatings Corp.; *Vice-Chairman*—Joseph A. Vasta, Du Pont; F. Louis Floyd, Glidden Coatings & Resins; S. Peter Pappas, North Dakota State University; Percy E. Pierce, PPG Industries, Inc.; Otto Vogel, Polytechnic University.

Nominations should be addressed to the Chairman, George R. Pilcher, Hanna Chemical Coatings Corp., P.O. Box 147, Columbus, OH 43216.

RTZ Chemicals Purchases Specialty Chemicals Business from Celanese

Celanese Corporation, New York, NY, has sold its specialty resins and water-soluble polymers business to RTZ Chemicals Ltd., a wholly-owned subsidiary of the Rio Tinto-Zinc Corporation, PLC, United Kingdom, for approximately $138 million. The sale is expected to be completed before the end of the second quarter. The businesses affected include Celanese Specialty Resins, with operations in Louisville, KY, and Los Angeles, CA; Celanese Water-Soluble Polymers, with operations in Louisville, Vernon, TX, and Dalton, GA; as well as overseas operations in Switzerland, Holland, Pakistan, and India.

Angus Opens Technical Center

Angus Chemical Co., Northbrook, IL, has opened its new Technical Center. The fully operational facility, also located in Northbrook, provides new applications research and expanded analytical capabilities to customers.

The center houses a new organic synthesis laboratory complete with facilities for high pressure catalytic reduction and oxidation systems. Twenty chemists, technicians, and support personnel are also located in the center, providing technical support for investigating, refining, and testing product applications.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Mechanism of Corrosion and Delamination Of Painted Phosphated Steel During Accelerated Corrosion Testing

Mark Knaster and Jeffrey Parks
Amchem Products Inc.*

A theoretical model for the delamination of organic coatings from zinc-phosphated steel surfaces is presented. It is shown that under ambient conditions and in neutral NaCl, media delamination occurs as a result of the formation of a surface-tension gradient during oxygen depolarization and, subsequently, the disruption of adhesion at the coating-phosphate interface. Dissolution of the phosphate coating occurs only after adhesion is lost. An accelerated cathodic delamination test showing good correlation with the long-term scab blistering test also is introduced.

INTRODUCTION

With the growing demand by the automotive industry to improve the quality of painted metals, much emphasis is being placed on accelerated corrosion tests for appraising paint performance. Such accelerated tests may indicate differences in the substrate material, the quality of the polymeric coating (paint), or variations in the metal pretreatment. For samples prepared using identical substrate and coating materials, differences in accelerated testing results must be attributed to the quality of the pretreatment, in particular phosphating. The delamination rate of paints applied to high quality phosphated surfaces has been observed to be far less than that for low quality phosphates.

In recent years, a number of publications have focused on the definition of pretreatment quality and the mechanism for the deterioration and delamination of painted metals during accelerated testing.[1-17] It has been shown[3] that the quality of a zinc-phosphate coating is dependent on the oxygen permeability through the coating. As oxygen penetrates the coating surface, corrosion accelerates and degradation of the painted system is observed. Other authors have shown that the formation of phosphophyllites on the surface and a fine crystal structure improve phosphate quality.[4,5] It has been recognized that, in addition to the physical characteristics, the electrochemical characteristics of the phosphate play a major role in determining coating quality.[6,7] The effects of secondary parameters, such as surface profile, inclusions, and contaminants from previous processing steps (e.g., cleaners), on phosphate quality must also be taken into account.[8]

Some of the research conducted on phosphate coatings in recent years have focused on improving the so-called alkaline resistance of the phosphate. Considering a simplified corrosion process, the main product of the cathodic half of the corrosion reaction is assumed to be OH^-. A number of researchers have proposed that there is a build-up of hydroxide beneath a coating adjacent to corrosion sites and that cathodic delamination results from dissolution of the phosphate layer.[1,9] Ritter[1] has measured the pH at the delaminating front and has found it to be on the order of 14, sufficient for dissolution. Thus, improving alkaline resistance would decrease the dissolution rate, thereby reducing delamination. More recently, a report claiming a pH of 1 immediately adjacent to a scribe when a painted phosphated steel panel corroded in NaCl media suggests the need for system resistance at both high and low pH's.[10]

In conjunction with the determination of localized pH regions beneath organic coatings, researchers have ap-

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*300 Brookside Ave., Ambler, PA 19002.

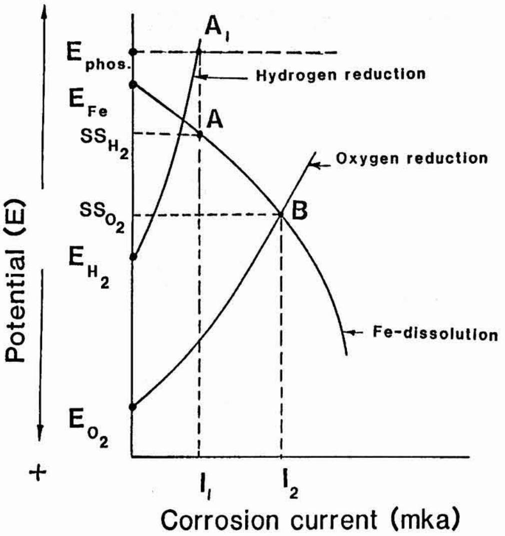


Figure 1—Schematic representation of the steady-state conditions for steel and phosphated steel in neutral electrolyte as a result of hydrogen and oxygen depolarization

plied impedance theory to study the diffusional penetration of electrolyte through paints and to evaluate coating quality.[11-17] Such studies, while allowing the development of electrical circuit models for thin films, provide little relevant information for the thicker, highly resistant multi-layered systems employed in the automotive industry.

This paper reviews the fundamentals of iron corrosion in neutral NaCl media, provides insight into the mechanisms of the corrosion of and delamination of paint from phosphated steel during accelerated corrosion testing, and proposes an alternative to the standard accelerated cathodic delamination test.

CORROSION OF IRON AND STEEL IN NEUTRAL NaCl SOLUTION

The degradation of iron in aqueous media has been investigated in depth for decades. The corrosion reaction is represented by two simple chemical equations: the cathodic reduction of oxygen (or hydrogen) and the anodic dissolution of iron. These reactions, while chemically simple, are fairly complex mechanistically. The general cathodic and anodic reactions, and overall reactions, observed for iron in NaCl are listed below. To better understand the corrosion mechanism, the anodic and cathodic reactions and the generation of the corrosion current will be investigated separately.

Cathodic Reactions

1c) $2H_2O + 2e^- \rightarrow 2OH^- + H_2$
2c) $1/2\,O_2 + H_2O + 2e^- \rightarrow 2OH^-$
3c) $O_2 + 2H^+ + 2e^- \rightarrow H_2O_2$
4c) $2H^+ + 2e^- \rightarrow H_2$

Anodic Reactions

1a) $Fe + 2H_2O \rightarrow Fe(OH)_2 + 2H^+ + 2e^-$
2a) $Fe + 3H_2O \rightarrow Fe(OH)_3 + 3H^+ + 3e^-$

Overall Reaction in Neutral NaCl

(1) $Fe + 2H_2O \rightarrow Fe(OH)_2 + H_2$
or (1′) $Fe + 1/2\,O_2 + H_2O \rightarrow Fe(OH)_2$

(2) $2Fe + 6H_2O \rightarrow 2Fe(OH)_3 + 3H_2$
or (2′) $2Fe + 3/2\,O_2 + 3H_2O \rightarrow 2Fe(OH)_3$

ANODIC REACTIONS

The dissolution of iron in neutral electrolyte results in the formation of iron-hydroxides with the simultaneous production of a stoichiometric number of protons. When a high concentration of oxygen is present at the metal surface, the iron is said to "actively dissolve," resulting in the formation of ferric (Fe^{3+}) rather than ferrous (Fe^{2+}) ions. One proposed mechanism is the formation of ferric or ferrous chlorides in solution which subsequently hydrolyze to form hydroxides,[10] though direct formation of the hydroxides is favored thermodynamically. The hydrolysis reaction for ferrous ion is:

$$Fe^{2+} + 2H_2O \rightleftharpoons Fe(OH)_2 + 2H^+ \qquad (1a')$$

The pH of the solution is defined by the equilibrium constant for the hydrolysis reaction

$$K_{hyd} = \frac{[Fe(OH)_2] \cdot [H^+]^2}{[Fe^{2+}]} \qquad (3)$$

where

$$[H^+] = 2[Fe(OH)_2] \qquad (3')$$

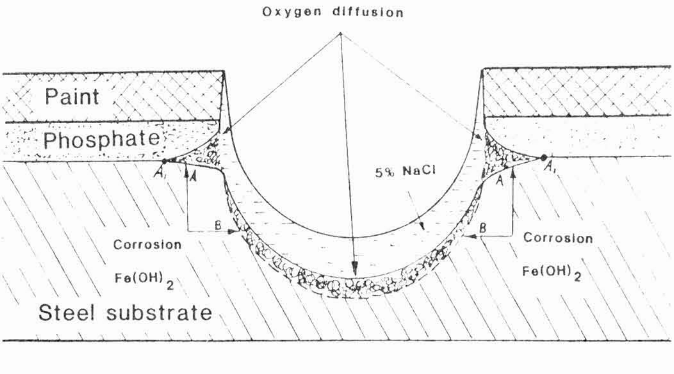


Figure 2—Schematic representation of corrosion in the scribe on painted phosphated steel during corrosion testing

If β represents the degree of hydrolysis, i.e., the fraction of the ferrous ions undergoing hydrolysis, then

$$[Fe^{2+}] = C_o(1-\beta) \tag{4}$$

where C_o is the molar concentration of $FeCl_2$ (in g-mol/cm^3), and

$$[Fe(OH)_2] = C_o\beta \tag{5}$$

The equilibrium constant becomes:

$$K_{hyd} = \frac{4(C_o\beta)^3}{C_o(1-\beta)} \tag{6}$$

The degree of hydrolysis for this reaction is small and equation (6) can be estimated by

$$K_{hyd} = 4C_o^2\beta^3 = \frac{[H^+]^3}{2C_o} \tag{7}$$

$$[H^+] = \sqrt[3]{2K_{hyd}\cdot C_o} \tag{7'}$$

For a 1M solution of $FeCl_2$

$$[H^+] = \sqrt[3]{2K_{hyd}} = 2\beta \tag{8}$$

The solubility of $Fe(OH)_2$ in water at room temperature is 0.00067 g/L (7.4×10^{-6}M),[18] therefore

$$[H^+] = 1.5 \times 10^{-5}, \ pH = 4.83 \tag{8'}$$

While the above calculation was made using several approximations, it is obvious that the pH developed by hydrolysis of $Fe(OH)_2$ cannot reach 1 as reported by Takahashi and Matsudo.[10] Furthermore, excess H^+ production will initiate the reduction of hydrogen according to equation (4c), thereby consuming H^+.

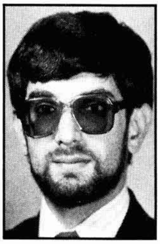
CATHODIC REACTIONS

The cathodic reactions during the corrosion process act to depolarize the surface, consuming electrons liberated during the anodic dissolution of metal. The depolarization reaction is highly dependent upon the type of corroding metal, the surface conditions, electrolyte, pH, and the amount of oxygen diffusing to the surface. The corrosion of iron (steel) in low pH electrolytes and at high temperatures is usually associated with hydrogen depolarization, while oxygen depolarization occurs in alkaline or neutral media and at moderate temperatures. Occasionally, surface conditions are such that both depolarization reactions occur simultaneously. The corrosion of zinc, which is highly negative relative to the hydrogen electrode, proceeds mostly by hydrogen depolarization. The corrosion reaction will proceed only if the electrolyte is conductive enough to support ion exchange. Therefore, the distance between the anodic and cathodic sites on a corroding surface is usually small. Accumulation of hydrogen ions in anodic regions may stimulate the reduction of oxygen [equation (3c)] as well as hydrogen reduction [equation (4c)]. The formation of peroxide [equation (3c)] catalyses the corrosion reaction.

Thermodynamically, the potentials at the hydrogen and oxygen electrodes[26] are given by the following equations:

$$E_{H^+/H_2} = E^o_{H_2} + 2.3\,\frac{RT}{2F}\log\frac{[H+]}{P_{H_2}} \tag{9}$$

MARK B. KNASTER is a Project Leader for automotive product development at Amchem Products, Inc. He received his Ph.D. in Physical Chemistry and Electrochemistry from Karpov's Physical Chemical Research Institute in Moscow, USSR, in 1962. Dr. Knaster managed the Corrosion Laboratory at the Research Institute of Cable Industry for seven years. He has also conducted research in the areas of chlorine production, batteries, and fuel cells.



JEFFREY PARKS received a Ph.D. in Chemistry from Lehigh University, in Bethlehem, Pennsylvania, in January, 1985, working under the auspice of Dr. Henry Leidheiser, Jr., of the Center for Surface and Coatings Research. He is currently employed as a Research Chemist at Amchem Products, Inc.

$$E_{OH^-/O_2} = E^o_{O_2} + 2.3\,\frac{RT}{4F}\log\frac{P_{O_2}}{[OH^-]^4} \tag{10}$$

where E is electrical potential at the metal-electrolyte interface (in volts).

Applying a series of thermodynamic and mathematical identities, equations (9) and (10) become

$$E_{H^+/H_2} = -b\cdot pH \quad (b = \text{constant}) \tag{11}$$

$$E_{OH^-/O_2} = 0.401 + 0.0592\,pH \tag{12}$$

In calculating the potential for the oxygen electrode only the reaction represented by equation (2c) was considered, thus, equation (12) is only approximate for other reactions. Equation (12) shows that a transition from pH 1 near the anode to 14 at the delaminating front would result in a potential shift of about 0.8 volts. A potential difference of this magnitude would result in the immediate evolution of hydrogen in the acidic region. Thus, it is unlikely that a solution having this pH gradient exists beneath a coating.

GENERATION OF THE CORROSION CURRENT

It has long been recognized that in order for the corrosion reaction to be sustained, the anodic and cathodic reaction sites must be in close proximity, allowing generation of a corrosion current. *Figure* 1 is a schematic representation of the two corrosion currents developed at a scribe on a painted phosphated steel panel. The zinc-phosphate surface is semiconductive in nature,[6] exhibiting a negative electrical potential (A_1) which is sufficient to support the hydrogen evolution reaction. The steel, which exhibits a more active potential than the phosphate, becomes the site at which stoichiometric amounts of iron dissolve. The overall current for the reaction is denoted I_1. *Figure* 1 also shows a second corrosion cur-

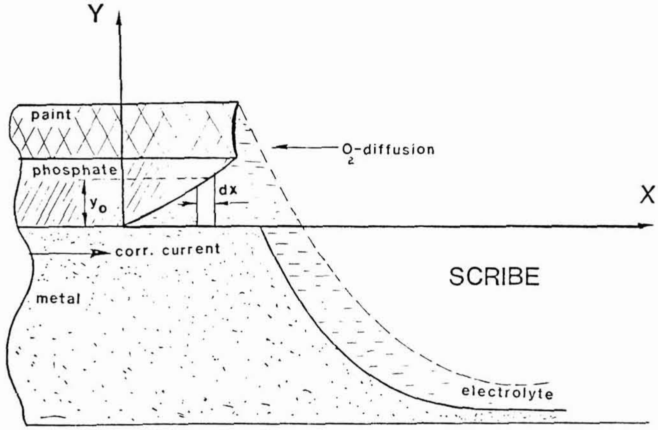


Figure 3—Model for the generation of heterogeneous corrosion current due to oxygen depolarization at the delamination front

rent, I_2, at the steady state potential (B) for the dissolution of iron coupled with the reduction of oxygen. The overall corrosion current corresponds to the sum of these two reactions, that is

$$I_{corr} = I_1 + I_2 \tag{13}$$

It should be noted that the above discussion does not take into account the reaction mechanisms (as presented previously) or the proximity of the corrosion sites.

By convention, corrosion of steel is considered to be the result of galvanic interactions resulting from the nonuniformity of the metal surface. However, it has been shown[6,7] that the corrosion of metals can occur without galvanic interactions by a "homogeneous mechanism." It was already shown[19-23] that anodic and cathodic reactions may occur simultaneously at the same corrosion site. In many cases, the most important factor determining corrosion is the establishment of a steady state corrosion potential (E_{ss}).[6,7] The value of E_{ss} obtained for a given system provides qualitative information regarding the probability of corrosion. While the homogeneous corrosion mechanism can be used to describe the corrosion of sheet steel, heterogeneous corrosion mechanisms must be taken into account when investigating the corrosion in crevices, at joints, or at scribes on painted steel.

Figure 2 is a schematic representation of a scribe on a painted phosphated steel surface exposed to electrolyte. Two major areas of corrosion are indicated. Region (B) is the uniform base of the scribe. In this region, there is free diffusion of oxygen to the metal surface allowing the establishment of E_{ss} and, therefore, homogeneous corrosion conditions. A second corrosion site is located along the metal-electrolyte-air interface (A). Oxygen reduction is favored in this region and a corrosion current is generated according to the heterogeneous corrosion mechanism outlined in *Figure* 3 and *Appendix* A. The total corrosion current is the sum of the currents established during the homogeneous and heterogeneous corrosion reactions. That is

$$I_{corr} = I_A + I_B \tag{13a}$$

I_B can be calculated by applying Fick's law to the diffusion of oxygen through the electrolyte to B. Calculation of I_A is based on defining the rate of diffusion of

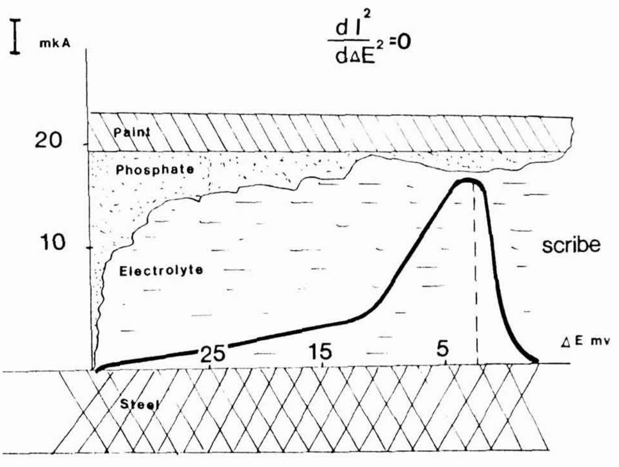


Figure 4—Model for the distribution of the corrosion current beneath the delamination coating

oxygen at the water line and the oxygen reduction rate. Occasionally, the two corrosion mechanisms overlap, with metal dissolution due to the establishment of E_{SS} and galvanic actions occurring in the same region. For cases such as this, the total corrosion current can be calculated using equations (14) and (15).

$$I_B = I_{hom\cdot corr} = 4SDF \; \frac{C_o - C_1}{\delta} \tag{14}$$

$$I_A = I_{heter\cdot corr} = \left[10RTDC_o L\eta \left(\frac{4F\Delta E}{5RT} + e^{-\frac{4F\Delta E}{5RT}} - 1 \right) \right]^{0.5} \tag{15}$$

where I = Corrosion current, ampers
S = Area of corrosion, cm^2
C_o = Solubility of oxygen in electrolyte, $g\text{-}mol/cm^3$
C_1 = Concentration of oxygen is defined surface, $g\text{-}mol/cm^3$
δ = Electrolyte film thickness, cm
η = Ionic conductivity of electrolyte, $ohms^{-1}$
L = Length of scribe, cm
ΔE = Electrical potential difference due to galvanic action, volts

Equation (15) gives the current distribution along a crevice and reflects the specific reaction kinetics for oxygen reduction in the crevice formed between a paint film and the substrate as a result of phosphate dissolution. A detailed description of the development of equation (15) is given in *Appendix* A and reference (24). Taking the second derivative of equation (15) with respect to potential and setting it equal to zero provides the potential at which there is the maximum acceleration in the current generated as a result of oxygen diffusion along the crevice and the development of the potential gradient.

$$\frac{d^2I}{d\Delta E^2} = 0 \tag{16}$$

For a 5% aqueous solution of sodium chloride, the maximum change in current was found to be at ΔE = 2.15 mV. Plotting the distribution of current along a crevice [as determined by equations (15) and (16)] shows that the current maximum exists adjacent to the crevice opening (*Figure* 4). The proximity of the anodic and cathodic sites prohibits the accumulation of free acidity or alkalinity and results in the formation of a neutral environment.

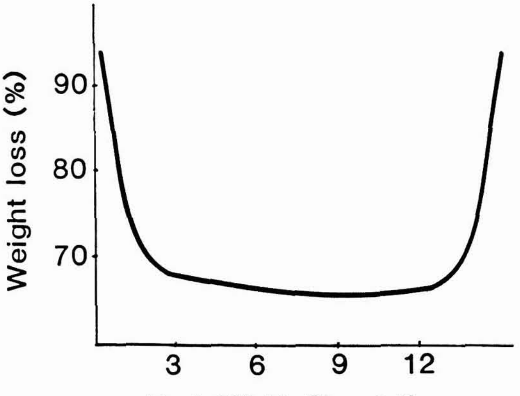


Figure 5—Dissolution of phosphate coating in 5% NaCl solutions as a function of pH

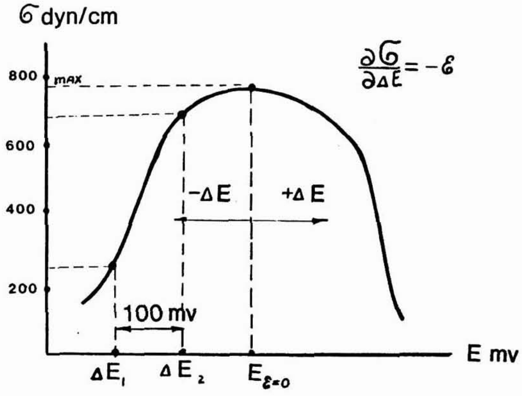


Figure 6—Electrocapillarity curve representing the effect of the oxygen reduction potential (E) on surface tension (σ) at the steel/electrolyte interface

DELAMINATION OF PAINTS FROM PHOSPHATED STEEL SUBSTRATES

The current distribution within the crevice formed between a paint film and phosphated steel suggests that delamination proceeds not by alkaline dissolution of the phosphate (as is widely believed) but by an alternate mechanism. A series of simple experiments were conducted to confirm this hypothesis. In the first experiment phosphated steel panels were immersed for 20 hr in deaerated 5% NaCl solutions, pH ranging from 1 to 14. The experiment was run under nitrogen to prevent corrosion due to oxygen depolarization. Dissolution of the phosphate was observed over a wide range of pH, including neutral solutions, as shown in *Figure* 5. A scribed painted phosphated panel was then immersed in the pH 14, 5% NaCl solution, again under nitrogen, for a period of three weeks. Examination of the test panel revealed no delamination. Since the phosphate readily dissolves at pH 12, one would expect severe delamination if the dissolution theory of delamination was valid. The experimental findings suggest that oxygen depolarization is necessary for delamination to proceed.

Figure 4 shows the oxygen reduction reaction as a result of the voltage gradient formed in the delaminating area. The Lippman equation[25] shows that for liquids there is a change in surface tension with potential assuming a change in the electrical charge of the double layer. That is

$$\frac{\partial\sigma}{\partial\Delta E} = -\xi \tag{17}$$

where σ is the surface tension and ξ is the electrical charge. *Figure* 6 is a graphic representation of the "electrocapillarity curve." Polarizing the oxygen electrode on the order of 50 mV reduces the surface tension about 250 dynes/cm. The oxygen depolarization reaction produces a potential gradient across the scribe which results in a corresponding decrease in the surface tension at the metal-electrolyte interface. The reduction in surface tension

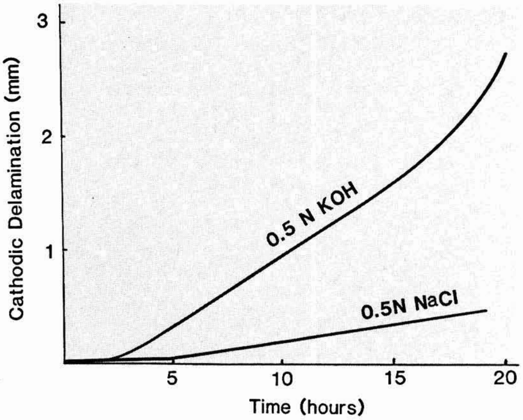


Figure 7—Representative data for the delamination of automotive paint from phosphated-steel panels exposed to 0.5N KOH and 0.5N NaCl solution under cathodic polarization. Current density: 25 mA/cm scribe

increases wettability within the crevice and actually draws solution towards the delamination front. A "force" builds up working against the adhesive forces between the paint, phosphate, and steel. If the adhesion between two of these layers is weak they will separate and delamination progresses. Strong adhesion minimizes penetration of the liquid layer. When reaction (1c) or (4c) occurs at the delamination front, the buildup of hydrogen beneath the paint forces the layers apart, and the liquid penetrates via capillary action. Dissolution of the phosphate layer appears to be a secondary process, occurring during or after liquid penetration.

The mechanism for the delamination in vicinity of a scribe on painted phosphated-steel can be summarized as follows:

(1) The corrosion and dissolution of steel in a neutral electrolyte is accompanied primarily by oxygen depolarization and only slightly by hydrogen evolution.

(2) Oxygen depolarization occurs via two different mechanisms, each defined by a unique kinetic expression, regulating the homogeneous and heterogeneous corrosion reactions.

(3) The heterogeneous corrosion reaction along the crevice formed between a paint and the phosphated substrate results in the formation of a potential gradient as a consequence of oxygen depolarization. The potential becomes more negative approaching the delamination front.

(4) Such changes in electrical potential result in a shift in the thermodynamic equilibrium and a reduction in surface tension according to the Lippman equation.

(5) The change in surface tension creates a "gradient of wettability" resulting in increased hydrophilic penetration of electrolyte under the film which may overcome the adhesion between the paint and substrate, advancing delamination.

(6) Delamination progresses via disruption of the adhesive forces between the paint film and substrate rather than the alkaline dissolution of the phosphate layer. However, dissolution of the phosphate can occur once delamination has been initiated. Thus, it is the adhesive characteristics of the phosphate to the steel (e.g., whether the coating is "tight" or "powdery") and coating which dictate delamination.

We have shown that the traditionally accepted mechanism for the delamination of coatings from phosphated steel is incorrect. The traditional point of view states that the development of an alkaline environment as a byproduct of the corrosion reaction results in the dissolution of the phosphate layer. The greater the rate of alkaline production and, therefore, the more alkali present beneath the coating, the greater the delamination rate. Thus, it would be corrosion and dissolution resistance that dictates delamination. Our data show that the corrosion stability of the phosphate coating is not as critical to delamination as the physical nature of the phosphate layer. The role of structure of the phosphate on adhesion will be discussed in greater detail in the next section.

The previous discussion was based on the assumption that the phosphate layer exists on a bare steel surface. Zinc-plated substrates, so-called "galvanized steels," exhibit a somewhat different delamination mechanism. The zinc layer is electrochemically more negative than the steel base or subsequent phosphate layer, providing a degree of cathodic protection to the steel while undergoing anodic dissolution. Delamination of paints from phosphated galvanized steel occurs only after substantial dissolution of the zinc layer. For this reason, the delamination rate for a given phosphate/coating system on galvanized steel is always less than that for the identical system on iron regardless of the degree of adhesion between the phosphate and substrate.

EVALUATING COATING ADHESION

During the evaluation of the overall adhesion of a paint to a phosphated surface, it is important to determine the degree of adhesion at both the steel-phosphate and phosphate-paint interfaces. The techniques currently employed to evaluate the performance of the painted steel rarely include independent checks of the adhesive

Table 1—Adhesion Test Results

	Type of Phosphating (Bath #)				
Type of Test	1	2	3	4	5
Steel					
240 Hours, water soak/ cross-hatch 2mm	10	10	10	6	4
Scab-Blister, 10 weeks	8	9	10	4	2
Electrolytic, 8 hours, 0.5 amp/scribe	8	9	10	5	2
Zn-Galvanized					
240 Hours, water soak/ cross-hatch 2mm	10	9	7	2	2
Scab-Blister, 10 weeks	10	10	8	8	6
Electrolytic, 8 hours, 0.5 amp/scribe	10	9	7	7	5

strength at these interfaces, preventing the determination of the plane of adhesion loss.

The adhesion of the phosphate to the steel is of critical importance to the overall performance of a painted metal. At present, one is able to obtain only estimates of the adhesive strength via impact or bending tests. These are pass/fail tests and do not allow discrimination between degrees of "good" adhesion. However, it has long been recognized that samples failing either of these tests would exhibit high delamination rates after painting. Further correlations between phosphate-steel adhesion and delamination performance cannot be made at the present time. Thus, there is an obvious need to develop more sensitive means of evaluating the adhesion of phosphates to the steel surface.

An independent evaluation of the degree of adhesion between the phosphate and paint layer is not available at this time. Current testing techniques provide the overall adhesion of the paint relative to a "passing" or "failing" phosphate-steel adhesion rating. These techniques include the water soak-cross hatch, bending impact, and scab-blister tests (*Appendix* B). These tests, while allowing recognition of large differences in adhesive behavior, are not sensitive enough to pick up small differences. The scab test, while more sensitive than the others, is a long-term test and, therefore, time consuming. There is also a lack of correlation between test methods. Scab-test samples exhibiting differences in delamination on the order of 20%, i.e., small but marked differences in the area of adhesion loss, will exhibit little or no adhesion loss during the cross-hatch test. However, failure of the cross-hatch test always means failure in the scab-test. Thus, there is a need for a sensitive short-term adhesion test which, along with phosphate-steel adhesion, heat treatment, and water soak tests, can be used to control the phosphating and painting processes without resorting to long-term climate testing.

One accelerated test for evaluating adhesion is the cathodic delamination technique. A scribed panel is immersed in electrolyte and then cathodically polarized at either constant voltage (-0.8-1.2V vs SCE) or constant current (0.5-1.0 amps). Sodium chloride (at a concentration of 0.5N) is the commonly used electrolyte. Delamination progresses via hydrogen evolution and hydroxide formation. This technique is not specific enough when evaluating paints on phosphated steel since the delamination rates decline sharply during testing making the process non-selective (i.e., all systems delaminate at about the same rate).

A modified cathodic delamination test, employing 0.5N KOH rather than 0.5N NaCl, is currently being used at Amchem to evaluate changes in the performance of phosphating baths. Alkaline solutions, such as KOH, exhibit a lower surface tension along the metal-solution interface than neutral solutions. The reduction in surface tension results in a greater ease of gas evolution, under identical potentials, and a more uniform distribution of gas along the scribe which facilitates delamination. *Figure* 7 shows the delamination curves for painted phosphated steel panels exposed to 0.5N KOH and 0.5N NaCl. Panels prepared as described in *Appendix* B for scab testing were immersed in KOH solution and then cathodically polarized at a constant current of 0.5 amps/scribe for a period of 5-8 hr. Polarizations were carried out using a Hewlett-Packard constant current-voltage power supply and a platinum counter electrode. The technique is quite sensitive to small differences in adhesion. *Table* 1 shows the results of cross-hatch, scab and electrolytic (cathodic delamination) tests performed on phosphated then painted steel and galvanized panels prepared by using five different phosphating baths. The rating systems are those used throughout the automotive industry, with 10 representing excellent performance and 1 total adhesive failure. Good correlation can be seen between the scab and cathodic delamination tests.

CONCLUSIONS

The mechanisms for corrosion in a scribe on a painted phosphated steel surface have been reviewed. It has been shown that the delamination of paints from phosphated steel panels, due to corrosion at a scribe, is a result of oxygen depolarization along the phosphate-paint interface and hydrogen evolution at the delamination front resulting in the development of a force disrupting adhesion. Dissolution of the phosphate layer occurs as a secondary reaction. The need for sensitive, short-term techniques for evaluating the adhesion at the phosphate-steel and phosphate-paint interfaces has been shown. A modified, short-term cathodic delamination technique for evaluating coating adhesion has been introduced showing good correlation with the long-term scab test.

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APPENDIX A

Calculation of Heterogeneous Corrosion Current I_A

Heterogeneous corrosion occurs as a result of oxygen permeation into the delaminated region of painted metals. Differences in oxygen concentration along the crevice formed during delamination lead to the generation of a corrosion current I_A via metal dissolution.

In deriving the equation for I_A, it was assumed that electrochemical polarization of the interfacial reaction is negligible and the potential can be measured only under equilibrium conditions. It was also assumed that oxygen diffuses only along the same axis along which the generated corrosion current is found.

A schematic representation of a crevice formed during delamination is given in *Figure* 3. The vertex of the crevice was chosen as the zero point of the coordinate system. Let us consider the generation of a corrosion current in a volume dv within the crevice.

The change in electrical potential at the interface due to an oxygen concentration gradient along the metal surface is calculated according to Nernst equation:

$$dE = \frac{RT}{4F} d\ln C_1 \qquad (1)$$

C_1 = oxygen concentration in dv.

The electrical resistance, dr, of the electrolyte within a volume dv is given by:

$$dr = \frac{1}{\eta} \cdot \frac{dx}{Y_o} \qquad (2)$$

Y_o = thickness of electrolyte and
η = electroconductivity.

According to Ohms law, the current is equal to:

$$i_{corr} = -\frac{dE}{dr} = -Y_o \frac{RTdC_1}{4FC_1dx} \qquad (3)$$

The corrosion current must also be equal to the amount of oxygen diffusion through the electrolyte into dv and the change in current within dv as a result of oxygen diffusion is given by:

$$di_{corr} = 4FD \left(\frac{C_o - C_1}{Y_o} \cdot dx \right) \qquad (4)$$

where D is the diffusion coefficient and C_o the solubility of oxygen in solution.

Multiplying equation (3) by (4), we obtain the differential equation (5).

$$i_{corr} \cdot di_{corr} = -DRT\eta dC_1 \left(\frac{C_1 - C_o}{C_1} \right) \qquad (5)$$

Integration of this equation under the conditions:

$x = 0; i = 0$ and $C_1 = 0$

over the entire length of the crevice, L, the total current I_A in the crevice is given by equation (6).

$$I_A = I_{corr} = \sqrt{2\,RTC_oL\,D\eta\left(\ln\frac{C_o}{C} + \frac{C_1}{C} - 1\right)} \qquad (6)$$

Considering the Nernst equation and relationship between oxygen concentration and potential, we obtained equation (7)

$$\frac{C_1}{C_o} = e^{-\frac{4F\Delta E}{5RT}} \qquad (7)$$

where ΔE is the electrical potential measured on the metal surface between areas of two concentrations of oxygen: C_o and C_1.

Substituting equation (7) into equation (6), we obtain the final equation for the crevice corrosion current.

$$I_A + I_{corr} = \left[10\,RTDLC_o\eta \left(\frac{4F\Delta E}{5RT} + e^{-\frac{4F\Delta E}{5RT}} - 1 \right) \right]^{0.5} \qquad (8)$$

APPENDIX B

Description of Adhesion Test Methods

(1) IMPACT TESTING: a qualitative method of evaluating adhesive strength and cracking resistance. The test apparatus consists of a tubular column which acts as a guide for a steel impact ball sitting above concave impact plate also of steel. The steel ball varies in size, shape, and weight with the unit. The test panel is placed on the impact plate and the steel ball raised to a pre-determined weight and dropped. The degree of adhesion loss/cracking is reported as a function of the depth and shape of the resultant indentation, usually reported on a pass-fail basis.

(2) WATER-SOAK/CROSS-HATCH TESTING: a semi-quantitative method of evaluating the resistance of coating systems to water immersion via the measurement of adhesion. One half of the test panel is immersed in distilled-deionized water at 122°F (50°C) for a period of 240 hr. The panel is then dried and a one-inch square cross-hatch pattern cut into the coating with a fine blade. The cuts are made at 2 mm intervals. Tape is applied to the scribed surface then quickly pulled off. The degree of adhesive loss is evaluated according to ASTM D-714 and D-3359. Panels are rated by the tester on a scale of 1-10, 10 being the best performers.

(3) SCAB-BLISTER TESTING: an accelerated corrosion test. Painted 4″ × 6″ panels are X-scribed (approximately 6″ per scribe covering an area of 3″ × 5″) using a fine blade. The panels are placed in an environmental chamber and exposed to salt spray and humidity as described in the following:

(a) 24-hour salt spray treatment (ASTM B-117)

(b) 96-hour exposure to humidity: eight hours at 100°F (38°C), 100% relative humidity followed by 16 hours at 65°F (18°C), 40% relative humidity. Four cycles per exposure.

Panels are rated on the degree of blistering/paint loss after ten weeks' exposure. A rating of 10 indicates no paint loss, 1 corresponds to 15 mm delamination.

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Development and Application Of Network Structure Models To Optimization of Bake Conditions For Thermoset Coatings

David R. Bauer and Ray A. Dickie
Ford Motor Company*

A physico-chemical model of crosslinked network formation has been applied to the evaluation and optimization of cure conditions for thermoset acrylic copolymer/melamine formaldehyde coatings in automotive assembly plant ovens. Cure response has been characterized in terms of an elastically effective crosslink density (C_{el}) calculated from a network structure model, a kinetic model of cure, and measured car body temperature profiles. Acceptability of cure has been assessed by comparing the calculated value of C_{el} with the range of values of C_{el} known to result in acceptable paint physical properties. Relationships between oven and paint parameters have been quantified using the model together with an optimization program. It has been found that the minimum bake time to achieve acceptable uniformity of paint cure is principally a function of the cure response (or "cure window") of the paint, the maximum allowed air temperature in the oven, and the minimum value of a heat transfer parameter on the car body. At constant bake time, more uniform paint cure can be achieved either by broadening the cure response of the paint or by increasing the minimum heat transfer parameter.

INTRODUCTION

The physical properties of automotive enamels are in large part determined by the crosslink structure developed in the paint films during the baking process. Enamels which are not cured sufficiently (undercured) are generally sensitive to humidity and solvents. In addition, they may be prone to chipping and cold cracking. Paints which have been baked excessively (overcured) exhibit intercoat adhesion failure. That is, subsequent coats (tutone or repair coats for example) do not adhere well to the coat that is overcured. Clearly, the physical properties of the paint depend on the bake time and temperature. The range of bake times and temperatures over which the paint has acceptable properties defines a "cure window." In practice a paint's cure window is determined by measuring a variety of physical properties for a large number of different bake times and temperatures. Such measurements provide useful information but do have several limitations. Although a wide variety of bake conditions are tested, these procedures cannot determine the cure response of a given paint to all the possible time-temperature profiles exhibited by different car bodies and ovens. The results of the physical tests are generally qualitative (e.g., pass or fail) rather than quantitative, and it is not possible to develop a scheme to predict cure response quantitatively for arbitrary bake schedules. Relationships between cure, paint formulation variables, and oven variables are often obscure, and process specifications must be developed for each specific paint.

A network structure model that allows calculation of network parameters from measured extents of reaction has been developed[1] based on the work of Macosko and Miller.[2,3] In studies in which calculated network parameters have been compared with physical property measurements on acrylic/melamine coatings, it has been found that for one such parameter, the elastically effective crosslink density (C_{el}), there is a well defined range of C_{el} over which acceptable cure is achieved.[4] Coatings

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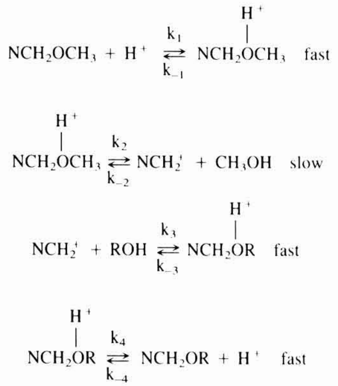
This paper is dedicated to Dr. Pierre Thirion on the occasion of his retirement. Reprinted from "Computers in Applied Polymer Science," T. Provder, Ed., *ACS Symposium Series*, with the permission of its publisher, American Chemical Society.

with values of C_{el} outside this range are either over- or undercured. Extents of reaction can be accurately measured for these coatings using infrared spectroscopy.[5-9] Based on these studies, a kinetic model for crosslinking with hexamethoxymethylmelamine has been proposed.[7] In this paper, the kinetic model and the network structure model are combined to provide a method for calculation of cure response for arbitrary bake oven profiles. The cure response of low and high solids paints to typical assembly bake ovens are determined. Oven optimization schemes that use these models together with the nonlinear optimization program (SIMPLEX)[10] to determine tradeoffs between paint and process parameters are described. In the sections that follow the kinetic and network structure models are described, results on model validation are presented, the important formulation and process variables are discussed, the optimization strategy is described, and finally the results and implications of the models are discussed.

MODEL DEVELOPMENT AND VALIDATION

Kinetic Model

All of the coatings used in this study are hydroxy functional acrylic copolymers crosslinked with melamine formaldehyde crosslinkers. The chemistry of crosslinking with melamine formaldehyde crosslinkers has been discussed in detail elsewhere.[5,11] The type and rate of the reactions depend primarily on the structure of the melamine. Fully alkylated melamines (e.g., hexamethoxymethylmelamine) undergo primarily a single reaction: the reaction of alkoxy groups with hydroxy groups on the polymer to form polymer-melamine crosslinks. The reactions of partially alkylated melamines are more complex. Formation of both polymer-melamine crosslinks and melamine-melamine crosslinks occurs. Although extents of reaction of coatings crosslinked with partially alkylated melamines have been measured,[5,6] no kinetic model that adequately describes the kinetics of crosslinking of partially alkylated melamines has been developed. A kinetic model of crosslinking in hexamethoxymethylmelamine based on the mechanism proposed by Blank[11] has been developed by Bauer and Budde.[7] The mechanism is as follows:



$$NCH_2OCH_3 + H^+ \underset{k_{-1}}{\overset{k_1}{\rightleftarrows}} NCH_2\overset{H^+}{\overset{|}{O}}CH_3 \quad \text{fast}$$

$$NCH_2\overset{H^+}{\overset{|}{O}}CH_3 \underset{k_{-2}}{\overset{k_2}{\rightleftarrows}} NCH_2^+ + CH_3OH \quad \text{slow}$$

$$NCH_2^+ + ROH \underset{k_{-3}}{\overset{k_3}{\rightleftarrows}} NCH_2\overset{H^+}{\overset{|}{O}}R \quad \text{fast}$$

$$NCH_2\overset{H^+}{\overset{|}{O}}R \underset{k_{-4}}{\overset{k_4}{\rightleftarrows}} NCH_2OR + H^+ \quad \text{fast}$$

Analysis assuming steady-state kinetics of the above reactions results in the following expression for the rate of disappearance of polymer hydroxy functionality:

$$[ROH] = \frac{-[H^+]K''\{k_3k_2[ROH][NCH_2OCH_3] - k_{-2}k_{-3}[CH_3OH]([ROH^\circ] - [ROH])\}}{k_3[ROH] + k_{-2}[CH_3OH]} \quad (1)$$

Several assumptions were made in order to analyze kinetic data in terms of this expression.[7] First it was assumed that $k_{-2} = k_3$, $k_2 = k_{-3}$, and $k_1/k_{-1} = k_{-4}/k_4$ ($= K''$). Second it was assumed that the rate constants were independent of the extent of reaction, i.e., that all six functional groups were equally reactive and that the reaction was not diffusion controlled. The concentration of polymer hydroxyl function-

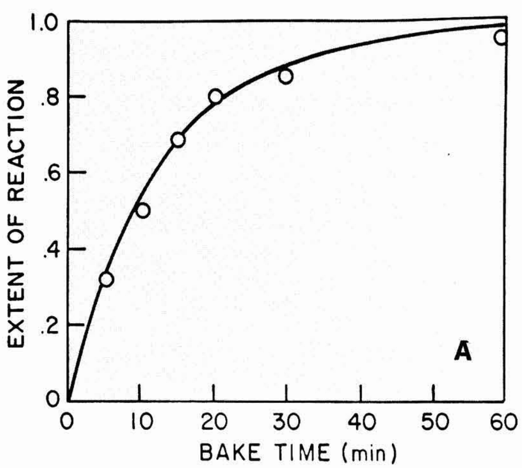


Figure 1a—Experimental (○) and calculated (——) extent of reaction vs bake time at 125°C and a PTSA concentration of 3.8 × 10^{-3} M

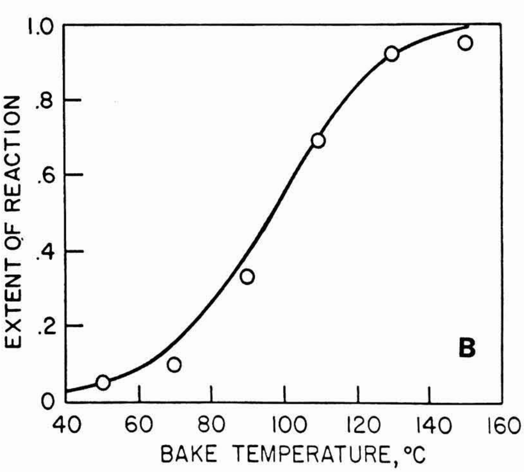


Figure 1b—Experimental (○) and calculated (——) extent of reaction vs bake temperature at a constant bake time of 20 min and a PTSA concentration of 5.8 × 10^{-3}M

ality was determined experimentally using infrared spectroscopy as described elsewhere.[7] A major unknown is the instantaneous concentration of methanol. Fittings to the kinetic data were made with a variety of assumptions concerning the methanol concentration. The best fit was achieved by assuming that the concentration of methanol was initially constant but decreased at a rate proportional to the concentration of residual polymer hydroxy groups towards the end of the reaction. As discussed elsewhere,[7] this is physically reasonable since at high extents of reaction, the rate of consumption of polymer hydroxyl decreases; thus the rate of production of methanol also decreases and the concentration of methanol in the film can be expected to decrease as well. The values of the parameters describing methanol concentration depended on the ratio of methoxy to hydroxy. In the coatings examples that follow, the ratio of methoxy to hydroxy was 1.5 to 1; for this ratio, the best fit to the kinetic data was obtained by assuming that the methanol concentration remained constant up to a hydroxy conversion of 67%. (Typically, values of the methoxy to hydroxy range from 1.5 to 2.5. The value of 1.5 was used in this work in order to minimize the effects of side reactions such as condensation of leftover methoxy groups. The effect of this restriction on the calculated results is, however, minor.) With these assumptions, equation (1) can be integrated to yield, for $p_A = 0$ to 0.67:

$$Kt = -0.5\ln(p_A^2 - 2.64p_A + 1.49) + 0.17\ln[(1.635 - 2p_A)/(3.645 - 2p_A)] + 0.34 \quad (= SK) \tag{2a}$$

and for $p_A = 0.67$ to 1.00:

$$Kt = -\ln(1.49 - 1.45p_A) + 0.22 \quad (= SK) \tag{2b}$$

where p_A is the fractional extent of reaction of hydroxy groups, $K = [H^+]K''k_2$, and t is the reaction time. The fit of equation (2) to the experimentally determined extent of reaction of polymer hydroxyl groups as a function of time (at constant temperature) is shown in *Figure* 1a. From this data, the value of the rate constant K can be determined. K has been measured as a function of temperature and found to fit an Arrhenius expression with an activation energy of 12.5 Kcal/mole.[7] A comparison of experimental and calculated extent of reaction vs temperature (at constant reaction time) is shown in *Figure* 1b. The rate constant K is proportional to catalyst level[7] and thus can be adjusted by changing the catalyst level so that optimum cure is achieved under standard fixed bake conditions. Considering the assumptions in the model, the agreement between experimental and predicted extents of reactions is excellent. The fits in *Figure* 1 are to the idealized conditions of either constant bake temperature or constant bake time. The extent of reaction for arbitrary bake profiles can be determined from equation (2) and the temperature dependence of K. In the present study, the extent of reaction has been determined using an incremental isothermal state approximation: the bake profile has been broken into a sequence of constant temperature intervals, K has been calculated for each interval, the values of KΔt have been summed over the bake cycle to yield a dimensionless parameter SK, and this parameter and equation (2) have been used to determine p_A. The calculation of KΔt can, of course, also be handled as an integration over time if an appropriate representation of the temperature history as a function of time is available.

Network Structure Model

The extent of reaction together with the hydroxy equivalent weight determines the number of chemical crosslinks formed during cure. The extent of reaction does not, however, correlate well with such physical measurements of cure as solvent resistance and intercoat adhesion.[1] It is found experimentally that coatings based on low molecular weight resins ("high solids" coatings) require higher levels of chemical crosslinking than do conventional coatings based on higher molecular weight resins ("low solids" coatings).[1] The main reason for this is that a large fraction of the chemical crosslinks formed in the high solids coating are simply building up the molecular weight of the starting materials. To develop a parameter which correlates with physical measures of cure it is necessary to devise a counting scheme which counts only "effective" crosslinks. Such schemes have long been of interest in, for example, studies of rubber elasticity; a network chain is considered to be elastically effective if its ends are effective crosslinks (i.e., crosslinks from which three or more chains lead out to the infinite network, to the sample surface).[3] The elastically effective crosslink density C_{el} has been found to correlate well with physical measures of paint cure.[1,4] Calculation of C_{el} is based on the probabilistic network model of Miller and Macosko;[2,3] expressions have been derived for calculation of C_{el} in coatings crosslinked with fully and with partially alkylated melamines. Only the model for the fully alkylated melamine is used here. Since the model has been described in detail elsewhere,[1] only a summary is presented here.

The model requires as input the extent of reaction and the distribution of functionality on the polymer and crosslinker. The extent of reaction used in the network structure model can be measured or calculated from a kinetic model. It is assumed that the melamine crosslinker is six functional and that all six groups are equally reactive; ring formation is ignored. The distribution of hydroxy functionality on the polymer is calculated for a polymer of given molecular weight and hydroxy equivalent weight assuming random copolymerization and a most probable molecular weight distribution. (The calculation could certainly be generalized to account for both non-random polymerization and different molecular weight distributions, but this was not necessary in the present study as the molecular weight distributions of the polymers of interest were very close to most probable.) The results are expressed in terms of the number fraction of polymers with I hydroxy groups on the chain, $X_n(I)$. In practice, the value of $X_n(I)$ is most important for low values of I since polymers with low functionality have the highest proportion of ineffective crosslinks. The Macosko formalism calculates the probability that looking out from a given group, Z, is a finite chain. This probability is denoted $P(F_Z^{out})$. If A denotes hydroxy groups on the polymer, B denotes methoxy groups on the melamine, and ALK is the ratio of methoxy to hydroxy, then the

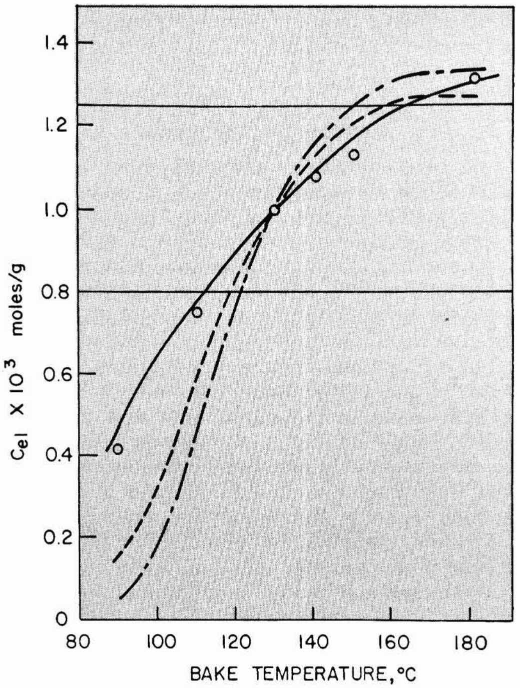


Figure 2—Elastically effective crosslink density vs bake temperature for a 17 min bake. Low solids: (○) experimental values, (——) model values; High solids 1: (-----); High solids 3: (–·–·–)

following expressions can be derived for $P(F_A^{out})$ and $P(F_B^{out})$:

$$P(F_A^{out}) = 1 - p_A + p_A P(F_B^{out})^5 \tag{3a}$$

$$P(F_B^{out}) = 1 - p_A/ALK + (p_A/ALK)(1/X)\sum_{I=1} IX_n(I)P(F_A^{out})^{I-1} \tag{3b}$$

where $X = \Sigma IX_n(I)$. A computer program using Newton's method has been written to solve for $P(F_A^{out})$ and $P(F_B^{out})$. For a crosslink to be elastically effective, there must be at least three independent paths out to the infinite network. The quantity $1 - P(F_Z^{out})$ is the probability that a single group on Z leads out to the infinite network. To calculate C_{el} it is necessary to modify this probability by the probability that there are at least two other paths out to the infinite network. This is just 1 − (the probability that there is either no other path or that there is only one additional path). Thus, C_{el} is given by the following expression:

$$\begin{aligned} C_{el} = {} & (1/2Q)\{[1 - P(F_A^{out})](1/X)\sum_{I=3} IX_n(I)\{1 \\ & - P(F_A^{out})^{I-1} - (I\text{-}1)[1 - P(F_A^{out})]P(F_A^{out})^{I-2}\} \\ & + ALK[1 - P(F_B^{out})][1 - P(F_B^{out}) - 5[1 - P(F_B^{out})]P(F_B^{out})^4]\} \end{aligned} \tag{4}$$

where Q is the hydroxy equivalent weight of the resin (including crosslinker); this is a special case of equation (A6) of Ref. (1) with g = 6 and h = 0.

Table 1—Paint Parameters

Parameter	Low Solids	High Solids 1	High Solids 2	High Solids 3
Acrylic M_n	8500	4000	3000	2000
Melamine functionality	10	6	6	6
Methoxy:hydroxy ratio	1.5	1.5	1.5	1.5
Hydroxy equiv. wt. of resin	760	750	700	650
Activation energy	8	12.5	12.5	12.5
Cure window	50	40	35	30

C_{el} has been found to correlate with physical measures of cure for a variety of coatings independent of polymer molecular weight and melamine crosslinker type. There exists a range of C_{el} around an optimum value of 1.0×10^{-3} moles/g for which acceptable cure is achieved.[4] If C_{el} is below about 0.8×10^{-3} moles/g, the coatings tend to be humidity sensitive or otherwise undercured. As C_{el} decreases from 0.8×10^{-3}, underbake problems become increasingly severe. Coatings with C_{el} above 0.8×10^{-3} do not exhibit underbake problems. Coatings whose value of C_{el} is greater than 1.25×10^{-3} moles/g typically exhibit intercoat adhesion failure. The boundary between coatings acceptably cured and overbaked coatings is remarkably sharp.[4] All coatings studied with a value of C_{el} greater than 1.27×10^{-3} exhibited severe intercoat adhesion failure while those with a value less than 1.24×10^{-3} had no failure.

Values of C_{el} can be calculated for arbitrary bake histories for arbitrary coatings by combining the kinetic model with the network structure model. Four coatings were considered in the current study: one, a conventional low solids paint formulated with a butylated melamine crosslinker, serves essentially as a control for evaluation of three hypothetical high solids formulations based on hexamethoxymethylmelamine. The kinetic model was developed for crosslinking with hexamethoxymethylmelamine and is not directly applicable to the butylated melamine crosslinker. There is no practical kinetic model for crosslinking with this particular melamine currently available. To calculate C_{el} for this coating as a function of bake history, the parameters used in the kinetic and network structure models were modified empirically. Extents of reaction for the low solids coating were measured spectroscopically as a function of a bake temperature at constant bake time. These extents of reactions were used in the general network structure model of Ref. (1) to determine experimental values of C_{el} for this coating. The results are shown in *Figure* 2. The value of the activation energy was modified in the kinetic model. In the network structure model, the value assumed for the functionality of the melamine was increased (to reflect the fact that butylated melamines are polymerized) and the assumed hydroxy equivalent weight was adjusted so that the calculated values of C_{el} matched as closely as possible the experimental values. The values of the parameters used are given in *Table* 1. The agreement between the experimental and calculated values of C_{el} is excellent. The data shown in *Figure* 2 are for a constant bake time of 17 minutes. The upper and lower limits on C_{el} define a cure window. The cure window for the low solids coating is 50°C. The model was further tested by measuring extents of reaction and temperature profiles for samples attached to different parts of a car body which passed through a pilot plant oven. This simulation tested the model under conditions where the substrate temperatures were far from constant. As shown in *Table* 2, the agreement between the experimental and calculated values of C_{el} is again excellent.

As has been discussed elsewhere, high solids coatings tend to have narrower cure windows than low solids coatings.[4] They also tend to be more sensitive to batch-to-batch variations which tends to further narrow the cure window. For this study, coating parameters were chosen to give cure windows at constant bake time of from 30 to 40°C (see *Figure* 2). All coatings were assumed to be crosslinked with hexamethoxymethylmelamine with a methoxy to hydroxy ratio of 1.5. The rate constant K (catalyst level) was adjusted so that an extent of reaction of 85% was achieved after 17 minutes at 130°C. The cure window was adjusted by varying the molecular weight of the polymer (lowering the molecular weight reduces the cure window). The hydroxy equivalent weight was adjusted so that $C_{el} \times 1.00 \times 10^{-3}$ at 85% conversion. The parameters used are summarized in *Table* 1. This choice of coatings—though admittedly somewhat arbitrary—allows the effect of narrowing the cure window on paint cure uniformity, and hence on process parameters, to be determined independently of details of paint chemistry and formulation.

CURE IN ASSEMBLY OVENS

Heat Transfer

Typical studies of cure kinetics in the laboratory involve measurements of cure at constant temperature and constant time (for example *Figure* 2). Cure of painted car bodies in assembly ovens is considerably more complex. The cross section of a typical assembly oven is shown in *Figure* 3. Oven air temperatures can be controlled independently in several zones.[3-5] The complex air flow patterns lead to variations of air temperature over the cross section as well as down the length of the oven. Paint cure is controlled by the substrate surface temperature rather than the air temperature. Thus heat transfer between the air and the surface of the car body is important. Variables affecting the rate of heat transfer include air velocity and substrate size, shape, and composition. Typically, exposed sheet metal heats up rapidly while more massive metal components such as pillars heat up more slowly. Thus heat transfer parameters vary from place to place on a given car body, from car body to car body, and from oven to oven. Assuming that local temperature and air velocity changes are small during a short time interval, Δt, a general expression for the transient heating of a conductive substrate in a hot air stream may be written in the following form:

$$T(t + \Delta t) = Ta - [Ta - T(t)]e^{-Z\Delta t} \qquad (5)$$

where T(t) is the car body temperature at time t, Ta is the oven air temperature, and Z is a heating rate constant. Data relating car body temperatures to oven air temperatures are available from routine checks on oven performance in which car bodies with thermocouples attached are passed through the ovens. Typical thermocouple locations are shown in *Figure* 4. From this data and equation (5), the heating rate constant can be derived for different car body positions. Due mainly to the fact that oven air temperatures vary somewhat over the crossection of the oven, the standard deviation of each individual measurement of Z is rather large. Nevertheless, the data are reasonably consistent from run to run. It is found that each car body has a range in heating rate constants. The minimum heating rate constant, Z_{min}, varies from $0.13 - 0.2\ min^{-1}$ while the maximum heating rate constant, Z_{max}, varies from $0.45 - 0.65\ min^{-1}$.

Table 2—Model Verification for Low Solids Coating

Body Position	$C_{el} \times 10^3$ moles/g Experimental	Model
Center roof	1.09	1.11
Center hood	1.07	1.05
Fender	1.10	1.06
Back post	0.97	1.01
Rocker panel	0.98	0.97

The heating rate constants determine the response of the car body to oven air temperature. Even if the oven air temperature was constant, different parts of the car would see different temperature profiles since they have different heating rate constants. The car body part with the smallest heating rate constant would be the part that would tend to be underbaked while the part with the highest heating rate constant would tend to be overbaked. There are several other process variations which can affect cure response. For example, occasionally it is necessary to stop the conveyor with cars still in the oven. If the stoppage is at all lengthy, the oven temperature is reduced. If the stoppage is short, no attempt can be made to reduce temperatures. Calculations of the effect of such stoppages on final crosslink density for typical temperature profiles reveals that the effects are small for the control coating. A more important variation is that of multiple bakes. An enamel coating will receive more than one bake if it is part of a tutone car or if it needs repair.

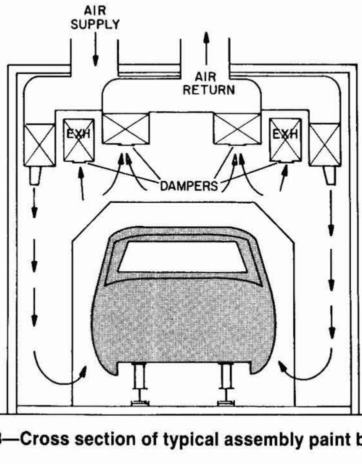


Figure 3—Cross section of typical assembly paint bake oven

Thus different coats on the same car can receive different numbers of bakes. This places a severe constraint on the cure window of the paint since the paint must achieve a crosslink density of at least 0.8×10^{-3} moles/g after a single bake at car body locations with a low heating rate constant and yet must not be overbaked (i.e., C_{el} less than 1.25×10^{-3} moles/g) after several bakes. It is known that the control coating passes all required performance specifications even after three passes (a worst case) through typical ovens. Calculations using the modified kinetic model yield values for C_{el} that are generally less than 1.25×10^{-3} moles/g after two passes but that are slightly greater than this value after three passes. Considering the many assumptions of the calculation, this does not seem a serious discrepancy. For the purposes of the model, the value of C_{el} calculated after two passes through the oven was used to evaluate overbake.

The car body temperature data used to calculate heating rate constants were also used as input data in the kinetic and network structure models to evaluate the cure response of the different paints to current assembly ovens. It was found (as expected from the physical property data) that the conventional low solids coating generally had acceptable cure performance. That is, there were few underbakes predicted for one pass through the ovens and few overbakes for two passes through the ovens. The few calculated over and underbakes that did occur were not severe (i.e., did not deviate greatly from the maximum and minimum allowed crosslink densities). When the high solids coatings were tested with the same data set, however, it was found that the number and severity of the under and overbakes increased dramatically as the cure window of the coating decreased. To achieve an acceptable uniformity of cure in these narrow cure window coatings, some modification in process was found to be required. A discussion of the tradeoffs and options is given in the next section.

Oven Optimization

The results of the calculation of C_{el} for the different coatings using the typical oven temperature profiles raises several questions:

- Can oven performance be improved by adjustments in the oven air temperature?
- Are there specific oven strategies which would improve performance?
- Quantitatively, what are the tradeoffs between cure window, paint cure uniformity, oven throughput, and heating rate constant?

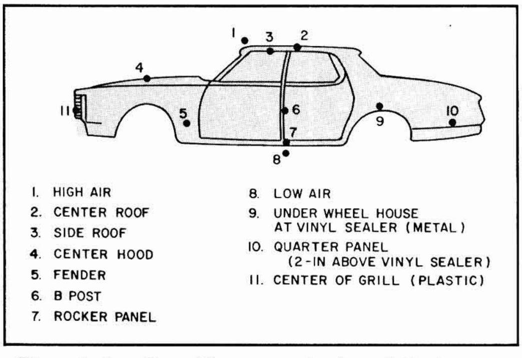


Figure 4—Location of thermocouples for paint bake oven survey

To answer these questions, the kinetic and network structure models were used in conjunction with a nonlinear least squares optimization program (SIMPLEX) to determine cure response in "optimized ovens." Ovens were optimized in two different ways. In the first, the bake time was fixed and oven air temperatures were adjusted so that the crosslink densities were as close as possible to the optimum value. In the second, oven air temperatures were varied to minimize the bake time subject to the constraint that all parts of the car be acceptably cured. Air temperatures were optimized for each of the different paints as a function of different sets of minimum and maximum heating rate constants.

In general, the SIMPLEX program adjusts variables subject to supplied constraints to minimize a given object function. The object function must be an explicit function of the variables. In the case where paint cure uniformity was optimized, the oven was divided into three zones and the variables were the three oven zone air temperature settings. Temperatures within the zone were interpolated from the two nearest zone settings. It was assumed that the oven air temperature was constant across a cross section of the oven. The oven air temperatures were constrained to be less than a given maximum air temperature. The maximum is in practice chosen to prevent degradation of paint or plastic components passing through the oven. Unless otherwise noted, the maximum air temperature was 149°C. For a given paint, there is a direct relationship between crosslink density, extent of reaction, and the sum of $K\Delta t$ (SK). Thus, minimizing the difference in crosslink density is the same as minimizing the difference in SK. For each paint there are values of SK that correspond to the minimum and maximum acceptable values of C_{el} (SK_{min} and SK_{max}) and to the optimum value of C_{el} (SK_{opt}). These values are of course different for each paint. For a given set of air temperatures, the lowest value of SK (SK_{low}) is determined using Z_{min} to calculate body temperatures while the highest value of SK (SK_{high}) is determined using Z_{max}. The value of SK_{high} is calculated assuming two passes through identical ovens. Paint cure quality is maximized when SK_{low} and SK_{high} are as close as possible to SK_{opt}. The specific object function that was used was:

$$OBJ = (SK_{low} - SK_{opt})^2 + (SK_{high} - SK_{opt})^2 \qquad (6)$$

To insure that there were as few over and under bakes as possible, the object function was modified so that it increased rapidly when SK_{low} was less than SK_{min} or when SK_{high} was greater than SK_{max}.

The results of this optimization are shown in *Figure* 5. Differences in C_{el} of less than 0.45×10^{-3} moles/g are acceptable while differences greater than that imply that a part of the car body is either undercured, overcured, or both. The control low solids coating is found to achieve acceptable cure in optimized ovens as long as Z_{min} is

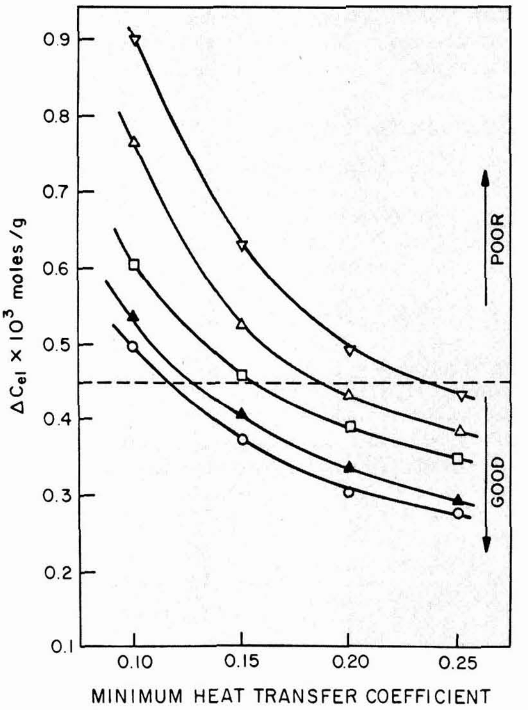


Figure 5—Paint cure uniformity vs minimum heating rate constant for the low solids paint (○), high solids 1 (□), high solids 2 (△), and high solids 3 (▽). The open symbols are for a 17 min bake and the closed symbols are for a 25 min bake

greater than 0.12 min^{-1}. Comparison of the paint cure uniformity of the low solids control in optimized ovens with actual assembly plant data on ovens with similar values of Z_{min} reveal that although the optimized oven does have better cure uniformity, the differences are not great. For example, for a Z_{min} of 0.2 min^{-1}, the assembly oven achieved a ΔC_{el} of 0.35 vs 0.3×10^{-3} moles/g for the optimized oven. In addition, analysis of the optimized air temperatures revealed no specific strategy to optimize oven performance aside from carefully controlling average air temperatures. Values of ΔC_{el} decrease with increasing cure window and increasing Z_{min}. Acceptable paint cure uniformity was achieved in a 17 minute bake for the paint with a cure window of 35°C only if Z_{min} was greater than 0.2 min^{-1}. The results are not very sensitive to the value of Z_{max}. Values of ΔC_{el} increase with decreasing cure window because a given variation in temperature profiles results in a wider disparity in crosslink density for the narrower cure window paints. Values of ΔC_{el} decrease with increasing Z_{min} since the car body temperature profiles become more uniform. Another way to increase car body temperature uniformity (and thus decrease ΔC_{el}) is to increase the bake time. For example, increasing the bake time from 17 minutes to 25 minutes essentially compensates for a decrease in cure window of 50° to 35°C.

The tradeoff between bake time and cure performance can be seen more directly by holding paint cure uniformity constant while minimizing the bake time. Again the variables are the oven zone air temperatures. In this case, bake time is another variable. The constraints are that SK_{low} be greater than or equal to SK_{min} and that SK_{high} be less than or equal to SK_{max}. Since these are not specific constraints on the air temperatures, they must be incorporated into the object function. This is fairly straightforward once it is recognized that minimum bake times are achieved when SK_{low} is as close as possible to SK_{min} and SK_{high} is as close as possible to SK_{max}. Put another way, minimum bake times are achieved when ΔC_{el} is less than, but as nearly equal as possible to, 0.45×10^{-3} moles/g.

The results of the minimization of bake time are shown in *Figure* 6. There is a direct tradeoff between bake time, cure window, and Z_{min}. Narrowing the cure window increases the minimum bake time required for acceptable cure uniformity. Increasing Z_{min} allows the bake time to be shorter. Narrow cure window paints require more uniform car body temperatures; this can only be achieved by increasing the bake time or Z_{min}. Somewhat surprisingly, the constraint on maximum air temperature affects the minimum bake time only for paints with wide cure windows and for car bodies with relatively high values of Z_{min}. Considering the typical range of Z_{min} normally encountered, a bake time of 17 minutes is just long

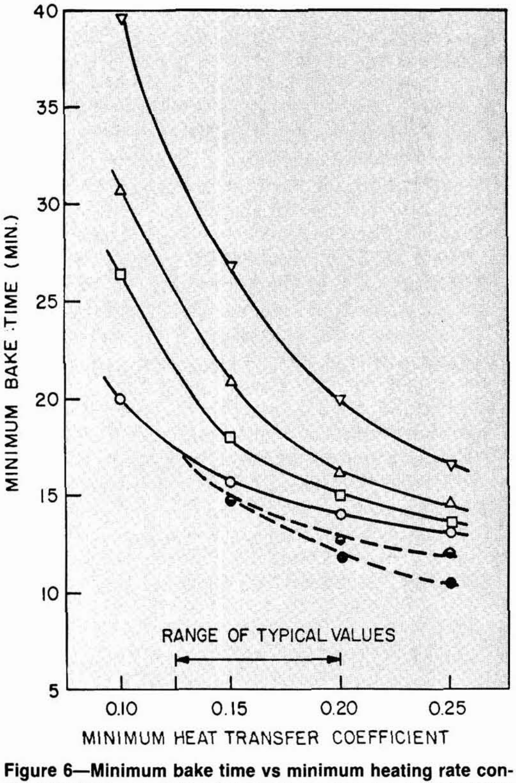


Figure 6—Minimum bake time vs minimum heating rate constant for the low solids paint (○), high solids 1 (□), high solids 2 (△), and high solids 3 (▽). The open symbols are for a maximum air temperature of 149°C. The half filled circles are for a maximum air temperature of 157°C and the filled circles are for a maximum air temperature of 166°C.

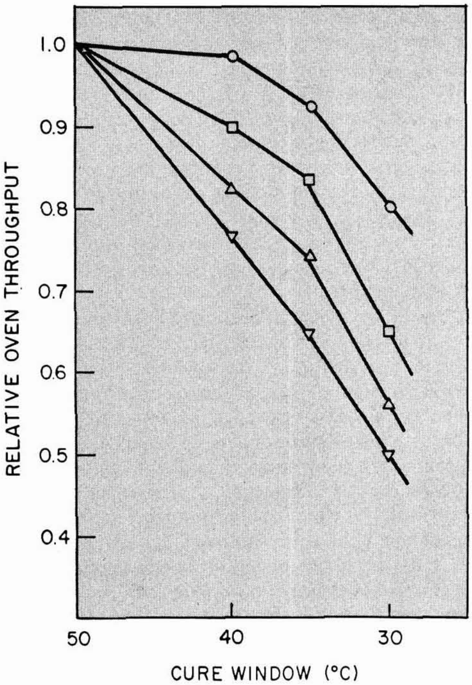


Figure 7—Relative oven throughput vs paint cure window for values of Z_{min} of 0.25 (○), 0.2 (□), 0.15 (△), and 0.10 min^{-1} (▽)

enough to provide acceptable paint cure for the conventional low solids enamel. It is possible to improve oven productivity (i.e., shorten the bake time) for this coating by increasing the lowest value of Z_{min} and raising the maximum allowed air temperature. For example, if oven air flows could be adjusted so that Z_{min} was at least 0.2 min^{-1}, the bake time could be reduced to 14 minutes while still maintaining cure quality. A further reduction to 12 minutes would be possible if the maximum air temperature could be increased to 166°C. Coatings with narrower cure windows than the control can not be acceptably cured even if the air temperatures are optimized. Longer bake times or improvements in heat transfer would be required to acceptably cure the narrow cure window paints. The tradeoff between paint cure window and oven productivity is shown in *Figure* 7. Assuming a fixed oven length so that longer bake times require slower line speeds, it can be seen that a small decrease in paint cure window can be tolerated without loss of productivity if the minimum heating rate is high. If, however, the minimum heating rate is low, any narrowing of the cure window results in a loss of oven productivity.

CONCLUSION

A network structure model has been developed from which a parameter that correlates well with physical measures of paint cure can be calculated. This model together with a kinetic model of crosslinking as a function of time and temperature has been used to evaluate the cure response of enamels in automotive assembly bake ovens. It was found that cure quality (as measured by the number and severity of under and overbakes) was good for a conventional low solids enamel. These results are in agreement with physical test results. Use of paints with narrower cure windows is predicted to result in numerous, severe under and overbakes. Optimization studies using SIMPLEX revealed that narrow cure window paints can be acceptably cured only if the bake time is increased or if the minimum heating rate on the car body is increased.

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Aqueous Dispersions Of Crosslinked Polyurethanes

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The importance of aqueous polyurethane dispersions to the coating industry has grown steadily since their introduction into the marketplace. The development of these aqueous coating systems has been motivated primarily by environmental considerations. A variety of polyurethane dispersions have found acceptance in applications such as textile and nontextile coatings, leather finishing, adhesives, and glass fiber sizings. These commercial products are predominantly linear thermoplastic polyurethanes dispersed in water.

In the past, the development of aqueous dispersions of crosslinked polyurethanes has been complicated by problems related to high-viscosity intermediates and poor coalescence. Recently, however, this type of water-borne coating has been successfully prepared in a manner which overcomes these difficulties. The resulting aqueous dispersions of crosslinked polyurethanes form films and coatings with outstanding properties. The performance of these coatings is comparable in many ways to that obtained from two-component solvent-borne polyurethane coatings.

INTRODUCTION

Polyurethane (PUR) coatings are noted for their high performance. In general, they provide excellent chemical, solvent, and abrasion resistance, as well as outstanding toughness combined with good low-temperature flexibility. The highest level of this combination of properties is attained generally by two-component solvent-borne polyurethane coatings. These systems provide highly crosslinked coatings which cure under ambient conditions. They are useful for durable coatings on large substrates (e.g., airliners or bridges), which are often exposed to harsh environments and cannot be subjected to baking conditions. Two-component systems with a lower crosslink density are also of commercial interest. They exhibit outstanding properties and are used for coating flexible substrates (e.g., thermoplastic parts), which cannot withstand high baking temperatures.

Volatile organic solvents are used to dissolve two-component polyurethane coatings, fully-reacted lacquers, and moisture cures. The solvent vapors which are released upon curing can lead to environmental problems and flammability hazards. These problems, coupled with escalating solvent prices and governmental restrictions on vapor emissions, have led to an increased emphasis toward the development of high-performance water-borne polyurethane coatings.

AQUEOUS POLYURETHANE DISPERSIONS

An aqueous polyurethane dispersion is a binary colloidal system in which particles of polyurethane are dispersed in a continuous phase (water). The particle size (diameter) can be varied from approximately ten to five thousand millimicrons and has a direct impact on the stability of the dispersion. Dispersions with relatively large average particle size (greater than 1000 mμ) are generally unstable with respect to sedimentation. A smaller average particle size (less than 500 mμ) is more useful since such dispersions will be storage stable and have a high surface energy. This results in a strong driving force for film formation.

Aqueous polyurethane dispersions were introduced into the marketplace in the late 1960's. Since then, this class of polyurethane has enjoyed considerable interest, as documented in more than 1000 U.S. patents and numerous publications. Today, there are a variety of aqueous dispersions which have gained commercial status. They are basically one-component, fully-reacted, predominantly linear polymers, and, as such, have found

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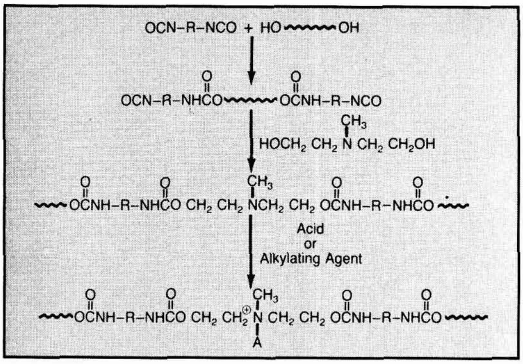

Figure 1—Preparation of cationic polyurethane ionomers

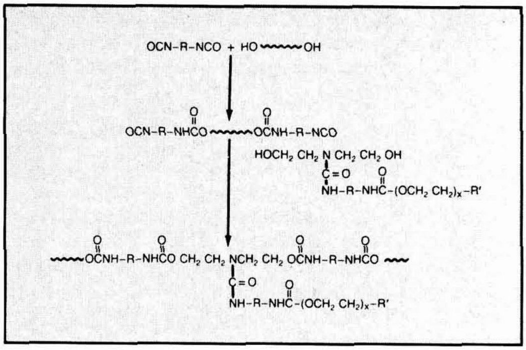

Figure 3—Preparation of a polyurethane with non-ionic hydrophilic components

applications in areas previously dominated by solventborne PUR lacquers. Some of these applications are listed in *Table* 1. In addition to their use as coatings, aqueous dispersions are utilized as adhesives on a variety of substrates.

Like most polymeric materials, conventional polyurethanes are not compatible with water. Therefore, they require special treatment and/or modification before dispersion in aqueous media will be possible. This is normally done by incorporating ionic groups into the polymer backbone. This special type of segmented polyurethane is called an ionomer.[1] The ionic centers are hydrophilic in nature and therefore function as internal (i.e., internal to the polymer) emulsifying agents. Polyurethane ionomers are self-dispersing and, under the proper conditions, form stable aqueous dispersion without the use of high shear force mixing or external dispersants. Both cationic and anionic groups have been utilized in the preparation of PUR ionomers.

Cationic polyurethane ionomers used in aqueous dispersions are generally prepared by incorporating tertiary amine functionality into the polymer. This is accomplished through the use of tertiary aminoglycol coreactants. Quaternization with an alkylating agent and/or protonation with a suitable acid results in the generation of the ionic group (*Figure* 1). Alternatively, a tertiary nitrogen-containing diamine or a bis-hydroxyalkyl-sulfide could be substituted for the aminoglycol. Aqueous dispersions prepared from cationic polyurethane ionomers are not used extensively at this time.

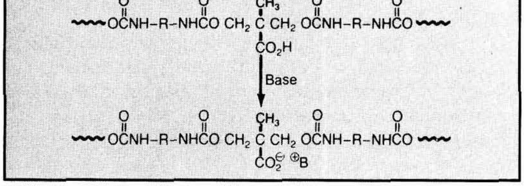

Figure 2—Preparation of anionic polyurethane ionomers

Anionic dispersions are commercially predominant. In the United States, they are commonly prepared from carboxylate group-containing polyurethane ionomers. Dimethylolpropionic acid is used extensively as the source of carboxylic acid functionality. The acid group is subsequently neutralized with a base (e.g., tertiary amines), resulting in the formation of an anionic polyurethane ionomer (*Figure* 2). Diols or diamines bearing sulfonate groups can also be used as ionic raw materials for the preparation of these charged polyurethanes. Coatings derived from sulfonate group-containing dispersions exhibit excellent hydrolytic stability, while ionomers prepared with carboxylates provide films which tend to show better water resistance.

Another approach to internally emulsified polyurethane employs hydrophilic polyether chain segments to aid in the dispersing process.[2] Polyethylene oxide chains of moderate molecular weight (200-4000) are attached to the polymer as lateral groups or chain termini (*Figure* 3).

Table 1—Typical Application Areas of Aqueous Dispersions

Coatings for:

Flexible Substrates
- Textiles
- Vinyl
- Leather
- Rubber
- Paper
- Film, Foil

Product Finishing
- Business Machine Housings
- Plastic Parts
- Metal Primers

Wood
- Furniture
- Flooring
- Paneling
- Sealers

Glass Fibers

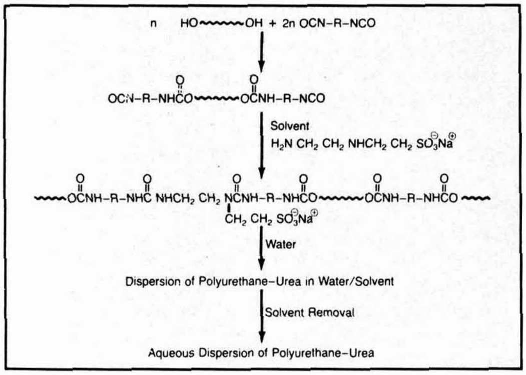

Figure 4—Solution process

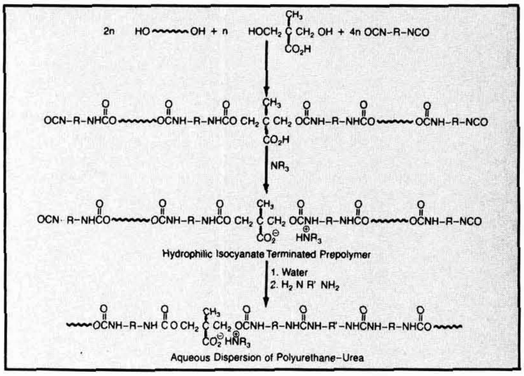

Figure 5—Prepolymer mixing methods

The reactants used to provide the lateral segments can be difunctional in hydroxyl or isocyanate groups. The chain-terminating segments are usually monofunctional ethoxylated alcohols. Aqueous dispersions prepared from this type of internally emulsified polyurethane are referred to as non-ionic dispersions.

PREPARATION PROCEDURES

Several processes have been described for the preparation of aqueous polyurethane dispersions.[3] The conditions and techniques used are of technical importance since they affect the polymer structure and the physical characteristics of the dispersion. In turn, these characteristics can influence the properties of the resulting coating.

Solution Process

A fully-reacted high molecular weight polyurethane modified with hydrophilic groups is prepared from an isocyanate functional prepolymer. The final molecular weight buildup is accomplished in an inert solvent which is diluted with water. As more water is added, a phase inversion occurs, water becomes the continuous phase, and a dispersion is formed. The solvent is then removed by distillation (*Figure* 4). The result is a solvent-free high molecular weight aqueous dispersion of a polyurethane-urea. This process is easily performed and very reproducible since the polymer formation is accomplished in a homogeneous solution. It is, however, limited to linear polyurethanes which have been modified with hydrophilic groups. This process also suffers from a low reactor volume yield due to the large quantities of solvent which are used.

Prepolymer Mixing Process

The prepolymer mixing process avoids the use of large amounts of solvents as necessary in the solution process. An isocyanate-terminated prepolymer which has been modified with hydrophilic groups is prepared initially. This prepolymer is dispersed by the addition of water and the use of high-speed agitation. External emulsifiers and high shear forces are not required. The viscosity of the

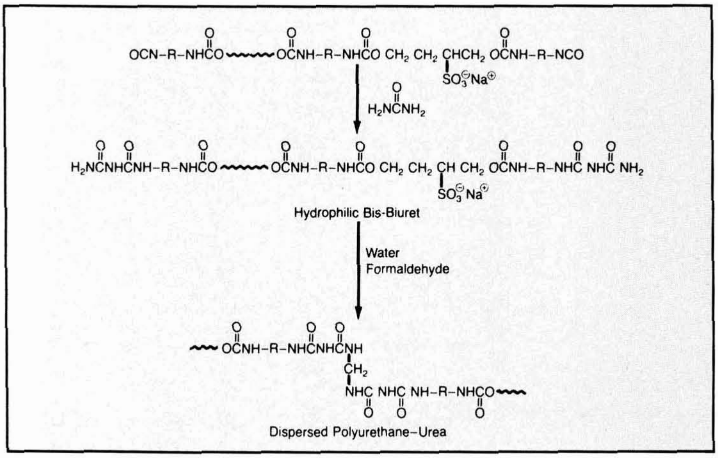

Figure 6—Hot melt process

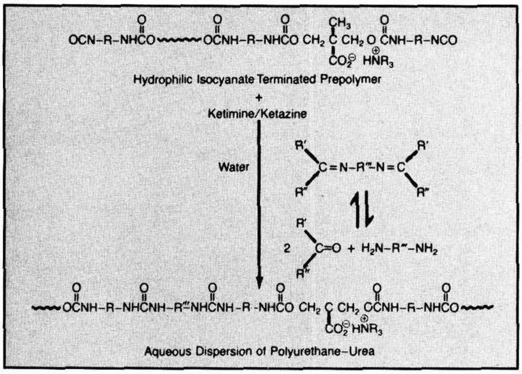

Figure 7—Ketimine/ketazine process

prepolymer, however, is critical and must be limited or the dispersing step will be difficult or impossible. Therefore, some solvent may be required to insure that the viscosity is in a workable range. Chain extension of the dispersed particles is usually accomplished with diamines. The chemistry of the process is illustrated in *Figure* 5.

Hot Melt Process

The hot melt process is a solvent-free method of preparing aqueous polyurethane dispersions. It combines the isocyanate polyaddition reaction, followed by an aminoplast polycondensation reaction. The first step is the synthesis of an isocyanate-terminated prepolymer containing hydrophilic groups. This is followed by capping of the prepolymer at elevated temperatures (≥ 130°C) with an excess of urea to form a biuret. After the product is dispersed in water, chain extension/crosslinking is accomplished by reaction with formaldehyde to form methylol groups and lowering of the pH to initiate the polycondensation reaction (*Figure* 6). Alternatively, crosslinking can also be accomplished by heating during or after film formation. Production of this type of dispersion requires powerful agitators, since even at temperatures around 100°C the viscosity of the prepolymer is usually high. Water-dispersed polyurethanes prepared by the hot melt method are generally branched and of lower molecular weight.

Ketimine/Ketazine Process

The ketimine process (*Figure* 7) is similar to the prepolymer mixing method (*Figure* 5), with one important difference. A blocked diamine is used as a latent chain extender. The blocked diamine, i.e., a ketimine, can be added to a hydrophilic isocyanate-terminated prepolymer without a reaction taking place. As water is added to disperse the mixture, the ketimine is hydrolyzed at a rate which is appreciably faster than the isocyanate reaction with water (*Figure* 7). The liberated diamine then reacts with the dispersed particles of polymer to give a chain-extended polyurethane-urea. The chain extension and dispersing step occur simultaneously and the viscosity increases steadily until a phase inversion (W/O→O/W) takes place. For this reason, powerful agitation and/or some co-solvent is often required. Dispersions prepared from this process can yield high-performance coatings.

A variation of the ketimine process uses ketazine as the latent chain extender. In this case, the ketazine hydrolyzes to hydrazine. Hydrolysis is slower as compared to that of a ketimine. This is an advantage when aromatic isocyanate prepolymers are used.

CROSSLINKING OF AQUEOUS POLYURETHANES

Although there are many quality dispersions available using the processes previously outlined, none can approach the performance level of two-component solvent-borne polyurethane coatings. The reason for this is that all commercially available aqueous PUR dispersions are predominantly linear thermoplastic polyurethanes dispersed in water. They specifically lack the crosslink density and high molecular weight obtainable from two-component solvent-borne polyurethane systems. As a re-

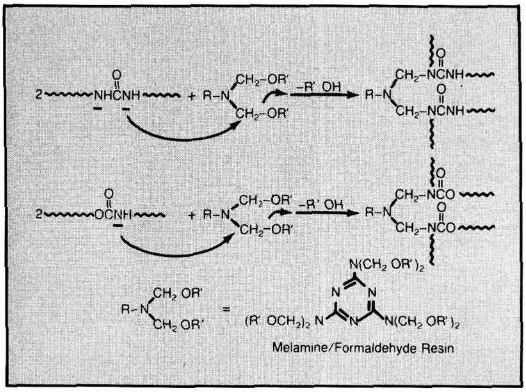

Figure 8—Melamine/formaldehyde crosslinking of a coating formed from an aqueous polyurethane dispersion

Table 2—Technical Data for Aqueous Polyurethane Dispersion XW-110 (E-761)

Solids content (% by weight)	35
Viscosity (mPa·s at 25°C)	130
pH	8.3
Freeze/thaw stability	Passes 5 Cycles
Elevated temperature storage (50°C)	Passes 30 Days
Charge	Anionic
Film properties	
Appearance	Clear
Tensile strength (psi)	6600
Elongation at break (%)	170
Yield modulus (psi)	5700
Modulus at 100% elongation (psi)	5200
Impact resistance (rev/dir, in./lbs)	160/160
Abrasion resistance (Wyzenbeek)	No visible wear
Hardness (shore D)	55
(pendulum, sec)	115
Drying time (3 mil wet thickness, 70°F, 30% RH.) through dry (minutes)	60

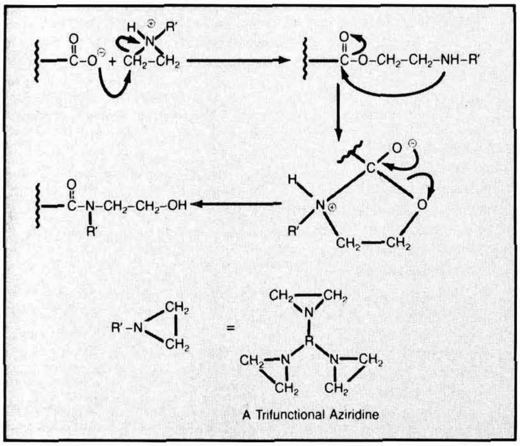

Figure 9—Polyaziridine crosslinking of a coating formed from an aqueous polyurethane dispersion

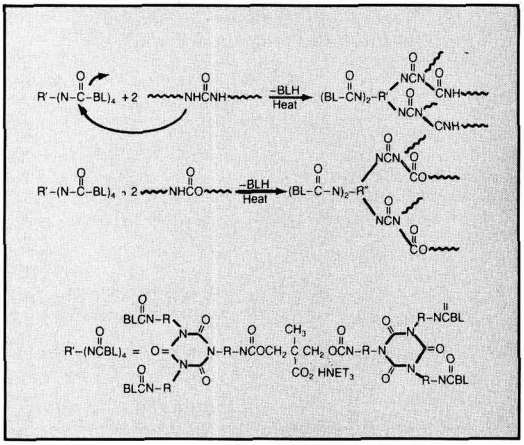

Figure 10—Crosslinking of a coating formed from an aqueous polyurethane dispersion with a polyisocyanate

sult, the water and solvent resistance of the films derived from these dispersions are relatively poor.

Improvements in the water and solvent resistance can be achieved by adding aqueous resins to the dispersion which provide crosslinking capability. Alkoxylated melamine/formaldehyde resins can be used in such a way. As the coating is cured at elevated temperatures, crosslinking occurs through the reaction of the methoxylated melamine resin with urea or urethane groups in the polymer (*Figure* 8). Carboxylic acid functionality, which is present in many anionic polyurethanes, can also be exploited for crosslinking through reaction with polyaziridines (*Figure* 9).[4] Relatively low temperatures are required to effectively cure a blend of polyaziridines with an aqueous dispersion. A relatively new development in aqueous crosslinkers is water-dispersible blocked polyisocyanates.[5] These isocyanate adducts can be blended with polyurethane dispersions. Crosslinks are formed at elevated temperatures when the blocking agents are displaced by reactive groups present in the dispersed polyurethanes. One example of a water-dispersible blocked isocyanate and the chemistry involved in its use is shown in *Figure* 10.

An alternative approach to using an external crosslinker, such as a melamine resin, would be to directly synthesize a crosslinked water-dispersible polyurethane. However, incorporation of the crosslinks before dispersing the polymer results in gel formation. Attempts to crosslink an already water-dispersed isocyanate-terminated ionomer using polyamines resulted generally in particles which precipitated and were isolated in the form of powders. In a few cases where stable dispersions were obtained, they lacked film-forming properties at ambient temperature.[6]

Recently, we prepared hydrophilically modified isocyanate-terminated prepolymers, which contained ionic groups as well as polyoxyethylene units, dispersed them in water and subsequently crosslinked the already dispersed particles with polyfunctional amines.[7] The amount of hydrophilic ethylene oxide polyether segments was in the range of 0.4-10 weight percent based on solid polymer. The average functionality of the amines used ranged

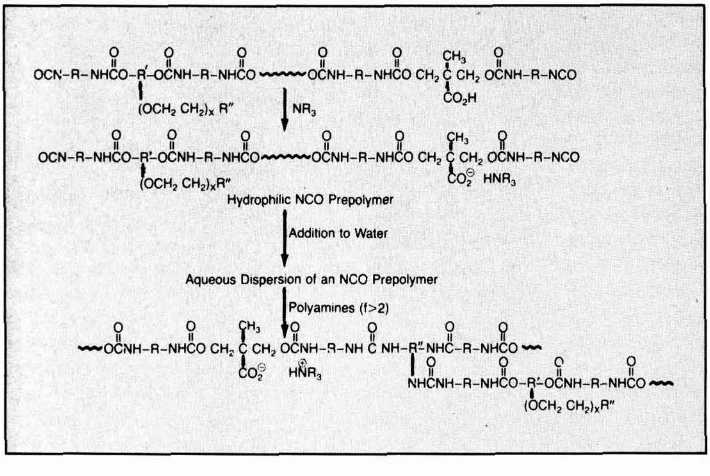

Figure 11—Preparation of crosslinked polyurethane in water

Table 3—Properties of Films Formed From Aqueous Polyurethane Dispersions

Dispersion	XW-104 (E-748)	Impranil DLN
Hardness (pendulum, sec)	45	30
Tensile strength (psi)	5800	3000
Elongation at break (%)	280	700
Modulus at 100% elongation (psi)	1600	200
Modulus at 200% elongation (psi)	3000	300
Set (%)	20	10
Volume solvent swell		
24 hr. immersion (%)		
Water	0	15
Isopropanol	73	52
2-Butanone	174	640
2 Ethoxyethyl acetate	146	392
Xylene	120	310
1,1,1-Trichloroethane	238	700

Table 4—Comparison of Film Properties for an Aqueous Dispersion of Crosslinked Polyurethane And a Two-Component Coating

	XW-110	Typical Two-Component Polyurethane Coating
Tensile strength (psi)	6600	4700
Yield modulus (psi)	5700	1200
Elongation at break (%)	170	110
Modulus at 100% elongation (psi)	5200	3000
Hardness (pendulum, sec)	115	180
Volume solvent swell		
24 hr. immersion (%)		
Water	0	0
Isopropanol	95	33
2-Butanone	146	95
2 Ethoxyethyl acetate	95	73
Xylene	73	73
1,1,1-Trichloroethane	120	95

from 2.2-4. This ionic/non-ionic hydrophilic modification resulted in stable dispersions with fine particle size, at an overall reduced hydrophilic group content. Surprisingly, these water-dispersed crosslinked polyurethanes showed excellent film-forming properties even at ambient temperatures.

Typical properties of these aqueous PUR-dispersions are:

(1) low overall hydrophilicity;
(2) tolerance to pH changes;
(3) elevated temperature stability;
(4) electrolyte stability;
(5) freeze/thaw stability; and
(6) mechanical stability.

The coatings prepared from dispersion of crosslinked polyurethanes show excellent film coalescence. In certain cases, however, some co-solvent is desirable to aid in film formation. The film-forming properties of these products are even more remarkable if one considers that the dispersed particles, as well as the resulting films, are insoluble in strong organic solvents (e.g., dimethylformamide). High levels of surface hardness and abrasion resistance can be achieved while retaining the valuable properties of elasticity and low-temperature flexibility. The technical data for an aqueous dispersion of crosslinked polyurethane (designated E-761) which exhibits many of these properties are shown in *Table* 2. A comparison of film properties illustrates the advantage of these aqueous crosslinked urethanes over similar dispersion of linear TPU's (*Table* 3). Even though the two products are of comparable hardness, the tensile properties and solvent resistance of the crosslinked system are superior. It is interesting to note that, by proper selection of starting material, a wide range of physical properties are accessible (compare E-748 to E-761, *Table* 2 and 3). In fact, the coating performance level of aqueous dispersions of crosslinked polyurethane can approach that of flexible two-component polyurethane coatings. A comparison of tensile properties and solvent resistance of E-761 and a typical two component flexible system supports this assertion (*Table* 4).

CONCLUSION

Most commercial PUR dispersions are predominantly linear thermoplastic polyurethanes dispersed in water. In general, films and coatings formed from these products show relatively poor water and solvent resistance. Improvements in these properties can be achieved by crosslinking a dispersed isocyanate prepolymer with polyfunctional amines. The polymer phase, chemically modified with ethylene oxide and ionic hydrophilic groups, will coalesce to high-quality polyurethane coatings. The performance of these coatings is comparable in some ways to that obtained from flexible two-component solvent-borne PUR coatings.

ACKNOWLEDGMENT

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Synthesis and Characterization Of Water-Soluble Phenolic Resins And Esters Based on Cardanol

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Water-soluble phenolic resins have been prepared from maleinized cardanol, the active phenolic constituent of cashew nut shell liquid (CNSL) by reaction with formaldehyde using acidic and basic catalysts. Phenolic esters and varnishes were prepared by reacting these phenolic resins with maleinized linseed oil fatty acids and maleinized linseed oil, respectively. The reaction product of resol from maleinized cardanol and maleinized linseed oil fatty acids was characterized by IR spectroscopy. The physical characteristics of the resins, esters, and varnishes were determined and the film properties of brush, spin-coated, and electrodeposited coatings were evaluated. The effect of variation of electrodeposition parameters such as voltage, pH, bath solids, time, and temperature on dry film thickness obtained have been studied. Iron oxide paints based on the above resins at 20 and 35% pigment volume concentration were prepared and evaluated for their anticorrosive properties.

INTRODUCTION

The use of water as a solvent for water-soluble resins has been the subject of a great deal of research. The elimination or reduction in the use of organic solvents in the surface coatings industry reduces cost, avoids pollution problems and introduces non-flammability and non-toxicity to the system. Further advantages of water-soluble resins are their adaptability to automation and their potential ability to be electrodeposited from aqueous solutions on metallic substrates. These films are deposited porous-free in thin layers even in places difficult to reach with brush-coating.

Maleinized drying oils or their fatty acids were the starting materials for the development of water-soluble vehicles. Air drying water-soluble vehicles can be prepared by reacting maleic anhydride with vegetable drying oils and converting the products to their water-soluble salts.[1] When used alone, these vehicles are unable to satisfy the high requirements in coating performance, hence, modification of these with phenolic resins[2] or further modification with rosin[3] has been studied. The use of phenolic resins in the alkyd and varnish areas was described by Payne.[4] Their use in upgrading the performance of maleinized oils has been described by Gilchrist,[5] Jerabek, and co-workers.[6] Hahn[7] revealed that the maleinized oils have improved their properties by esterification. Albers et al.,[8] and Van Westrenen[9] have described water-soluble resins based on polyesters and epoxies, respectively. Electrodeposition of water-soluble vehicles has been the subject of voluminous literature.[10] Beck[11] has given a detailed review of mechanism and the fundamental aspects of electrodeposition of paint.

The addition of maleic anhydride to cardanol and linseed oil was studied for the preparation of water-soluble resins to be used in anionic electrodeposition coatings.

This paper deals with the preparation of phenolic resins based on phenol, cardanol, and maleinized cardanol. These phenolic resins have been further modified with maleinized linseed oil and linseed oil fatty acids. Reaction conditions, physical characteristics, such as melting point or softening point, gelation time, etc., and the film properties of the phenolic resins, such as adhesion and scratch hardness, have been studied. The structure of the ester formed between the resol of maleinized cardanol-formaldehyde resin and maleinized linseed oil fatty acids

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was characterized by IR spectroscopy. The effect of variation of electrodeposition parameters, such as voltage, pH, bath solids, time, and temperature on dry film thickness obtained has been studied.

Iron oxide paints at 20 and 35% pigment volume concentration (PVC) levels suitable for electrodeposition were developed and evaluated for their film properties.

EXPERIMENTAL

Materials

The following materials were used for the preparation of water-soluble phenolic resins.

Cardanol: Cardanol was obtained by vacuum distillation of cashew nut shell liquid at 6 mm of Hg and temperature between 245 ± 5°C.

Linseed Oil: Alkali refined.

Phenol: L.R. grade.

Solvents: Formaldehyde (37-40% formalin), hydroxylamine hydrochloride, sodium hydroxide, maleic anhydride, dimethylethanolamine, butyl cellosolve, sulphuric acid, and ammonium hydroxide are all reagent grade chemicals.

Pigment: Iron oxide, specific gravity 5.2, oil absorption 13.2.

Driers: Cobalt naphthenate (6% Co metal content) and lead naphthenate (18.0% Pb metal content) in butyl cellosolve.

Preparation of Water-soluble Vehicles

Maleinization of Cardanol/Linseed Oil:[12] Maleinization was carried out in a four-necked round bottom flask equipped with stirrer, thermometer, reflux condensor, and nitrogen inlet tube. The flask was charged with weighed quantities of cardanol/linseed oil and heated to 140°C. At this temperature, varying amounts of maleic anhydride (8-32%) on the weight of cardanol/linseed oil were added. The temperature was raised to 200 ± 5°C and maintained for two to three hours until the content of free maleic anhydride was decreased to less than one percent. The unreacted maleic anhydride was removed by steam distillation, until a drop of distillate showed a pH of 6.

Preparation of Non-Reactive (Novalac) Resins from Maleinized Cardanol and Formaldehyde Using Acidic Catalyst:[13] Maleinized cardanol (1 mole), aqueous formaldehyde (0.9 mole) 37% by weight, and 1% sulphuric acid were charged into a four-necked flask and heated to 75-80°C. The reaction was carried out until the content of free formaldehyde was decreased to below 1%, determined by using hydroxylamine hydrochloride method[14] and maintaining the pH during the reaction between 0.5-4.0. Water was removed by vacuum and free cardanol was removed by distillation. Samples (1-2 mL) were withdrawn and tested for water solubility after being neutralized with dimethylethanolamine. Physical characteristics are given in *Table* 1.

Preparation of Varnishes Using Maleinized Cardanol Novalac Resins and Maleinized Linseed Oil: Varnishes were prepared by heating maleinized linseed oil (100 g) to about 160°C and adding the non-reactive novalac resin (25 g) in small lots and cooking at 240-250°C. The degree of heat polymerization of the resin was followed by the string test. This was performed by placing a drop of the reaction product on a glass plate, cooling it, and rapidly drawing a string of the resin with the finger tip and assessing the length of a continuous string that could be drawn. The reaction was carried out until a string of 16-18 in. was obtained. The 16-18 in. string indicates an approximate viscosity of two to three poises at 30°C of the resin in 50% solution in xylene: white spirit (1:1, v/v). The clear varnishes were thinned with 5% butyl cellosolve by weight based on resin solids and then neutralized with dimethylethanolamine and diluted with deionized water to the required consistency (Ford cup No. 4, 30 sec). Cobalt and lead naphthenate

Table 1—Physical Characteristics of Novalac Resins and Varnishes

Sl. No.	Amount of Phenol and Cardanol Taken (w/w)		Reaction		Resinification		Softening Point °C		Gel Time (min)		Color		Solubility in Water after Neutralization with DMEA	
	Phenol (g)	Cardanol (g)	Temp. °C	Time (min)	Temp. °C	Time (min)					R	Y		
			Novalac		Novalac		Novalac	Varnish	Novalac	Varnish	Novalac		Novalac	Varnish
1.	100	0	85-87	120	120	60	72.0	68.0	30	40	20.0	16.0	I	I
2.	0	100	85-90	240	250	120	68.0	62.0	NG	NG	24.0	14.0	I	I
3.	100	10	86-90	150	245	90	71.0	67.0	60	90	3.0	10.0	I	I
4.	100	20	85-90	165	240	100	70.5	65.0	80	120	3.5	9.2	I	I
5.	100	30	85-89	180	230	120	70.0	64.5	120	NG	5.0	4.7	I	I
6.	100	50	85-89	190	185	135	69.5	64.0	NG	NG	7.0	4.2	I	I
7.	100	75	85-88	210	180	150	69.0	63.0	NG	NG	9.0	3.0	I	I
8.	100	100	85-86	240	170	180	68.0	62.5	NG	NG	12.0	6.0	I	I
9.	100	150	85-86	255	165	180	66.0	62.0	NG	NG	13.0	9.0	I	I
10.	8% MC		75-80	180	95	60	36.0	39.0	120	NG	14.0	12.0	PS	S
11.	16% MC		75-80	210	100	60	32.0	35.0	90	NG	14.5	14.0	S	S
12.	24% MC		75-78	240	90	60	30.0	34.0	60	30	14.8	15.0	S	S
13.	32% MC		75-80	270	90	60	29.0	32.0	30	20	16.0	12.0	S	S

Novalacs and varnishes are soluble in white spirit, butanol, xylene and acetone. Maleinized cardanal (10-13) are soluble in alcohol and water after neutralization with amine; the rest are insoluble NG = No gelatin up to 3 hr; I = insoluble; S = soluble; PS = partly soluble; DMEA = dimethylethanolamine.

Table 2—Film Characteristics of Novalac Resins and Varnishes

Sl. No.[a]	Practical Adhesion Values (kg/cm²)				Scratch Hardness (g)				Gloss at 45° (Std. value 52)				Humidity Corrosion Test (7 Days)				Sodium Hydroxide (Time to Wrinkle in min.)			
	Spin-coating		Electro-deposition		Brush-coating		Electro-deposition		Brush-coating		Electro-deposition		Brush-coating		Electro-deposition		Brush-coating		Electro-deposition	
	N.	V.	N.	V.	N.	V.	N.	V.	N.	V.	N.	V.	N.	V.	N.	V.	N.	V.	N.	V.
1[b]....	50	55	—[c]	—	250	300	—	—	33	35	—	—	5F	6F	—	—	20	25	—	—
2	45	48	—	—	200	250	—	—	35	37	—	—	P	P	—	—	25	28	—	—
3	43	45	—	—	250	300	—	—	34	35	—	—	5F	6F	—	—	21	26	—	—
4	40	44	—	—	250	300	—	—	34	35	—	—	5F	6F	—	—	22	24	—	—
5	38	42	—	—	250	300	—	—	34	35	—	—	6F	6F	—	—	22	23	—	—
6	37	39	—	—	200	250	—	—	34	35	—	—	6F	6F	—	—	23	23	—	—
7	36	38	—	—	200	250	—	—	35	36	—	—	6F	P	—	—	24	25	—	—
8	35	36	—	—	200	250	—	—	35	36	—	—	P	P	—	—	24	25	—	—
9	34	35	—	—	200	250	—	—	35	36	—	—	P	P	—	—	24	25	—	—
10	55	62	60	68	300	400	350	450	43	45	44	46	6F	P	P	P	15	20	18	22
11	68	80	75	90	400	500	450	600	46	48	47	49	P	P	P	P	20	27	24	30
12	58	65	60	70	350	400	400	500	45	47	46	48	P	P	P	P	18	22	20	24
13	54	60	56	64	300	350	350	400	44	46	45	47	4F	P	F	F	6	12	10	15

(a) Samples 1-13 follow *Table* 1.
(b) All the above films except 1, 3-5 passed flexibility and impact resistance tests.
(c) (–) indicates lack of water solubility after neutralization with amine, so there was no electrodeposition.
(d) P = pass, F = fail, N = novalac, V = varnish.
(e) Films are resistant to distilled water, sulphuric acid (2%), sodium carbonate (5%), sodium bicarbonate (5%), xylene, butanol & white spirit according to IS 101-1964.

(0.05 and 0.5% on the metal content, respectively) were added as driers.

Properties of the films obtained by brush-coating and electrodeposition were evaluated. Results are tabulated in *Table* 2.

PREPARATION OF REACTIVE RESINS (RESOLS) FROM MALEINIZED CARDANOL AND FORMALDEHYDE USING BASIC CATALYST:[13] Maleinized cardanol (1 mole), aqueous formaldehyde (1.3 and 1.5 moles) 37% by weight and ammonia solution (1%) were charged into the 500 mL round bottom flask equipped with reflux condensor, stirrer, thermometer, and a nitrogen inlet tube. The pH was adjusted between seven to eight and the reaction was carried out by stirring at 60-65°C for two to four hours. The reaction was carried out until the formaldehyde content, determined by using hydroxylamine hydrochloride method[14] was less than 1%. Water and unreacted cardanol were removed by distillation. Samples (1-2 mL) were withdrawn and tested for water solubility after being neutralized with dimethylethanolamine. The physical characteristics are given in *Table* 3.

ESTERIFICATION REACTION BETWEEN MALEINIZED CARDANOL RESOL AND MALEINIZED LINSEED OIL FATTY ACIDS: Resols were esterified in a four-necked round bottom flask equipped with stirrer, thermometer, nitrogen inlet tube, and Dean-stark apparatus (IS 101-1967). Maleinized linseed oil fatty acids were reacted with different amounts of reactive resins (resols). It was observed that 25% resin modification gave a satisfactory product. So, maleinized linseed oil fatty acids and the resol from maleinized cardanol were taken in the ratio 4:1 (25% of resol) and heated to 240°C. The water formed during esterification was removed by azeotropic distillation with 3% xylene, based on the total weight of reactants. The

Table 3—Physical Characteristics of Resols and Esters[a]

Sl. No.	Type of Phenol (1 mole)	Formal-dehyde (moles)	Reaction Temp. °C	Reaction Time (min)	Resinification Temp. °C	Resinification Time (min)	Softening Point °C		Gel Time (min)		Color R	Color Y	Solubility in Water after Neutralization with DMEA	
			Resol		Resol		Resol	Ester	Resol	Ester	Resol		Resol	Ester
1.....	Phenol	1.3	60-62	60	90	30	68	G	4	G	1.9	3.2	I	I
2.....	Phenol	1.5	60-62	90	92	40	69	G	5	G	1.8	3.3	I	I
3.....	Cardanol	1.3	60.00	120	200	60	65	68	6	10	2.4	2.3	I	I
4.....	Cardanol	1.5	60.00	130	200	120	67	69	8	12	2.4	3.0	I	I
5.....	8% MC[b]	1.3	60-62	150	64	45	35	40	10	15	5.1	3.3	PS	PS
6.....	8% MC	1.5	60-62	160	64	50	34	39	12	17	4.9	12.0	S	S
7.....	16% MC	1.3	62-63	180	62	35	32	36	NG	NG	4.9	30.0	S	S
8.....	16% MC	1.5	62-63	200	62	40	30	32	NG	NG	4.5	40.0	S	S
9.....	24% MC	1.3	60-65	210	60	30	28	29	120	80	4.5	41.0	S	S
10	24% MC	1.5	62-65	215	60	35	27	28	30	20	4.0	4.2	S	S
11	32% MC	1.3	62-65	240	60	30	26	G	25	G	3.5	4.4	S	G
12	32% MC	1.5	62-65	255	60	30	26	G	20	G	3.5	4.5	S	G

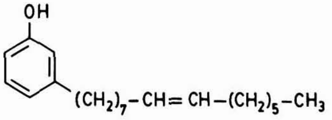
(a) Resols and esters are soluble in white spirit, xylene, butanol and acetone.
(b) Maleinized cardanol (MC) (6-12) are soluble in alcohol and water after neutralization with amine; the rest are insoluble.
(c) NG = No gelatin up to 3 hr; G = gelled; I = insoluble; PS = partly soluble; S = soluble; DMEA = dimethylethanolamine.

esterification reaction was stopped when the acid number of the reaction mixture decreased to less than one.

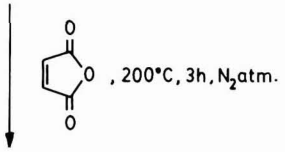
The film properties are given in *Table* 4. These esters were characterized by IR spectroscopy.

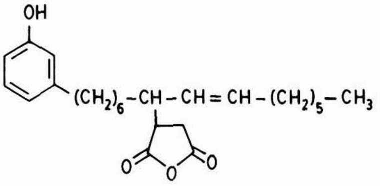
The sequence of reactions in the above preparations are as follows:

Step I—Maleinization of Cardanol



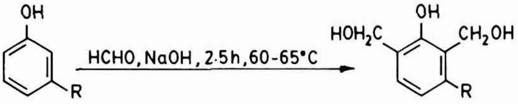
Cardanol (1)





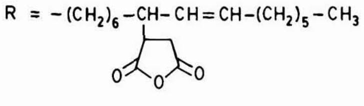
Maleinized cardanol (2)

Step II—Reaction of Maleinized Cardanol with Formaldehyde in the Presence of a Base

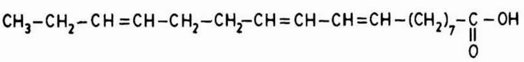


(2) (3)

Where,

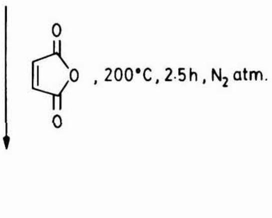


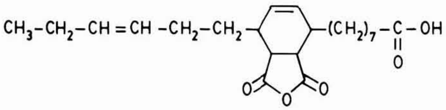
Step III—Maleinization of Linseed Oil Fatty Acids



$$CH_3-CH_2-CH=CH-CH_2-CH_2-CH=CH-CH=CH-(CH_2)_7-\underset{\underset{O}{\|}}{C}-OH$$

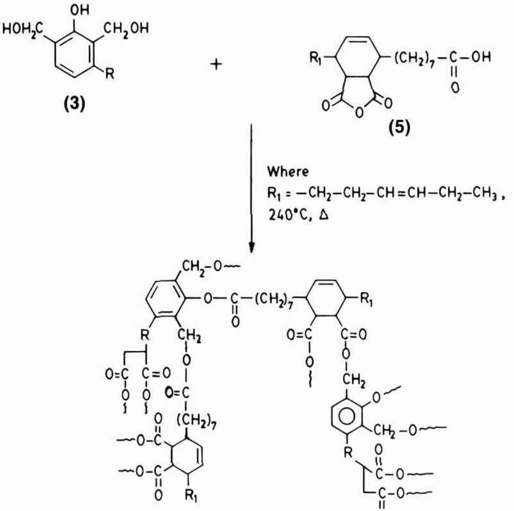
Linseed oil fatty acids (4)





Maleinized linseed oil fatty acids (5)

Step IV—Esterification Reaction Between the Resol of Maleinized Cardanol (3) and Maleinized Linseed Oil Fatty Acids (5)



(3) (5)

Where $R_1 = -CH_2-CH_2-CH=CH-CH_2-CH_3$, 240°C, Δ

Ester (6)

Preparation of Paints: Paints were prepared at 20 and 35% PVC based on water-soluble vehicle (ester from maleinized linseed oil fatty acids and resol of maleinized cardanol, *Table* 4 vehicle 8) using iron oxide. The paints were applied by brush as well as by electrodeposition. The coated test pieces were baked at 145 ± 5°C for 30 minutes.

Preparation of Solutions for Electrodeposition: An aqueous solution for electrodeposition was prepared by neutralizing the above prepared resins and paints with dimethylethanolamine, followed by the addition of 5% butyl cellosolve (by weight) and sufficient deionized water to provide 12% solids content and the pH of the solution was found to be 7.1-7.5.

ELECTRODEPOSITION

Electrodeposition was carried out by the use of the above water-soluble resin and paint solutions using replaceable mild steel panels and rods, as anodes and mild steel cathode using 50 volts for two minutes under the following conditions. Current density was 3-5 amp/sq ft, temperature 28°C, pole to pole distance 6 cm. The coated test pieces were washed with deionized water and baked at 140°C for 30 minutes.

Table 4—Film Characteristics of Resol Resins and Esters

Sl. No.	Practical Adhesion Values (kg/cm²)				Scratch Hardness (g)				Gloss at 45° (Std. Value 52)				Humidity Corrosion Test (7 Days)				Sodium Hydroxide (Time to Wrinkle in Minutes)			
	Spin-coating		Electro-deposition		Brush-coating		Electro-deposition		Brush-coating		Electro-deposition		Brush-coating		Electro-deposition		Brush-coating		Electro-deposition	
	Resol	Ester	Resol	Ester	Resol	Ester	Resol	Ester	Resol	Ester	Resol	Ester	Resol	Ester	Resol	Ester	Resol	Ester	Resol	Ester
1[a]	72	G	—[b]	G	200	G	—	G	35	G	—	G	2F	G	—	—	7	G	—	—
2	75	G	—	G	200	G	—	G	36	G	—	G	2F	G	—	—	8	G	—	—
3	65	75	—	—	250	300	—	—	40	42	—	—	4F	6F	—	—	8	10	—	—
4	67	80	—	—	300	350	—	—	42	43	—	—	4F	6F	—	—	9	13	—	—
5	108	118	112	122	400	500	450	700	44	46	45	48	6F	P	P	P	6	8	7	11
6	110	120	115	125	450	600	500	800	45	48	47	50	6F	P	P	P	8	10	10	14
7	116	138	128	149	600	800	700	1100	47	50	48	56	P	P	P	P	7	13	9	16
8	125	143	135	207	700	1100	900	1500	48	54	52	58	P	P	P	P	9	15	12	20
9	112	120	118	126	450	550	500	800	46	48	47	53	6F	6F	P	P	4	9	6	12
10	116	122	120	128	500	600	550	850	45	47	46	55	6F	6F	P	P	5	10	8	14
11	107	G	114	G	300	G	400	G	45	G	46	G	4F	G	P	G	3	G	5	G
12	108	G	115	G	300	G	400	G	45	G	46	G	4F	G	P	G	3	G	6	G

(a) All of the above films passed impact resistance and flexibility, except 1 and 2 which failed. All the films were resistant to distilled water, sulphuric acid (2%), sodium carbonate (5%), sodium bicarbonate (5%), xylene, butanol, and white spirit according to IS 101-1964.

(b) G = gelled; P = pass; F = fail.

(c) (–) indicates lack of water-solubility after neutralizing with amine, so there was no electrodeposition.

Effect of variation of voltage, pH, bath solids, time, and temperature on dry film thickness obtained and the film properties of the deposited films were studied. The results are given in *Figures* 1-3.

Evaluation of Resins, Esters, and Paints

HYDROLYTIC STABILITY:[9] Hydrolytic stability of the aqueous system at 10% and 20% solid concentrations was determined by bottle storage tests on the vehicle and paint solutions. Hydrolytic stability of the vehicle and paints was found to last more than 16 months.

STORAGE STABILITY: Storage stability of the vehicle and paints was assessed by taking out samples periodically, neutralizing with dimethylethanolamine, and diluting with deionized water. Vehicle and paints were stable up to a period of one year, as no turbidity developed.

SOFTENING/MELTING POINT:[15] Softening/melting point was determined by Durrans method.

GEL TIME:[16] Gel time was determined by dissolving 5 g of the resin in an equal amount of linseed oil in 6 × ½″ test tube, by heating to about 140°C in an oil bath while stirring with glass rod. The temperature of the oil bath was then raised and maintained at 250 ± 1°C. The glass rod was periodically raised to see if the test tube could be lifted with it, thus, showing that the material had gelled. The gel time was taken as the time from the start of heating at 250°C until the mixture in the test tube had gelled.

COLOR OF THE RESINS: Color was determined by using 2% solution in acetone with a Lovibond Tinctometer using 1 cm cell.

SOLUBILITY IN DIFFERENT SOLVENTS: Solubility in different solvents was determined by heating 1 g of the resin in 5 mL of each solvent at its boiling point and observing the clarity at room temperature.

ADHESION: Bond strengths (practical adhesion values) of the electrodeposited and spin-coated test pieces were determined by the Sandwich pull-off technique using a Hounsfild Tensometer.[17,18]

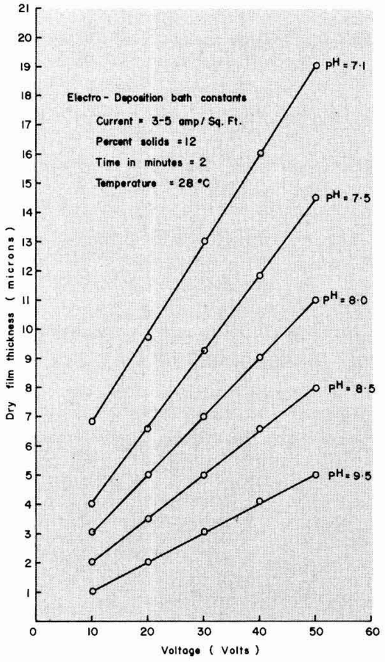


Figure 1—Effect of pH and voltage on dry film thickness of the ester

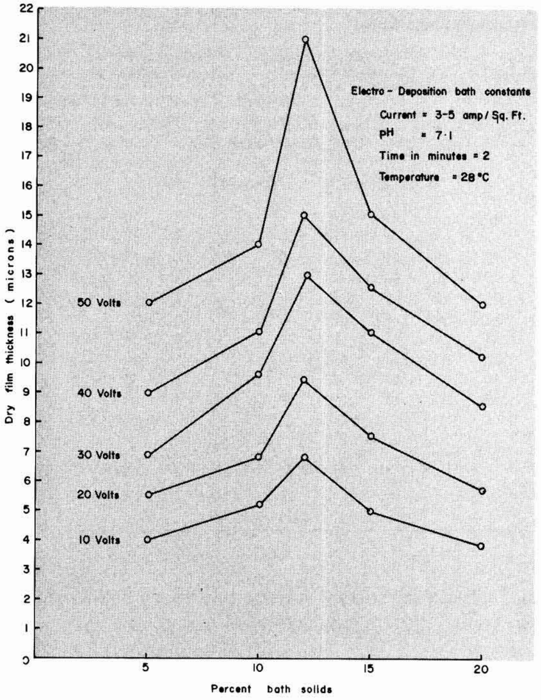


Figure 2—Effect of voltage and percent bath solids on dry film thickness of the ester

Scratch Hardness:[19] Scratch hardness was determined on an automatic power operated test unit (Research Equipment London, Ltd.).

Gloss:[20] Gloss was measured at 45° as prescribed in IS 101-1964 using a Gardner Multi-angle Glossmeter.

Humidity Corrosion: Humidity corrosion test was carried out according to IS 101-1964.

Flexibility: Flexibility was determined by using ¼″ mandrel, as per IS 101-1964.

Impact Resistance:[21] Impact resistance was measured by a falling weight type instrument using 10.5 lb (4.7 kg) weight from a fixed height of 23″ (58.0 cm).

Resistance to Chemicals/Solvents: Resistance to chemicals and solvents was measured according to IS 101-1964 using distilled H_2O, H_2SO_4 (2%), NaOH (1%), Na_2CO_3(5%), $NaHCO_3$(5%), xylene, white spirit, and butanol.

RESULTS AND DISCUSSION

The hydrolytic and storage stability tests show that the cardanol, maleinized cardanol/linseed oil vehicles and paints were stable up to 16 months and one year, respectively.

Novalac Resins

The physical characteristics of novalac resins based on ordinary phenol, cardanol, and maleinized cardanol are given in *Table* 1. These resins have comparatively low melting points and good solubilities and compatibilities with various drying oils. By virtue of these properties, these resins can be used in high quality varnishes. Pure phenolic resins are brittle and gel at a faster rate when compared to cardanol resins. The addition of cardanol to phenol results in the lowering of melting point, resinification time but the reaction time increases. This may be due to a long hydrocarbon chain substituent in cardanol, which serves to provide internal plasticization of the cured product resulting in excellent flexibility.

Pure phenolic resins are insoluble in hydrocarbons, while similar cardanol resins are soluble in both aromatic and aliphatic solvents. Resins obtained by using maleinized cardanol gave good water solubility at 16% maleinization. The color darkened by the addition of cardanol to phenol. This may be due to the oxidation of a double bond present in the side chain of the cardanol. Water solubility was increased with an increase in the amount of maleic anhydride and, as a result, water resistance decreased.

The electrodeposited, brush- and spin-coated film characteristics of the resins were compared at the same coating thickness. The film characteristics of novalac resins are given in *Table* 2. Phenolic resins, being relatively non-polar, show poor adhesion. The adhesion of novalac resins was found to decrease with the addition of cardanol. This may be due to bulky hydrocarbon side chain in meta position which reduces the polarity. With the introduction of maleinized cardanol, the polarity increases and the adhesion values also increase. Maleinization leads to high scratch hardness, flexibility, impact

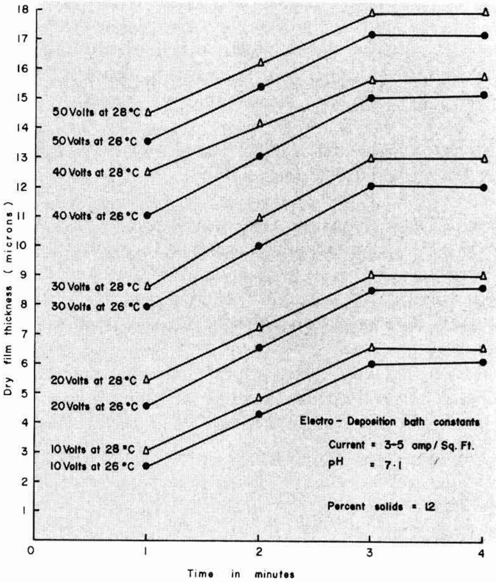


Figure 3—Effect of voltage, temperature, and time of deposition on dry film thickness of the ester

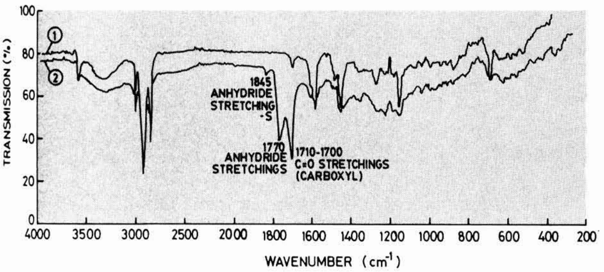


Figure 4—IR spectrum of cardanol (1) and IR spectrum of adduct from cardanol and maleic anhydride (2)

resistance, and gloss, etc., but poor caustic and water resistance of the film are due to the presence of free carboxyl groups. However, these resins may serve as potential water-soluble vehicles for electrodeposition.

Resol Resins

Physical characteristics of the resol resins and esters of phenol, cardanol, and maleinized cardanol are given in *Table* 3. The softening point and resinification time are decreased, whereas reaction time, gel time, and viscosity are increased by the substitution of phenol by cardanol or by reaction with maleinized cardanol. Water solubility is increased by the introduction of a greater number of carboxyl groups.

Film characteristics of the resols are given in *Table* 4. Adhesion of resol was found to increase with an increase in the percentage of maleinization of cardanol with maleic anhydride, but to decrease when cardanol was used alone. This may be attributed to the hydroxyl (in resol), carboxyl, and ether groups present in the initial resin chain and in the cured system. Use of cardanol and maleinized cardanol in place of phenol improved the resistance to impact, chemicals/solvents, and flexibility. The esterified products showed better adhesion and hardness than the cardanol resins because the resin can react with the linseed oil fatty acids to form high molecular weight polymer which gives better hardness and adhesion. Scratch hardness also follows the same trend. The electrodeposited films had higher adhesion values than the spin-coated films. This may be attributed to the increase in the bond strength of the film in electrodeposition due to chemical bond between metal (M^{+}) and (COO^{-}) ion. The gloss of the brush-coated films was found to be lower than the electrodeposited films. This may be due to uniform and compact film obtained by electrodeposition. The humidity corrosion resistance of maleinized resols and esters was better when electrodeposited; this may be a result of better adhesion to the substrate.

The film characteristics of resols and esters show that the values are increased to 16% maleinization with cardanol formaldehyde ratio (1:1.5), and then again decreased. This shows that 16% maleinization with cardanol formaldehyde ratio of 1:1.5 (*Table* 4, vehicle 8) is suitable for formulating paints for electrodeposition.

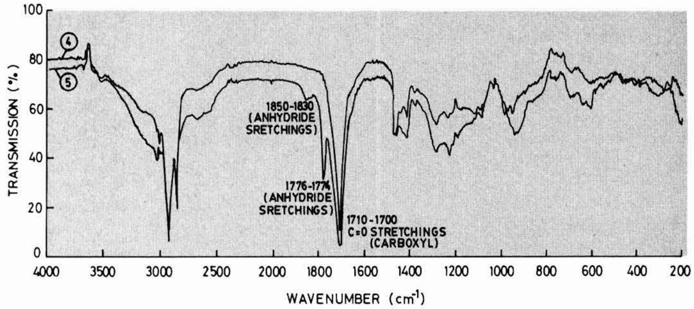
Characterization of Esters By IR Spectroscopy

The sequence of reactions shown previously is supported by the following observations.

The IR spectrum of cardanol (1) shows absorptions at 3590-3370 cm^{-1} and 1410 cm^{-1} due to –OH stretchings. Cardanol, when maleinized at 200°C with maleic anhydride, gave product (2), the spectra of which showed the presence of anhydride group along with the carboxyl group. These anhydride peaks appear at 1845 cm^{-1} and 1770 cm^{-1}. The product (2), when allowed to react with formaldehyde in an alkaline medium at 60-65°C, gave rise to product (3), with absorptions at 1260 cm^{-1} and 1150 cm^{-1} due to methylol groups.

Linseed oil fatty acids (4), when maleinized with maleic anhydride, yielded Diels Alder adduct (5) with anhydride peaks at 1850-1830 cm^{-1} and 1776-1774 cm^{-1} along with carboxyl group at 1710-1700 cm^{-1} and a peak at 720 cm^{-1} due to cyclohexene ring. When product (3) was esterified with product (5) at 240°C, it gave product (6) with a new absorption peak at 1730 cm^{-1}

Figure 5—IR spectrum of linseed oil fatty acids (4) and IR spectrum of adduct from linseed oil fatty acids and maleic anhydride (5)



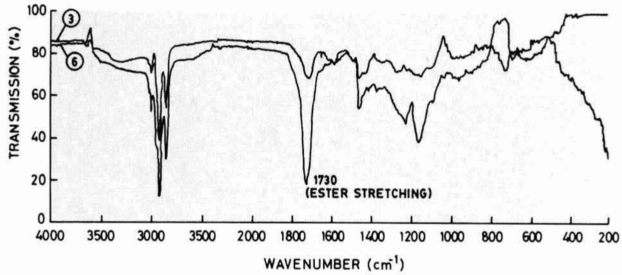


Figure 6—IR spectrum of resol from maleinized cardanol and formaldehyde (3) and IR spectrum of ester from maleinized linseed oil fatty acids and resol (6)

due to the formation of ester linkages, with a decrease in intensity of the peaks related to methylols, anhydride, and −OH groups (*Figures* 4-6).

Electrodeposition characteristics and the relation between the various deposition parameters are given in *Figures* 1-3. The effect of voltage and pH on dry film thickness (*Figure* 1) showed that maximum thickness (19 μ) is obtained from a bath which is maintained at lower pH, i.e., 7.1 at 50 volts for two minutes.

As seen from *Figure* 2, the film thickness increased as the bath solids increased to 12%, but the thickness again decreased even with an increase in percent solids. Film thickness also increased with increase in temperature and time (*Figure* 3) up to three minutes, when it is almost constant even with further increase in voltage and time. This shows that the degree of migration of water-soluble resin increases with a rise in temperature giving a consequent increase in deposition rate.

Film characteristics of the paints at 20 and 35% PVC using iron oxide are given in *Table* 5. It shows that 35% PVC has good adhesion, flexibility and humidity corrosion resistance when compared to 20% PVC. In impact resistance, the electrodeposited paints showed better performance than brush-coated paint films. Both paints were resistant to chemicals, solvents, and water resistance for one week.

Table 5—Film Properties of Iron Oxide Paints Based on Water-Soluble Vehicle 8 (*Table* 4)

		20% PVC		35% PVC	
Sl. No.	**Film Properties**	**Spin-coating**	**Electro-deposition**	**Spin-coating**	**Electro-deposition**
1[a]	Thickness (microns)	20.0	20.0	20.0	20.0
2	Adhesion (kg/cm^2)	268.0	334.5	301.3	405.0
3	Scratch hardness (g)	1800.0	2200.0	2100.0	2600.0
4	Gloss at 45°	22	30	2.5	5.0
5	Impact resistance				
	Direct	P[b]	P	P	P
	Reverse	F	P	P	P
6	Flexibility (¼″ mandrel)	P	P	P	P
7	Humidity corrosion test (7 days)	P	P	P	P
8	Hydrolytic and storage stability (1 year)	P	P	P	P
9	Sodium hydroxide (time to wrinkle in minutes)	20	28	25	30

(a) All paint films were resistant to distilled H_2O, H_2SO_4(2%), Na_2CO_3(5%), $NaHCO_3$(5%), xylene white spirit and butanol for more than one week.

(b) P = pass, F = fail.

SUMMARY

Novalac and resol resins based on maleinized cardanol were found to be water-soluble after neutralization with dimethylethanolamine. Resols of maleinized cardanol gave coatings with better adhesion and scratch hardness than those from the novalac resins of maleinized cardanol.

The esterified product from resol of maleinized cardanol and maleinized linseed oil fatty acids was found to give a water-soluble vehicle suitable for electrodeposition after neutralization with dimethylethanolamine. The electrodeposited films on the mild steel surface have good adhesion and possess better scratch hardness than the brush- and spin-coated films.

The iron oxide paints gave films which had better adhesion, hardness, and chemical resistance than that obtained from unpigmented composition. The paint coatings showed better adhesion to mild steel substrate when they were applied by electrodeposition than when they were spin-coated.

ACKNOWLEDGMENTS

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ERRATA

The photograph in *Figure* 1 in the article, "Reflections on the Phenomenon of Fading," by Ruth M. Johnston-Feller, (JCT May, p. 34) was reversed. Original alizarin concentration should have been displayed in the left column of chips, evidenced by darker shades of color, with the right column of chips reflecting the faded state.

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Influence of Rheology Modifiers On the Performance Characteristics Of Latex Paints

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A series of latex paints was prepared based on a range of commercially available rheology modifiers, including cellulose derivatives, alkali-soluble and polyurethane associative thickeners. An extensive range of rheological, optical, and physical properties was determined to evaluate the relative performance characteristics of each system.

It was found that the associative thickeners offered superior application properties, together with increased flow and leveling, compared with systems based on cellulosic polymers. However, some deficiencies in sag resistance were observed. When polyurethane associative thickener/cellulose combinations were used, the overall performance of the system was found to be inferior relative to an associative thickened system, with application properties in particular being adversely affected.

INTRODUCTION

Until relatively recently, cellulose derivatives (particularly HEC and CMC) had been the major products utilized by the latex paint industry for the control of rheological behavior. To overcome problems of biological degradation, alkali-soluble polymers which also offered improved flow and increased gloss potential, were developed. Both cellulosic and alkali-soluble polymers induce viscosity in a latex paint system by chain entanglement, thus, their thickening power is primarily a function of molecular weight. These materials are compatible with a wide variety of commercial latices, although the alkali-soluble materials do tend to function best in high pH systems and some problems of alkali sensitivity in the resultant films have been observed. The limitations of this thickening mechanism have been reviewed by various authors.[1,2]

Currently, a new class of materials termed associative thickeners is being extensively evaluated in the trade sales sector. Improved flow and leveling, the elimination of roller spatter, higher gloss, minimal pigment/latex flocculation, and a more "alkyd-like" rheology are just some of the claims being made for these products. Initially, two types of associative thickeners were developed: hydrophobe-modified ethoxylated urethanes[3] (HEUR)

Table 1—Influence of Thickener Type on Viscosity Stability

	Stormer Viscosity (KU)					
	Gloss		Semi-Gloss		Flat	
	Initial	6 wk at 50°C	Initial	6 wk at 50°C	Initial	6 wk at 50°C
HEC	91	112	90	102	98	118
CMC	90	112	90	107	96	105
Alkali Soluble Associative Thickener 1	91	99^{a}	92	97^{a}	94	79^{a}
Alkali Soluble Associative Thickener 2	88	101^{a}	90	101^{a}	100	115^{a}
HEUR Associative Thickener 1	95	108^{b}	95	100^{a}	100	114^{b}
HEUR Associative Thickener 2	90	96^{a}	91	100^{a}	100	116^{a}
HEC/HEUR Associative Thickener 1	96	117^{b}	96	108^{b}	94	120^{b}
HEC/HEUR Associative Thickener 2	94	113^{b}	95	102^{b}	94	104^{b}

(a) Slight syneresis observed.
(b) Severe syneresis observed.

Presented at the 63rd Annual Meeting of the Federation of Societies for Coatings Technology, in St. Louis, MO, October 8, 1985, and winner of the A.F. Voss/*American Paint & Coatings Journal* Award.

Table 2—Flow and Leveling and Sag Resistance Properties of Gloss Latex Paints

		Predicted Flow and Leveling + Sag Resistance Rating[a]			
	Sheared Yield Value	Flow & Leveling	Sag Rating	Actual Flow and Leveling	Actual Sag Resistance
HEC	18.28	6	3	4½	12
CMC	13.36	5	4	5	12
Alkali Soluble Associative Thickener 1	5.34	4	5	9	9
Alkali Soluble Associative Thickener 2	0.43	1	8	9	7
HEUR Associative Thickener 1	2.26	3	6	8	8
HEUR Associative Thickener 2	2.21	2	7	10	8
HEC/HEUR Associative Thickener 1	20.17	8	1	6	12
HEC/HEUR Associative Thickener 2	19.66	7	2	6	12

(a) Where 1 = Best flow and leveling and sag resistance;
8 = Poorest flow and leveling and sag resistance.

and alkali-soluble carboxylated acrylic latices.[4] Associative thickeners are relatively low in molecular weight, typically from 10,000 to 100,000, and introduce viscosity into paints primarily by specific interactions with the latex particles present in the system. These polymers have pendant hydrophobic groups incorporated into their structure which enable them to associate not only with latex particles, but also with other thickener molecules, certain pigment surfaces, dispersants, and other surface active agents. The mechanism of association has been characterized[5,6] and is thought to proceed via the adsorption of the hydrophobe portion of the thickener at the latex surface. Compared to conventional cellulose ether thickeners, both types of associative thickener are much more sensitive to formulation variables, with parameters such as latex particle size,[7,8,9] and surfactant levels[3,4] being particularly important.

Recent work has resulted in the development of other types of associative thickeners based on hydrophobically modified cellulose[10] and a mixed alkali-soluble/urethane polymer.[2]

EXPERIMENTAL

A series of commercially available rheology modifiers, including cellulose derivatives, alkali-soluble, and HEUR associative thickeners was evaluated in a range of simple latex paint systems. Full formulation details are given in the *Appendix*. The aim was to produce a series of paints with very similar mid-shear rate viscosities, as determined by the Stormer viscometer, and then to evaluate an extensive range of rheological, optical, and physical properties.

The following properties were studied to determine the relative performance characteristics of the different rheology modifiers.

Rheological Measurements

The viscosity of each of the prepared paints was determined using both Stormer and Brookfield viscometers. The equilibrated viscosity of each system, together with the viscosity stability after six weeks' storage at 50°C, was measured using a Stormer viscometer. The results obtained are shown in *Table* 1.

The data obtained from the Brookfield viscometer was applied to the Casson[11] equation, using a method devised by Pierce,[12] to predict the sag resistance and flow and leveling properties of the prepared paints. Casson, using a Ferranti-Shirley viscometer, proposed an equation (1) to predict the relationship between the shear stress and shear rate of a pigmented system

$$\tau^{1/2} = K_0 + K_1\,\gamma^{1/2} \qquad (1)$$

This equation was subsequently rearranged to give a more representative expression,[13] equation [(2)].

Table 3—Flow and Leveling and Sag Resistance Properties of Semi-Gloss Latex Paints

		Predicted Flow and Leveling + Sag Resistance Rating[a]			
	Sheared Yield Value	Flow & Leveling	Sag Rating	Actual Flow and Leveling	Actual Sag Resistance
HEC	25.59	8	1	5	12
CMC	14.88	5	4	5	12
Alkali Soluble Associative Thickener 1	6.46	4	5	9	10
Alkali Soluble Associative Thickener 2	0.52	2	8	9	8
HEUR Associative Thickener 1	0.50	1	7	8	8
HEUR Associative Thickener 2	3.69	3	6	10	8
HEC/HEUR Associative Thickener 1	19.20	6	3	6	12
HEC/HEUR Associative Thickener 2	20.93	7	2	6	12

(a) Where 1 = Best flow and leveling and sag resistance;
8 = Poorest flow and leveling and sag resistance.

Table 4—Flow and Leveling and Sag Resistance Properties of Flat Latex Paints

	Sheared Yield Value	Predicted Flow and Leveling + Sag Resistance Rating[a]		Actual Flow and Leveling	Actual Sag Resistance
		Flow & Leveling	Sag Rating		
HEC	31.11	8	1	5½	12
CMC	27.94	7	2	6	12
Alkali Soluble Associative Thickener 1	4.72	3	5	8½	12
Alkali Soluble Associative Thickener 2	4.57	2	6	8	10
HEUR Associative Thickener 1	0.08	1	8	10	9
HEUR Associative Thickener 2	6.12	4	7	8	10
HEC/HEUR Associative Thickener 1	12.19	5	4	6	12
HEC/HEUR Associative Thickener 2	20.31	6	3	6	12

(a) Where 1 = Best flow and leveling and sag resistance;
8 = Poorest flow and leveling and sag resistance.

$$\eta^{1/2} = \eta_{\infty}^{1/2} + \tau_0^{1/2}\gamma^{-1/2} \qquad (2)$$

This equation suggests that if the square root of viscosity is plotted against the reciprocal of the square root of the shear rate, a straight line will be obtained with the intercept equal to the infinite shear viscosity ($\eta_{\infty}^{1/2}$) and the slope being the yield value ($\tau_0^{1/2}$). The parameters, infinite shear viscosity and yield value, have been related to product performance and composition variables. Sheared yield values have been successfully used to predict the flow and leveling and sag resistance properties of latex paint systems.[14] The results obtained are shown in *Tables* 2-4.

The Haake Rotovisco was employed to construct a rheological profile of each system over the shear rate range 0-2400 s^{-1} (see *Figures* 1-3) and also to determine the viscosity at 10,000 s^{-1} (see *Table* 5).

Optical Properties

A series of optical properties was determined on the prepared paints including opacity, color, and gloss.

In addition to these relatively simple optical measurements, the degree of titanium dioxide pigment dispersion was also studied using the flocculation gradient technique.[15] This method is based on the principle that pigment flocculates can be considered as large single particles and, as such, preferentially scatter long wavelength radiation. By determining the amount of infrared backscatter of a series of paint films, at varying thicknesses, a flocculation gradient can be obtained. The larger the value of the gradient, the higher the level of pigment flocculation in the paint. The inferior optical properties of a paint system having a high flocculation gradient have been well documented.[15] The flocculation gradient technique has been applied to a variety of paints,[16,17] although some problems have been encountered with high PVC systems.[15]

To give a visual appreciation of the flocculation gradient values obtained, the degree of pigment dispersion was also studied using scanning electron microscopy. The paint films were etched, using excited oxygen, which partially erodes the paint surface and allows the pigment distribution to be examined with a scanning electron microscope (see Simpson for details and examples of the technique[18]).

Details of the optical properties determined are shown in *Table* 6.

Physical Properties

A series of physical properties was determined on the prepared paints, including flow and leveling (according to ASTM D4062-81), sag resistance (using a Leneta anti-sag meter), alkali resistance (according to CGSB 1-GP-71 Method 106.3—1978), color acceptance, and scrub resis-

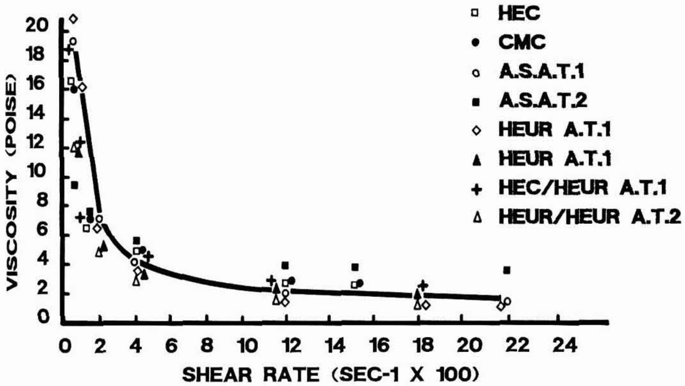

Figure 1—Rheological profiles of gloss latex paints

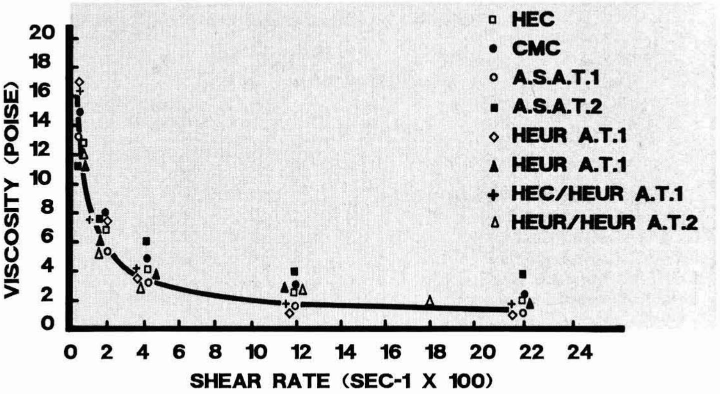

Figure 2—Rheological profiles of semi-gloss latex paints

tance. The results obtained are shown in *Tables* 2-4 and 7.

The application properties of each paint were assessed using brush and roller techniques. The degree of flow and leveling obtained after brushing, and the level of roller spatter observed after roller application, were assessed on an arbitrary 0-5 scale, where 0 indicated the lowest level of performance and 5 the highest. To assess roller application properties, two coats were applied to a paper substrate with a 15 minute period between each coat. The level of performance was assessed by a visual examination of each film for flow and leveling, and also general appearance. The films were described as either excellent, fair, or poor, after both the initial application and the subsequent coat. The results obtained are shown in *Table* 8.

RESULTS AND DISCUSSION

Rheological Characterization

As previously described, each series of paints was designed to have the same equilibrated Stormer viscosity. Limits of ±3 KU were established as being realistic errors and almost all of the prepared paints were found to be within these limits, as shown in *Table* 1. The viscosity stability of each of the prepared systems was considered to be acceptable, with the associative thickeners generally giving superior stability as compared to the cellulosic products. A problem was encountered with one of the alkali-soluble polymers in the flat latex system, where a significant reduction in viscosity was observed. This was attributed to a fall in pH of the system. Varying levels of syneresis were observed, after the period of storage, with all systems containing non-cellulosic thickeners.

The sheared and unsheared viscosity values, determined using the Brookfield viscometer, were substituted into the Casson equation using the method of Pierce, and the respective yield values calculated. The relative sag resistance and flow and leveling properties of each system were predicted on the basis of the yield values obtained. The predicted rankings were found to correlate quite well with the experimentally determined values, as shown in *Tables* 2-4. Using this approach, it was possible to differentiate between cellulose-based paints and those containing associative thickeners. It can be seen that paint systems based on cellulosic thickeners gave high sag resistance but poor flow and leveling properties, whereas the associative thickeners gave improved flow, but generally with some loss in sag resistance.

In an attempt to determine the "market acceptability" of each of the prepared paints, limits were established to determine what was felt to be an acceptable level of performance. Thus, a paint with a flow and leveling value of six or greater, coupled with a minimum sag resistance value of ten, was required. This level of performance was consistantly achieved with the HEC/HEUR associative thickener combinations. All of the associative thickeners were found to give relatively poor sag resistance properties in the gloss and semi-gloss systems and it was felt that the resultant paints would not be commercially acceptable products. In the flat latex system, the sag resistance performance of the associative thickeners was improved, which, coupled with superior flow and leveling, produced paints with excellent all-round performance characteristics.

Figure 4 is an attempt to correlate the flow and leveling and sag resistance data of all the prepared paints. These results suggest that it is possible to achieve adequate sag resistance, coupled with acceptable flow and leveling, by careful selection of rheology modifier.

Rheological profiles of each system, constructed using the Haake Rotovisco viscometer over a shear rate of 0-2400 s^{-1}, are shown in *Figures* 1-3. By examining the

Table 5—High Shear Viscosity Values

	Viscosity at 10,000 s^{-1} (poise)		
	Gloss	Semi-Gloss	Flat
HEC	1.1	1.1	1.3
CMC	1.0	1.1	1.3
Alkali Soluble Associative Thickener 1	1.1	1.2	1.3
Alkali Soluble Associative Thickener 2	1.8	1.9	2.8
HEUR Associative Thickener 1	1.3	1.4	1.8
HEUR Associative Thickener 2	1.3	1.3	1.7
HEC/HEUR Associative Thickener 1	1.0	1.0	0.9
HEC/HEUR Associative Thickener 2	1.0	1.1	1.2

Table 6—Optical Properties of Latex Paints

	Paint System																
	Gloss						Semi-Gloss						Flat				
Thickener	Contrast Ratio 1 mil	Color L	Color a	Color b	60° Gloss	FG[a]	Contrast Ratio 1 mil	Color L	Color a	Color b	60° Gloss	FG	Contrast Ratio 1 mil	Color L	Color a	Color b	Scrub Resistance
HEC	93.7	95.6	−0.9	−0.2	66	1.1	93.9	96.1	−0.9	−0.2	43	1.1	93.8	95.2	−0.9	1.3	standard
CMC	93.6	96.6	−0.9	−0.2	60	1.1	93.6	96.0	−1.0	−0.2	35	1.2	94.2	95.7	−0.8	1.4	similar
Alkali Soluble Associative Thickener 1	93.8	95.4	−0.9	0	66	1.2	93.6	96.1	−0.9	−0.2	42	1.3	94.3	95.6	−1.0	1.5	similar
Alkali Soluble Associative Thickener 2	93.3	95.3	−0.9	0	80	1.2	93.4	95.6	−0.9	0	52	1.2	93.8	95.0	−1.0	1.2	similar
HEUR Associative Thickener 1	93.5	95.3	−0.9	+0.2	73	1.2	93.3	95.7	−0.9	−0.4	43	1.3	93.5	94.4	−1.0	0.6	similar
HEUR Associative Thickener 2	93.7	95.0	−0.9	0	79	1.2	93.5	95.3	−0.9	+0.2	48	1.3	93.5	95.2	−0.9	1.3	similar
HEC/HEUR Associative Thickener 1	93.9	95.7	−0.8	+0.3	72	1.1	93.5	95.9	−0.9	0	42	1.3	93.6	95.6	−0.8	1.6	similar
HEC/HEUR Associative Thickener 2	93.4	95.1	−0.8	−0.1	75	1.2	93.6	95.4	−0.9	0	46	1.3	93.6	94.7	−0.9	0.8	similar

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(a) FG = flocculation gradient

very low shear rate portion of the profile (approximately 0-50 s^{-1}), it is theoretically possible to predict the flow and leveling characteristics of each paint system. However, interpretation of this data is very difficult without the use of stress relaxation techniques, as certain rheology modifiers, particularly cellulose derivatives, are known to show distinct yield values at low shear rates. The results obtained generally could be related to the flow and leveling behavior observed, although a much better degree of correlation was obtained using the Brookfield viscometer method of Pierce.

By studying the viscosity of each system at a shear rate of 10,000 s^{-1} (see *Table* 5), it is possible to predict the degree of brush drag and hence the degree of film build attainable. The higher the viscosity, the higher is the film build. Associative thickeners have been claimed to give significantly increased high shear viscosities, relative to cellulosic polymers. In the flat latex system this was indeed found to be the case. However, in the gloss and semi-gloss paints, only Alkali-Soluble Associative Thickener 2 was found to give a significant improvement in high shear viscosity. It has been shown that by modifying the surfactant and/or co-solvent combination present in the paint system, improved high shear viscosities can be obtained.[3-5] No attempts were made to optimize the simple paint formulations used in this evaluation.

Gloss Development And Pigment Flocculation

From the results obtained, the opacity and color of the prepared paints were not significantly affected by thickener selection. However, the level of gloss achieved, particularly in the full gloss system, was markedly influenced by thickener type. The associative thickeners gave superior levels of gloss, particularly high values being obtained with Alkali-Soluble Associative Thickener 2 and HEUR Associative Thickener 2. CMC was found to give the lowest gloss values.

It has been shown that the gloss of paint systems is markedly influenced by the surface roughness of the resultant film.[19] Surface roughness can be considered to comprise of two fractions, namely macro-roughness and micro-roughness. Macro-roughness is the result of sur-

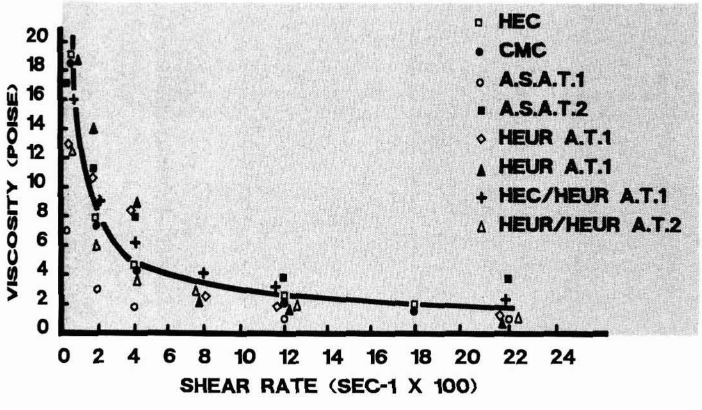

Figure 3—Rheological profiles of flat latex paints

Table 7—Physical Properties of Latex Paints

	Paint System									
	Gloss			Semi-Gloss			Flat			
Thickener	Color Acceptance	Alkali Resistance	pH	Color Acceptance	Alkali Resistance	pH	Color Acceptance	Alkali Resistance	pH	Scrub Resistance
HEC	good	good	8.5	good	good	8.5	good	good	7.6	standard
CMC	good	good	8.5	good	good	8.5	good	good	7.5	similar
Alkali Soluble Associative Thickener 1	good	good	8.8	good	good	8.7	good	good	7.8	similar
Alkali Soluble Associative Thickener 2	good	poor	8.9	good	poor	8.9	good	poor	8.0	similar
HEUR Associative Thickener 1	good	good	8.6	good	good	8.6	good	good	7.6	similar
HEUR Associative Thickener 2	good	good	8.6	good	good	8.6	good	good	7.6	similar
HEC/HEUR Associative Thickener 1	good	good	8.6	good	good	8.6	good	good	7.5	similar
HEC/HEUR Associative Thickener 2	good	good	8.6	good	good	8.5	good	good	7.6	similar

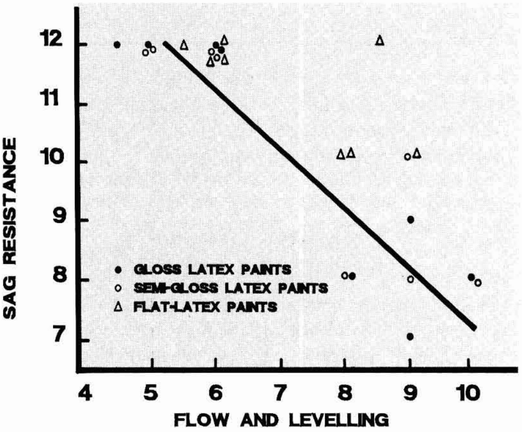

Figure 4—Correlation of sag resistance and flow and leveling data

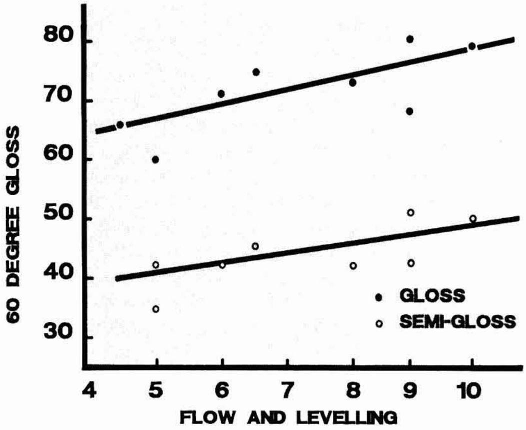

Figure 5—Influence of flow and leveling on gloss

Table 8—Application Properties of Latex Paints

	Paint System											
	Gloss				Semi-Gloss				Flat			
			Roller Application				Roller Application				Roller Application	
Thickener	Brush.	Spat. Res.	1st coat	2nd coat	Brush.	Spat. Res.	1st coat	2nd coat	Brush.	Spat. Res.	1st coat	2nd coat
HEC	fair	1	fair	poor	poor	0	poor	poor	poor	0	poor	poor
CMC	fair	2	fair	poor	poor	2	poor	poor	fair	2	poor	poor
Alkali Soluble Associative Thickener 1	fair	5	fair	poor	fair	4	fair	poor	fair	4	fair	fair
Alkali Soluble Associative Thickener 2	excel.	5	excel.	poor	excel.	4	excel.	fair	excel.	4	excel.	excel.
HEUR Associative Thickener 1	excel.	4	fair	poor	excel.	4	excel.	fair	excel.	5	excel.	excel.
HEUR Associative Thickener 2	excel.	4	excel.	poor	excel.	4	excel.	fair	excel.	4	excel.	excel.
HEC/HEUR Associative Thickener 1	fair	2	fair	poor	poor	1	fair	poor	fair	1	fair	fair
HEC/HEUR Associative Thickener 2	fair	2	fair	poor	poor	1	fair	poor	fair	1	fair	fair

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(a) 5 = zero roller spatter
0 = excessive roller spatter

Brush. = brushability
Spat. Res. = spatter resistance
excel. = excellent

face defects of 1 μm or more, while micro-roughness is attributed to defects of the order of the wavelength of light or less (i.e., less than 0.6 μm).

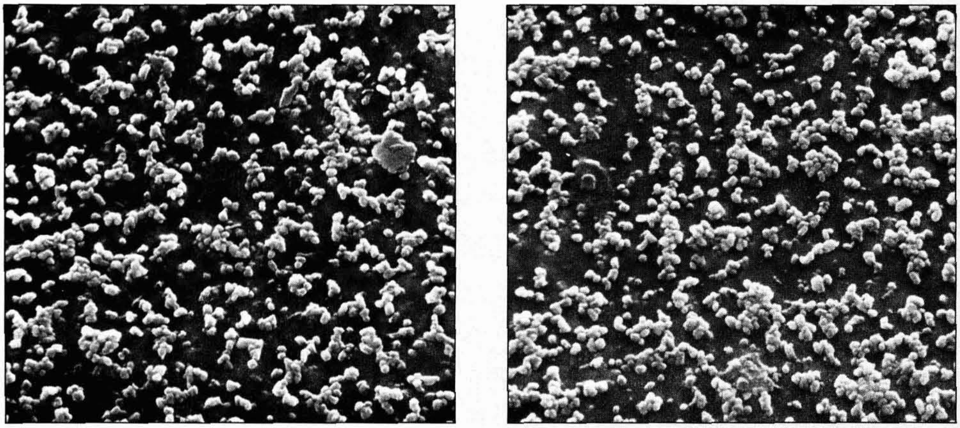
Micro-roughness is primarily influenced by very small surface defects, such as those which result from pigment flocculation. The level of pigment flocculation in all of the gloss and semi-gloss latex systems was quite high (see *Table* 6), tending to reduce the absolute gloss values obtained. Macro-roughness, the result of relatively large surface defects, is influenced to a large degree by the flow and leveling characteristics of the coating. As can be seen in *Figure* 5, the gloss values of the prepared systems could be related to the degree of flow and leveling achieved. However, the factors controlling the gloss of latex paints have been shown to be rather complex,[19] although macroscopic flow is certainly a contributory factor.

Scanning electron micrographs of the etched films confirmed that no differences in the degree of pigment dispersion could be detected, as previously suggested by the flocculation gradient values. Selected examples are shown in *Figure* 6.

Application Properties

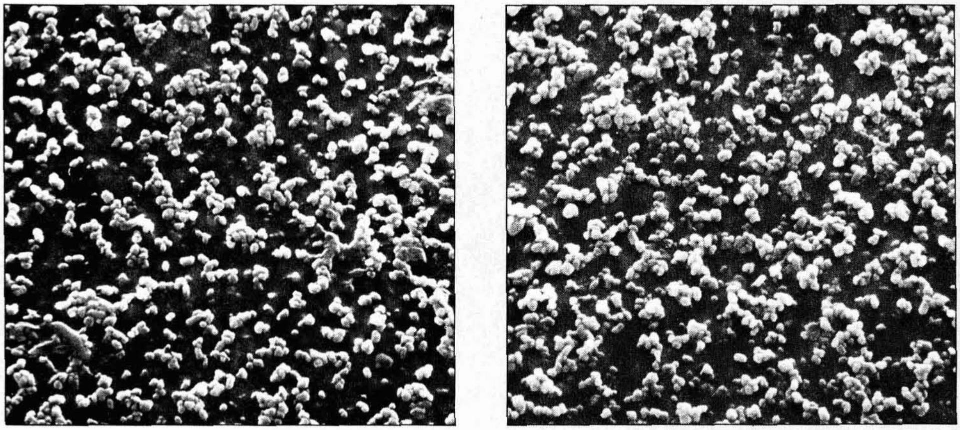
Attempts were made to quantify the application properties of each paint using brush and roller techniques. Although the results obtained could only be assessed using a crude empirical system, certain trends were observed.

As evident in *Table* 8, significant levels of roller spatter were observed with all of the systems based on cellulosic thickeners. The associative thickeners gave much lower levels of roller spatter, in some cases virtually spatter-free systems were prepared. When HEC/HEUR associative thickener combinations were used, the level of roller spatter increased markedly, such that the performance observed was similar to that of the cellulose-based systems. When applied by roller, all paints based on the



(a) HEC

(c) HEUR Associative Thickener 2



(b) Alkali Soluble Associative Thickener 2

(d) HEC/HEUR Associative Thickener 2

Figure 6—Influence of rheology modifier on pigment dispersion in gloss latex paints

Table 9—Cost Efficiency of Rheology Modifiers

Thickener	Gloss	Semi-Gloss	Flat
HEC	standard	standard	standard
CMC	similar	similar	similar
Alkali Soluble Associative Thickener 1	similar	similar	similar
Alkali Soluble Associative Thickener 2	+7.5%	+7.5%	+12.5%
HEUR Associative Thickener 1	+2.5%	+2.5%	+7.5%
HEUR Associative Thickener 2	+5.0%	+5.0%	+10.0%
HEC/HEUR Associative Thickener 1	+1.0%	+1.0%	+4.0%
HEC/HEUR Associative Thickener 2	+2.5%	+2.5%	+5.0%

associative thickeners gave superior flow and leveling, relative to cellulosic based systems, after one coat was applied. Upon application of a second coat, after a drying time of only 15 minutes, a relatively poor level of performance was obtained with all the gloss and semi-gloss systems. In these high glycol content systems, drying times were prolonged and perhaps such a test procedure was too critical. In the flat latex systems, the superior performance of the associative thickeners was largely retained after the application of the second coat.

When applied by brush, all paints based on the associative thickeners gave superior flow and leveling, relative to cellulosic based paints. When a composite cellulosic/associative thickener system was employed, the degree of flow and leveling in the dry film was impaired such that the performance observed was closer to that of the cellulosic, rather than the associatively thickened paint systems.

Cost Efficiency

The cost of the quantity of thickener necessary to achieve the required stormer viscosity was expressed relative to the cost of the same paint system based on HEC. This enabled an indication of the relative cost efficiency of each thickener to be calculated:

$$\%\ \text{Cost Efficiency} = \frac{\begin{array}{c}\text{Cost of paint based}\\ \text{on alternative}\\ \text{thickener}\end{array} - \begin{array}{c}\text{Cost of paint}\\ \text{based on HEC}\end{array}}{\begin{array}{c}\text{Cost of paint based}\\ \text{on HEC}\end{array}} \times 100$$

Thus, the higher and more positive the value, the lower the cost efficiency relative to HEC. The results obtained are shown in *Table* 9.

Alkali-Soluble Associative Thickener 1 and CMC were found to produce paints similar in raw material cost to HEC, although all of the other thickeners produced higher cost systems. While this increased cost perhaps could be justified by the improved performance characteristics achieved, it was felt that some of the cost increases observed in the flat systems would be commercially unacceptable. By utilizing HEC/associative thickener combinations, it was possible to improve the cost efficiency of the system.

Other Properties

Other properties determined included alkali resistance, scrub resistance, and color acceptance. With the exception of the gloss and semi-gloss systems based on Alkali-Soluble Associative Thickener 2, all of the prepared paints were found to have good alkali resistance properties. The alkali sensitivity of these systems could be attributed to the unusually high concentrations of Alkali-Soluble Associative Thickener 2 necessary to give the required stormer viscosity.

Neither scrub resistance nor color acceptance appeared to be significantly affected by the type of thickener present.

CONCLUSIONS

Associative thickeners were found to offer improved performance characteristics in comparison with their cellulosic equivalents in a variety of latex paint systems. Significant improvements in flow and leveling were obtained with the non-cellulosic rheology modifiers, although this was often only accomplished with some loss in sag resistance. Syneresis was also a problem after a period of storage. By manipulating simple viscosity values obtained with a Brookfield viscometer, using Pierce's methods it was possible to largely predict the relative flow and leveling and sag resistance of the prepared paints.

The optical properties of the paints, other than gloss, were unaffected by thickener selection. The differences in gloss observed could be related to the macroscopic flow properties of the paint film. The level of titanium dioxide dispersion, as determined by the flocculation gradient technique and electron microscopy, was also found to be unaffected by thickener selection.

Paints based on associative thickeners were generally higher in cost than their cellulosic equivalents, although this largely could be justified by their improved performance characteristics, particularly in the gloss and semi-gloss systems. By utilizing a cellulosic/HEUR associative thickener combination, only a minimal cost increase resulted. However, inferior performance characteristics were observed, with application properties in particular being adversely affected, relative to systems based on associative thickeners only.

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APPENDIX

	Gloss Latex lb	Semi-Gloss Latex lb	Flat Latex lb
Propylene glycol	90.0	90.0	—
Ethylene glycol	—	—	50.0
Polyacrylate dispersant (25% nv)	10.0	10.0	6.0
Non-ionic surfactant	4.0	4.0	4.0
Defoamer	2.0	2.0	2.0
Titanium dioxide	250.0	250.0	200.0
Calcium carbonate (~ 0.8 μm)	—	50.0	—
Calcium carbonate (~ 25 μm)	—	—	150.0
China clay	—	—	150.0
Water	—	—	203.0
Disperse using HSD and add			
Water	286.6	286.6	222.3
Coalescent	30.0	30.0	8.0
Preservative	1.0	1.0	1.0
Acrylic latex	600.0	550.0	—
Vinyl—Acrylic latex	—	—	275.0
Ammonia	—	—	2.0
TOTAL	1273.6	1273.6	1273.2
Thickener as required, e.g., HEC	4.4	4.4	5.7
PVC	20.0	26.1	55.5
Volume solids	31.0	31.0	33.0
Weight solids	43.0	45.0	52.0

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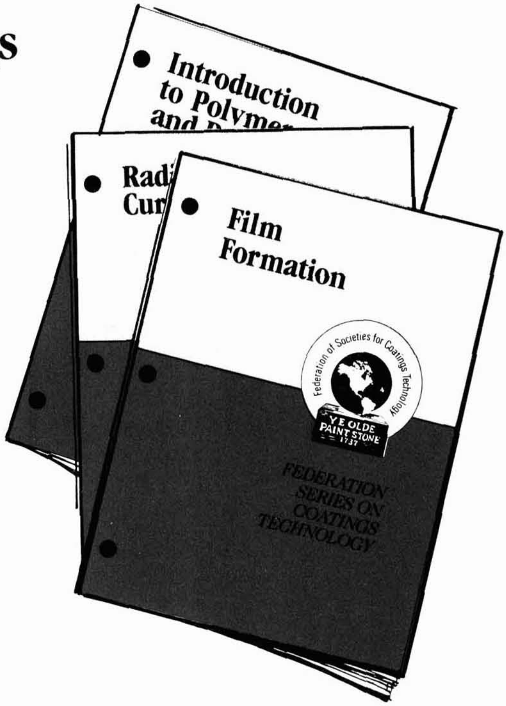

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RS/1, An 'Electronic Notebook'

Timothy D. Costello
E.I.du Pont de Nemours & Co., Inc.

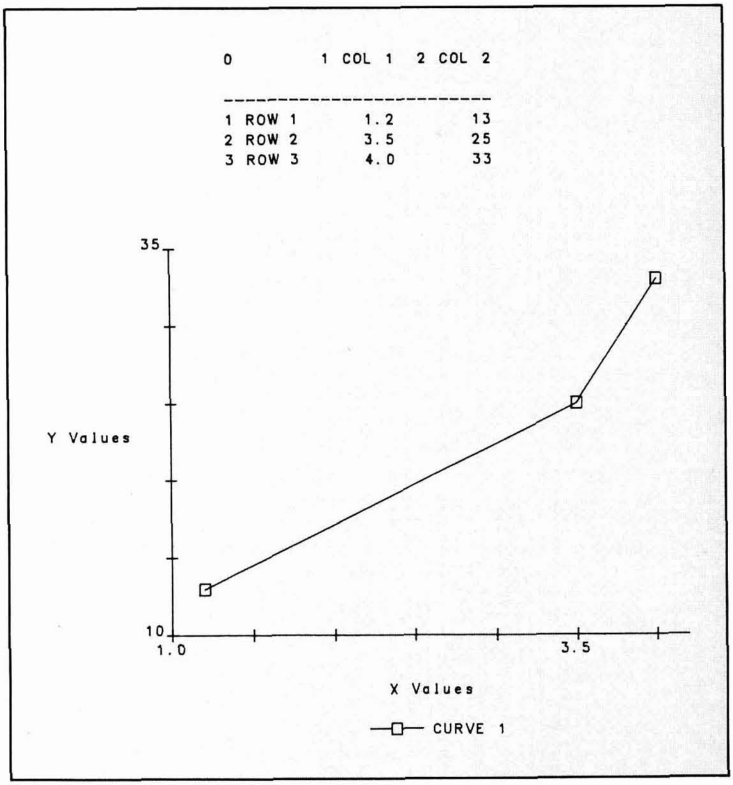
Introduction

RS/1, the Research System, is a software package marketed by Bolt, Beranek, and Newman, available for Digital Equipment Corp. (DEC) VAX, PDP-11, PRO 300 Series, and IBM-AT computers. Intended as a computer aid for the scientist and engineer, it is considered an "electronic notebook," useful not only for organizing and manipulating experimental data, but also as a means of data analysis. This program was designed to be easy to use and, at the same time, flexible enough to be tailored to suit the individual using it.

The ease of use is inherent in the structure of the program. The commands that RS/1 interprets are simple English phrases that describe the desired function. For example, to view a portion of previously entered data, the simple command is:

```
#DISPLAY COLUMNS 3 TO 7
OF TABLE SAMPLE_DATA
```

The manner that RS/1 uses to store data is a simple scheme—data tables. For those who have used one of the many spreadsheet programs, this is a very familiar format.



```
0            1 COL 1   2 COL 2

---------------------------
1 ROW 1         1.2        13
2 ROW 2         3.5        25
3 ROW 3         4.0        33
```

Figure 1—Sample data and graph

Presented at the Annual Meeting of the Federation of Societies for Coatings Technology, in St. Louis, MO, on October 9, 1985.

*Finishes and Fabricated Products Dept., Experimental Station, Wilmington, DE 19898.

Table 1—Results of Experiments Performed as Initial Evaluations of Coatings

ALL_FILMS 70R × 2C

0 Diluent	1 Cratering	2 Toluene Resistance
1 MAK	BAD	BAD
2 MAK		BAD
3 MAK	POOR	GOOD
4 MAK	POOR	GOOD
5 MAK	BAD	POOR
6 MAK	GOOD	GOOD
7 MAK	GOOD	GOOD
8 MAK	POOR	GOOD
9 MAK	GOOD	GOOD
10 MAK	GOOD	GOOD
11 MAK	POOR	GOOD
12 50% BENZ ALC/MAK	BAD	POOR
13 50% BENZ ALC/MAK	GOOD	BAD
14 50% BENZ ALC/MAK	GOOD	BAD
15 50% BENZ ALC/MAK	BAD	GOOD
16 BENZ ALC	GOOD	GOOD
17 BENZ ALC	BAD	BAD
18 BENZ ALC	BAD	BAD
19 BENZ ALC	BAD	GOOD
20 BENZ ALC	BAD	GREAT
21 20% MESIT/BENZ ALC	BAD	GREAT
22 50% MESIT/BENZ ALC	BAD	GREAT
23 80% MESIT/BENZ ALC	BAD	GREAT
24 MESIT	POOR	GOOD
25 MAK	GOOD	BAD
26 20% MESIT/MAK	POOR	GOOD
27 50% MESIT/MAK	POOR	GOOD
28 80% MESIT/MAK	GOOD	GREAT
29 MESIT	GOOD	GREAT
30 MAK	GREAT	BAD
31 20% MESIT/MAK	POOR	GOOD
32 50% MESIT/MAK	POOR	GOOD
33 80% MESIT/MAK	BAD	GREAT
34 MESIT	BAD	GREAT
35 MAK	POOR	GOOD
36 MAK	POOR	BAD
37 MAK	POOR	BAD
38 MAK	GOOD	GOOD
39 MAK	POOR	GREAT
40 MAK	BAD	GOOD
41 20% MESIT/MAK	BAD	GOOD
42 50% MESIT/MAK	BAD	GOOD
43 80% MESIT/MAK	POOR	GREAT
44 MESIT	GOOD	GREAT
45 MAK	BAD	GOOD
46 20% MESIT/MAK	BAD	GOOD
47 50% MESIT/MAK	BAD	GREAT
48 80% MESIT/MAK	BAD	GREAT
49 MESIT	GOOD	GREAT
50 TOL	GREAT	
51 TOL	GREAT	
52 TOL	GOOD	GOOD
53 TOL	GOOD	GOOD
54 TOL	GOOD	BAD
55 TOL	GOOD	POOR
56 TOL	POOR	POOR
57 TOL	POOR	POOR
58 TOL	POOR	POOR
59 TOL	POOR	POOR
60 TOL	POOR	BAD
61 20% BUTANOL/TOL	POOR	BAD
62 50% BUTANOL/TOL	POOR	BAD
63 80% BUTANOL/TOL	POOR	BAD
64 BUTANOL	POOR	BAD
65 TOL/VH-5379	POOR	GOOD
66 TOL/VH-5379	GOOD	GOOD
67 TOL/VH-5379	GOOD	GOOD
68 TOL/VH-5379	GOOD	GOOD
69 TOL/VH-5379	GOOD	BAD
70 TOL/VH-5379	GOOD	BAD

However, this does not mean that RS/1 is just an expensive spreadsheet program. For one thing, the number of allowable cells in an RS/1 table is limited only by the available disk space of the particular computer on which the program is running. Each row and column of a table can be named and that name can be used to refer to the data stored in that row or column, instead of the row or column number. Data can be entered into a table in completely free format: RS/1 automatically interprets the type of information being entered whether it is number, date, or text. Furthermore, each individual cell of an RS/1 table can contain whatever data one might choose to place in it (this includes over 32,000 characters of text or about 15 double spaced typewritten pages). Thus, one can freely intermix text and numbers in a single row or column.

Table 2—Experiments Where Solvents Demonstrated Worst Problems

BAD_FILMS

0 Diluent	1 Cratering	2 Toluene Resistance
1 MAK	BAD	BAD
2 BENZ ALC	BAD	BAD
3 BENZ ALC	BAD	BAD
4 MAK	POOR	BAD
5 MAK	POOR	BAD
6 TOL	POOR	BAD
7 20% BUTANOL/TOL	POOR	BAD
8 50% BUTANOL/TOL	POOR	BAD
9 80% BUTANOL/TOL	POOR	BAD
10 BUTANOL	POOR	BAD

Tables are easily created in RS/1, by the simple command:

#MAKE TABLE SAMPLE_DATA.

A dialogue guides the user in entering the desired values in the proper cells. Once a table has been created, any single cell can be modified, rows or columns added or deleted, or parts of the table copied into another table, all via simple one line commands. A table editor is included which allows the user to immediately observe the changes being made to the table.

Once a data table has been created, a variety of tools built into RS/1 can be used with that data. Probably, the most important of these is the ability to create graphs and charts. Anything from a simple scatter plot to 3-D pictures can be generated from within the program. In its simplest mode, all the user need supply is the row or column of a table containing the values to be used for a graph. The axes generation, labeling, and scaling are all taken care of automatically. Once

Table 3—Rate Constant and Temperature at Which Rate Constant Was Measured

REACTION_RATE

0	1 Temperature	2 Rate Constant, k
1	323	0.01
2	357	0.04
3	403	0.25
4	448	1.90
5	485	10.00
6	500	15.00

again, this is accomplished by a simple command that describes the desired function:

```
#MAKE GRAPH SAMPLE_GRAPH FROM
COL 1 OF SIMPLE_DATA VS COL 2 OF
SIMPLE_DATA.
```

(See *Figure* 1.)

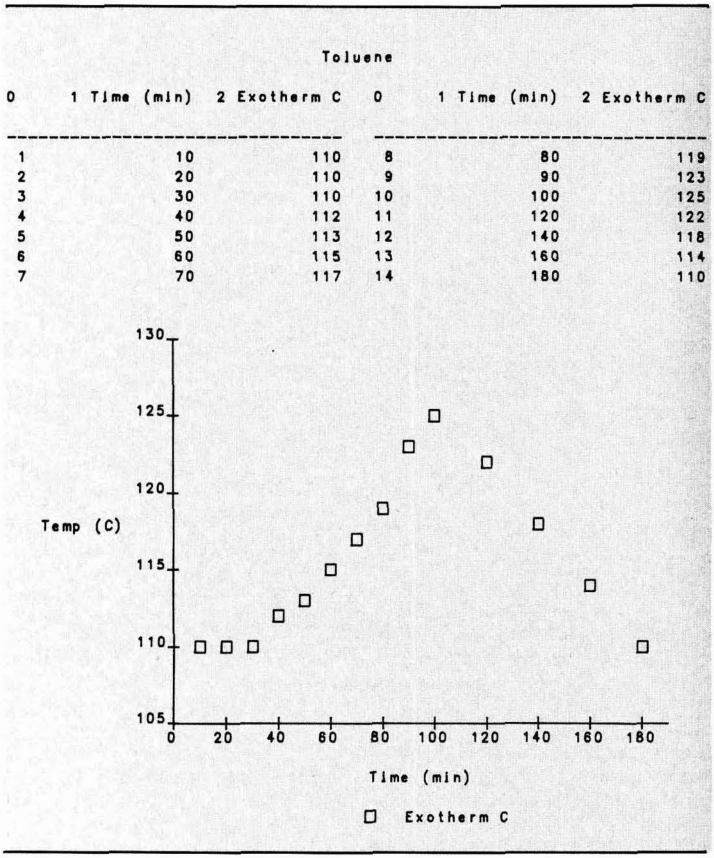
RS/1 also includes a large amount of built-in capability in curve fitting and statistics. This includes the following:

(1) Linear and multiple regression
(2) Polynomial fit
(3) Function fit (with a user supplied function)
(4) Calculations of standard deviations
(5) T-tests
(6) F-tests
(7) One- and two-way analyses of variance.

While RS/1 does not contain all the tools and power built into other statistical analysis packages, such as SAS® or MINITAB®, sold by the SAS Institute, Inc. and Minitab, Inc., respectively, those included are enough for most common needs. For the individual who requires the greater power of SAS, RS/1 includes a method of exchanging data with that package.

Last, but not least, for the user who finds he is often performing repetitive tasks and for the user who would like to exercise a little more control over the RS/1 environment, a programming language is also included. The language is actually just an extension of the simple English commands one types on a single line. A procedure to perform repetitive tasks can be made from a record of the commands that are used to perform that task. Once this conversion has occurred, the procedure can be run at any time with one command. This is similar but not identical to macros used in common spreadsheet programs. For those with programming experience, RPL (Research Programming Language) resembles a combination of PL/1 and PASCAL.

The capabilities of this package are not limited to a single user. There are two more functions contained in RS/1 that are very useful to a member of a project with shared responsibility and data. First, the data table



```
                              Toluene
0     1 Time (min)  2 Exotherm C   0      1 Time (min)  2 Exotherm C
---------------------------------  ---------------------------------
1               10           110   8                80           119
2               20           110   9                90           123
3               30           110  10               100           125
4               40           112  11               120           122
5               50           113  12               140           118
6               60           115  13               160           114
7               70           117  14               180           110
```

Figure 2—Reaction exotherm

can be stored in various subdirectories. Thus, the user can name a subdirectory with a title that represents a selection of data, such as:

Pigment_dispersants
Exotherm_data
References

thereby keeping his electronic notebook segregated in discrete packages of related information. The user can then easily move from area to area as required.

Second, RS/1 has a hierarchical structure for sharing tables and graphs with other RS/1 users. These are called group and public homes. The public home is an area where any user on the same computer can have access to tables and procedures stored there. The group home allows a selected set of users and only that set of users to access and share common data. Therefore, some data can be restricted for use only by those who "have the need to know." The value of this capability is that newly en-

Table 4—Logarithm of Rate Constant and Inverse of Temperature

REACTIO_RATE
Variable Temp fit

0	1 Temperature	2 1/T	3 Rate Constant, k	4 ln(k)
1	323	0.003096	0.01	−4.605170
2	357	0.002801	0.04	−3.218876
3	403	0.002481	0.25	−1.386294
4	448	0.002232	1.90	0.641854
5	485	0.002062	10.00	2.302585
6	500	0.002000	15.00	2.708050

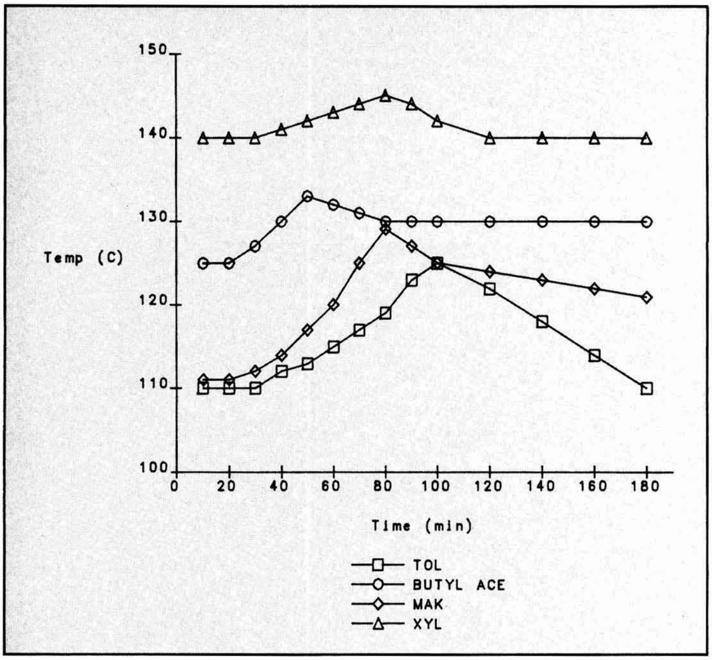


Figure 3—Solvent vs exotherm

tered or altered information is immediately available to all members of a group when any single individual enters or changes it. This can help avoid many of the problems inherent in physically distributing multiple copies of information to members of a group.

This introduction to the capabilities of RS/1 is only a partial representation of all its functions. More information can be obtained directly from the vendor or by consulting the documentation for RS/1.

Examples

This section contains examples of the use of RS/1 in a coatings R&D environment. These examples are generalized for the sake of presentation and in the hope that any scientist or engineer might understand the utility of RS/1 for his or her own applications.

Example 1: The first example is a representation of the method we all use for empirical determination of the best method or conditions for performing a given experiment. Scientists often find themselves in the position of reviewing a large mass of similar experiments to decide which of them represents the optimum conditions for experimental success. For example, when a coating scientist examines a new composition for a finish, two of the important parameters to examine are the smoothness or cratering seen when a certain composition is sprayed and the solvent resistance of that cured coating.

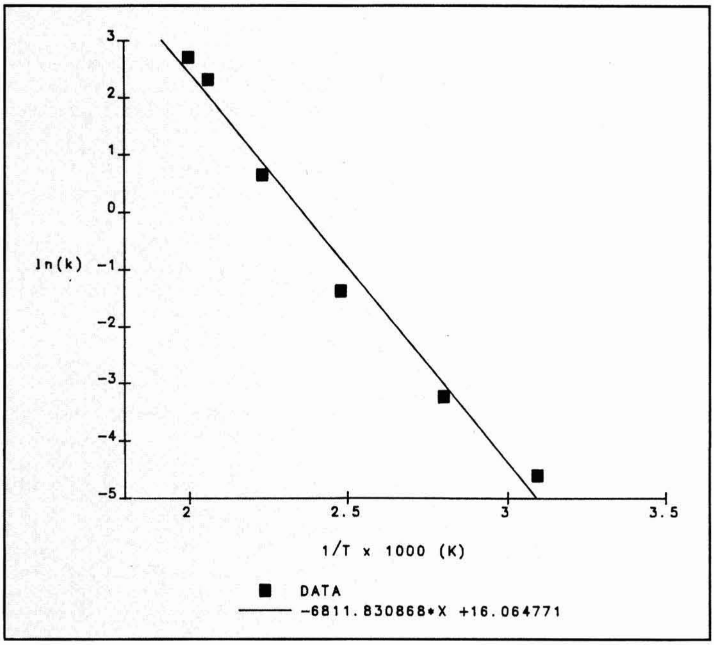


Figure 4—Kinetic graph

Table 1 contains the results of many experiments performed as a first evaluation of an imaginary coating. The factor which is changing in each experiment is the solvent used to dilute the resin before application. Cratering and toluene resistance are rated according to an empirical four value scale of bad, poor, good, and great. Suppose one wanted to determine which solvents demonstrated the worst problems in these experiments. RS/1 can simplify this task through the creation of a table of those experiments where toluene resistance is the worst and cratering is also bad or poor. The following command creates *Table* 2, which is a subset of the 70 experiments of ALL_FILMS (*Table* 1):

```
#MAKE TABLE BAD_FILMS FROM
TABLE ALL_FILMS WHERE COL
'TOLUENE RESISTANCE'= 'BAD' AND
(WHERE COL 'CRATERING'='POOR' OR
WHERE COL 'CRATERING'='BAD').
```

This type of data reduction is something we all do with or without a computer program. This example just demonstrates the ease by which a common data set can be re-examined in a qualitative way, using the built-in abilities of RS/1. The benefit is that RS/1 can perform this "bookkeeping" much faster than pencil and paper.

Example 2: The previous example did not rely on actual numeric results from an experiment. RS/1 can manipulate numbers just as well as words. Consider the case of a scientist who wants to follow the temperature profile of a resin cook as a function of the solvent in which the polymerization is run. A scientist creates a table such as Reaction_Exotherm (see *Figure* 2).

Of course this scientist wants a graphical representation of the time profile of this reaction. By typing the command:

```
#MAKE GRAPH EXOTHERM_GRAPH
FROM COL 1 OF REACTION_EXOTHERM
VS COL 2 OF REACTION_EXOTHERM
```

the graph (*Figure* 2) is drawn on the terminal, as he/she watches. If this scientist also has the same data entered for this reaction in other solvents, he/she can go ahead and add this data to the same graph. The important thing is that RS/1 will automatically scale each experiment to fit on the same graph (*Figure* 3).

Example 3: Of course RS/1 does not limit the user to just plotting provided data. Consider the case of examining the results of a variety of experiments in which the rate constant of a reaction has been determined, at a variety of temperatures. The activation parameters for this reaction can easily be determined by making a graph out of the rate and temperature data followed by determining the slope and intercept of a line fitted to the experimental points. *Table* 3 contains the basic data of rate constant and the temperature at which that rate constant was measured. To determine activation energy and entropy, the logarithm of the rate constant and the inverse of the temperature are plotted against one another. These values are provided by the following RS/1 commands:

```
#INSERT COL 2 OF KINETIC_DATA;
SET COL 2 TO LOG (COL 1)
#COL 4 OF KINETIC_DATA = 1/(COL 3)
```

The new values, placed in *Table* 4, can be used to make the graph KINETIC_GRAPH. Then the FIT LINE routine can be used to calculate the least squares line which best fits the experimental data. This routine allows the user to add the fitted line directly to the graph, along with the equation of the line. The FIT LINE routine also provides goodness of fit and residuals data for the fitted points in separate tables (see *Figure* 4).

Example 4: Procedures are a more difficult subject to present by example. Their uses are only limited by the ingenuity of the RS/1 user. Procedures have been developed to do such things as calculate Tg of a polymer, data-logging with error correction, and interactive routines that determine the amounts of reagents to use in a specific reaction.

```
/* Maintainance of the Appointment Calendar
   Requires a table named Calendar in your RS1 area
   with columns Date, Time, and Subject */
PROCEDURE;
        CALL ERASE;/* Erase the Screen */
        TABL='CALENDAR';
/* Main Menu of Options of the Procedure */
        Type "Choices Are:
                A    Enter New Appointment
                B    Look at Schedule of Appointments
                E    Exit the Program";
/* Get the users choice and go to that part */
        CHOICE=GETTEXT('What is Your Choice?');
        IF CHOICE='B' THEN GOTO VIEWSCHED;
        IF CHOICE='E' THEN GOTO LEAVE;
/* Part that enters a new appointment in the calendar */
NEWDAT: TYPE "To Exit Input Type 'Return' for the Date.";
        DO WHILE TRUE;
                D=GETDATE('What is the Date of Your Appointment?',TRUE);
                IF D=EMPTY THEN DOEXIT;
                T=GETTEXT('What Time is Your Appointment?');
                S=GETTEXT('Enter the Subject and Location of Your Appointment
');
                CALL NEWROW(TABL,D,T,S);
        END;
        SORT TABLE(TABL) BY COL 0;/* Places the calendar in order by date */
        CALL ERASE;
/* Ask if the user would like to see part of the schedule after entering a new d
ate */
        IF YESANSWER('Do You Want to Look at Part of the Schedule?', FALSE)
          THEN GOTO VIEWSCHED;
          ELSE GOTO LEAVE;
/* Section for viewing schedule for a certain date */
VIEWSCHED:
        DA=GETDATE('Schedule for what Date?');
/* Do loop required so that no error is generated when a date is not in calendar
 */
        DO J=1 TO LASTROW(TABL);
                IF (ROW J COL 0 OF TABLE(TABL)=DA) GOTO DISDATE;/* If the date i
s in the table */
        END;
        GOTO NOSCHED;
DISDATE:
        DISPLAY TABLE(TABL) WHERE COL 0=DA COLWIDTH 50;
/* Just repeats the loop if another date is asked for */
QUERY:
                IF YESANSWER("Do You Want to See Another Date?", FALSE)
                THEN GOTO VIEWSCHED;
/* If after seeing schedule for a date a new appointment is to be scheduled */
        IF YESANSWER('Would You Like to Schedule a New Appointment?', FALSE)
          THEN GOTO NEWDAT;
          ELSE GO TO LEAVE;
/* Trap for a date that is not in the table calendar */
NOSCHED:
        TYPE "You Have Nothing Scheduled for That Day";
        GOTO QUERY;
/* The exit routine that gets rid of any dates older than the current date */
LEAVE:
        ADATE=DATE();
        LTROW=LASTROW(TABL);
        DO I=1 TO LTROW;
                IF (ROW I COL 0 OF TABLE(TABL)<ADATE) THEN
                        DO;
                           DELETE ROW I OF TABLE(TABL);
                           I=I-1;
                        END;
                IF (I=LASTROW(TABL)) DOEXIT;
        END;
END;
```

Figure 5—RPL procedure for appointment scheduling

As one example of a procedure which shows that RS/1 can be used for things other than just scientific data, an RPL procedure for appointment scheduling is presented (see *Figure* 5). This routine allows the user to review future appointments and schedule new appointments. It is used in concert with another procedure as a tickler file that informs the user of any appointments during the present day, when the user first logs onto the computer in the morning. The procedure also deletes those entries which have passed by so that the table in which appointments are stored does not become overly large. Furthermore, since the appointment data is stored in a table, the entire set of appointments can be easily displayed for examination of "the big picture."

Limitations and Deficiencies

RS/1 is a good program for use as an electronic notebook or recordkeeper. However, this is not to say that it is without faults. In this section, some of the problems, as seen by the author, are presented.

Table 5—Abbreviations in RS/1

0 Command	1 Abbreviations
1 DISPLAY	DIS
2 DIRECTORY	DIR
3 COLUMN(S)	COL(S)
4 DELETE	DEL
5 PROCEDURE(S)	PROC(S)
6 EQUAL	EQ, =
7 NOT EQUAL	NE, <>
8 GREATER THAN	GT, >
9 GREATER THAN OR EQUAL	GE, >=
10 LESS THAN	LT, <
11 LESS THAN OR EQUAL	LE, <=

One of the attractions of RS/1 is that the commands to the program are in English. However, once a user becomes familiar with the program, he would like to be able to use abbreviations and shortened command lines. RS/1 allows only the abbreviations shown in *Table* 5. Furthermore, commands must be exactly syntactically correct. If a mistake is made in a long command line, the entire line must be re-entered, which can be very frustrating. BBN maintains another scientific program for biomedical applications called PROPHET. It incorporates some command line spelling and syntax correction ability. One wonders why this same capability was not included in RS/1.

When a mistake is made on a command line, only one error message is displayed:

```
# THIS IS THE MOST COMMON ERROR
MESSAGE COMPILATION ERROR:
COMMAND TERMINATED
PREMATURELY (AT <#>):
(COMMAND):1 THIS
IS THE <#> MOST COMMON
ERROR MESSAGE
```

This certainly is not much help to the novice or the experienced user. One particularly frustrating problem involves an inconsistency in command line interpretation by RS/1. When the user wants to display a single cell of a table, the command can take on two forms:

```
#DISPLAY COL X OF ROW Y OF
TABLE EXAMPLE
vs
#TYPE COL X ROW Y OF
TABLE EXAMPLE
```

Notice that the correct use of the DISPLAY command must include the OF between row and column descriptors but that the TYPE command signifies an error if the OF is included!

Documentation for RS/1 is another area that could be improved. All of the commands that RS/1 accepts are covered in the documentation, but frequently, details must be inferred from descriptions of another somewhat related command. Descriptions of common errors are completely lacking in the documentation. Many of us use the index as the way of looking up information in program manuals. The RS/1 indices are not very well cross-indexed and, in some cases, the page numbers referred to are incorrect.

For all the power that RS/1 includes in graphics, the 3-D capabilities leave something to be desired. The ability to plot single points in 3-D space is not available. Axes labeling is also not available nor can the user add labels or notes to a 3-D graph. An option with 3-D's is that an equation can be used to create a three dimensional surface. However, something as simple as the equation of a sphere is not conveniently represented.

Conclusions

These examples of the use of RS/1 necessarily have been very generalized. The intention was to show that this package can be of help in an environment where many related experiments must be compared, such as a coatings lab. Furthermore, the ability to control the flow of information, for example, through the use of group and public homes is a decided benefit. Due to its ease of use and customizability, RS/1 can help not only the coatings scientist but anyone involved in information intensive work.

Addendum

In the time since this presentation was originally prepared, BBN has released Revision 2 of RS/1. Included in this update of the program are fixes which make the program much easier and faster to use. Two of the problems mentioned in the original presentation have been addressed. RS/1 now includes command line editing, allowing the user to recall the most recently entered command and correct any mistakes, eliminating the need to completely re-enter a long, complicated command. The error messages are now much more informative, giving the user a much better idea of the corrections necessary on the command line.

Furthermore, RS/1 now includes the capability of plotting a second, independent Y-axis on a graph and contour plots can also be produced. In addition, the statistical package has been expanded, a method to create abbreviations for commands has been included, and the on-line help facility is much faster, albeit with some loss in completeness. Overall, BBN has succeeded in making an already useful program all the more beneficial.

Open Forum is an experiment in communications designed to give readers the opportunity to share creative concepts in all aspects of coatings. Suggested topics include color, formulation and manufacture, testing, and selection of raw materials. These "tricks of the trade" need not be prepared formally such as research papers, but should, however, be thorough in their preparation and presentation. Submissions should be sent to "Open Forum" Editor, Journal of Coatings Technology, 1315 Walnut St., Philadelphia, PA 19107.

Society Meetings

BALTIMORE .... APR.

"Higher Solids Coatings"

The meeting opened with the presentation of a 25-Year Pin to Jim Mislak, of Lenmar, Inc., by Society President Frank Gerhardt, of Bruning Paint Co.

Announcements of upcoming activities were then read. The Cleveland Society's Annual Technical Conference "Advances in Coatings Technology" will be held April 29 to May 1, 1986 at NASA's Lewis Research Center, Cleveland, OH.

On June 3-4, 1986, the Federation is co-sponsoring a Symposium on "Automotive Color Control" at the Michigan Inn, Southfield, MI, with the Detroit Colour Council, and the Manufacturing Council on Color and Appearance.

Ted Grumbine, of Lenmar, Inc., Society President-Elect and Chairman of the Technical Steering Committee reported on the status of the Society's two technical working groups. He noted that samples have been distributed for viscosity measurements by the Testing Correlative Group.

Mr. Grumbine then asked John Kurnas, of Sherwin-Williams Co., to provide a report of the findings from the Pocket Computer Group. Mr. Kurnas explained that the pocket computer is a portable type approximately the size of a calculator. It fits into a printer containing a rechargeable battery and requires thermal paper. The computer also contains an interface to a cassette recorder for storing programs and data.

As applicable uses for the pocket calculator, he listed scaling (or reallocating) a formula to a desired quantity; VOC calculations; resins blending (viscosity—% solids); temperature conversion (C↔F); FMC 2 color difference; and steam pressure determinations. He also noted that the particular pocket computer his committee had reviewed sold for approximately $100.

The guest speaker for the evening was Jimmy E. Bassett, of Eastman Chemical Products, Inc. Mr. Bassett spoke on "ADJUSTING THE ELECTRICAL RESISTANCE OF HIGHER SOLIDS COATINGS THROUGH SOLVENTS SELECTION."

He began by stating that many coating users are adopting electrostatic spray techniques to apply high solids coatings since increased transfer efficiency results. To obtain maximum transfer efficiency, he explained, a higher solids coating should have the proper electrical resistance to match the particular application equipment being used.

Next, Mr. Bassett detailed methods for adjusting electrical resistance. One popular method he noted was solvent selection. High solids coatings have more formulating restraints (low VOC, low viscosity, and package stability) than conventional systems, he said. Therefore, adjustments in electrical resistance via solvent selection are more critical with higher solids coatings.

A discussion of how electrical resistance is measured was then given by the speaker. The unit of measure is the megohms, he stated, and the high solids, electrostatically-applied coatings should be formulated to have a resistance in the range of 0.1-1.0 megohms.

Concluding his presentation, Mr. Barrett explained that ketones and alcohols have very low resistivity. Their low electrical resistance can be offset when they are blended with an ester and/or hydrocarbon solvents to achieve the correct megohms.

ED COUNTRYMAN, *Secretary*

BIRMINGHAM .... MAR.

"Improvement of Solvent and Water-Based Coatings"

The technical presentation was given by R. Wolf, of Sandoz Chemicals. Dr. Wolf described "IMPROVEMENT OF SOLVENT AND WATER-BASED COATINGS BY THE USE OF UV STABILIZERS."

Dr. Wolf stated that all synthetic polymers were affected by UV radiation, causing degradation. UV absorbers had been recognized and used by the early 50's to prolong the life of surface coatings.

Next, the speaker discussed the classes of UV absorbers. They are 2 hydroxybenzophenones and oxalanilides. He also outlined the classification of the UV spectrum. UVA (315-400 nanometers) causes some polymer degradation, will tan not burn; UVB (280-315 nanometers) is responsible for most polymer damage and causes sunburn; and UVC (below 280 nanometers) is found only in sunlight in outer space.

The results of natural weathering and accelerated weathering tests were then compared by Dr. Wolf. Comparison of exposure times for two coat automotive metallic paints were discussed, with the conclusion that the best combination of absorbers was 2.8% oxalanilide 3206 and 1% Hals 3052.

Lastly, the speaker told of the use of UV absorbers in acrylic alkyd water-based wood coatings and the effects of accelerated weathering.

DAVID M. HEATH, *Secretary*

BIRMINGHAM............. APR.

"Role of Loss Adjusters"

Mr. John Gray, of Thomas Howells, delivered a talk on "THE ROLE OF THE LOSS ADJUSTER."

An explanation of the difference between a loss assessor and loss adjuster opened the presentation. Mr. Gray noted that assessors supply information in the case of a claim, whereas the adjuster is responsible for determining the reimbursement.

Next, a case study in which a factory had been burnt down was explored by Mr. Gray. He emphasized that reimbursement may not be sufficient to keep a company in business after a serious fire, particularly if the following points are ignored: good security, particularly during non-working hours; listing of key personnel's telephone numbers located outside the worksite; training of a "special operations team" to be mobilized quickly; an agency of contractors; duplication of records; arrangements with similar manufacturing companies, who would be prepared to subcontract their work in an emergency; and protection of expensive or difficult-to-replace machinery.

DAVID M. HEATH, *Secretary*

CHICAGO .... APR.

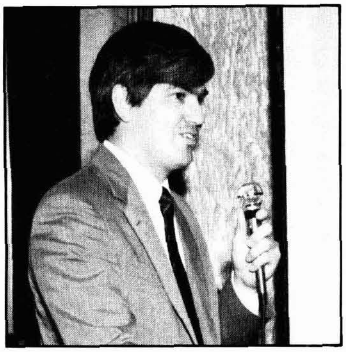
"Tools and Rules of Adhesion Science"

The Nominating Committee presented the following slate of officers for the year 1986-87: Vice-President—Ray Cziczo, of Reliance-Universal, Inc.; Secretary—Evans Angelos, Kraft Chemical Co., Inc.; and Treasurer—Kevin P. Murray, DeSoto, Inc.

Doug Rahrig, of S.C. Johnson & Sons, provided a technical talk on "TOOLS AND RULES OF ADHESION SCIENCE."

Dr. Rahrig began by explaining that commercial applications of adhesion science range from cases where no adhesion is the goal, to situations where permanent adhesion is critical.

The mechanism of adhesion and techniques for evaluating adhesion were then addressed by the speaker. He explained that



CHICAGO SOCIETY technical speaker, Doug Rahrig, discussed "Adhesion Science" at the April meeting.

the mechanisms can range from simple surface wetting to mechanical interlocking and covalent chemical bonding. The techniques, he noted, can vary from simple fundamental tests to complex techniques affected by a number of variables in addition to adhesion. Despite the diversity, there are some universal rules which adhesion scientists have found useful in attacking almost any adhesion problem.

Dr. Rahrig concluded his presentation by offering a survey of factors influencing adhesion and contrasted it with some of the errors commonly made in doing adhesion research.

Ray Cziczo, *Secretary*

CLEVELAND.............APR.

"Micro-Electronic Components for Biomedical Uses"

Officers elected for 1986-87 include: President-Elect—Richard Eley, Glidden Coatings & Resins, Div. of SCM Corp.; Secretary—R. Edward Bish, Jamestown Paint & Varnish Co.; Treasurer—Illona Nemeth, Sherwin-Williams Co.; and Society Representative—Fred G. Schwab, Coatings Research Group, Inc.

Science Fair awards were presented to two local students whose projects were related to coatings. Jennifer Luko, an eighth-grade student at Holy Family Academy, received an award for her project on Corrosion of Steel, and Debbine Cyerniawski, an eleventh-grade student at Magnificat High School, received an award for her study of Epoxy-Amine Reaction Mechanism. Each youngster received a check in the amount of $100.

Upcoming events were then announced. The Society's 29th Annual Educational Symposium will be held April 29-May 1, 1986, at the NASA Lewis Research Center in Cleveland, OH. On June 3-4, 1986, the Detroit Society is co-sponsoring a symposium on "Automotive Color Control."

Joseph Chadbourne, the first speaker for the evening, discussed "The Cleveland Teacher Internship Program."

Mr. Chadbourne explained that the program places high school and college science faculty in industrial positions for a temporary period of time. The teachers work on projects related to their discipline in a business environment. Business benefits from the teachers' fresh perspective and problem solving skills. The program's main beneficiaries, stated Mr. Chadbourne, are the students who benefit from their teachers' "on the job experience" and new knowledge and skills.

In closing, Mr. Chadbourne reviewed the main goals of the program: to provide classroom teachers with actual industrial experience; to provide summer seminars for science teachers; and to provide new classroom material and/or activities for the teachers to incorporate in their curriculum the following year.

The technical speaker was C.C. Liu, of Case Western Reserve University. Dr. Liu discussed "Organic and Inorganic Coatings Used in the Microelectronic Industry."

Commencing the program, Dr. Liu issued a challenge to the polymers and resins industry to formulate a biomedical protective coating or encapsulate for devices imbedded in the body which will give the necessary 10-15 year protection. He explained that those devices currently available have protective coatings which are deficient in the following areas: resistance to gas permeation; ion migration; and moisture diffusion.

Next, the speaker described historic materials offering advantages and disadvanages of each. He then highlighted the current materials being used for microelectronic components, including epoxies, silicone rubbers, acrylics, fluorocarbons, glasses, ceramics, and metals (tantalum).

Dr. Liu concluded by focusing on two key problems today: interfacial expansion of dissimilar layers and corrosion at the lead wire interface.

Richard R. Eley, *Secretary*

Federation Membership Anniversaries

50-Year Members

New York

Arthur I. Nortman, Nortman Associates, Inc.

25-Year Members

New York

Peter Baganakis, Inmont Corporation.
James E. Borner, Spraylat Corporation.
R.E. Chamberlin, Valspar Corp.
Arnold J. Eickhoff, Consultant.
Israel Feld, Nuodex, Inc.
George Hausman, Cellofilm Corporation.
Emil Heisz, Martin Paint & Chemical Corp.
George F. Kovach, Duralac Inc.
Sherman Steinberg, North American Paint Corp.
Frank Navas, Jr., Long Island Paint & Chemical Co.

New England

Sid Lauren, California Products Corporation.

LOS ANGELES...........APR.

"High Solids"

Don Curl, of E.T. Horn Co., reported on the progress of the Environmental Legislative Regulatory Advocacy Program (EL RAP). He told that the Legislative Committee of Southern California Paint and Coatings Association meets the first Thursday of every month. The Committee is comprised of 14 members from the San Diego and South Coast districts. Committee member Lloyd Haanstra will act as liaison to the Architectural Coatings Task Force, which EL RAP supports financially and Ray Robinson, of Robinson & Associates, will serve as the Legislative Advocate of EL RAP, stated Mr. Curl.

EL RAP is using the Turnis and Houston lobbying firm to monitor new bills affecting the industry, he explained. The firm is now registered as the S.C.P.C.A.'s Lobbyist in Sacramento, CA, and is being sent to meet with Senators and Assembly offices on specific bills. Mr. Curl also noted that EL RAP has cemented its ties with National Paint and Coatings Association, Washington, D.C. NPCA Executive Director Larry Thomas attended the March meeting of S.C.P.C.A. and spoke to the group.

Mr. Curl also discussed the involvement of EL RAP with the EPA and 380/250 Rule. He told that some companies may receive letters from the EPA and that he should be made aware of this. EL RAP is working with EPA District 9 and trying to put together a group of contractors to visit. The 380/250 Rule is not settled, he stressed. EPA has agreed to hold off on the inspectors and citations until they have had a better look at the problem.

EL RAP has become involved with Major Paint's problem concerning their Carson aerosol plant being cited as a manufacturer. Ray Robinson explained to people at the South Coast District that the Carson plant is only a filler so that they backed off their citation.

Mr. Curl also discussed the upcoming bill in Sacramento regarding household hazardous waste and how EL RAP is working with the Clorox Co., Oakland, CA, and NPCA.

Lastly, Mr. Curl urged those firms that have not contributed to EL RAP to do so.

Lloyd Haanstra, of Guardsman Chemical Co., gave an environmental report. He discussed a subject that arose at the meetings between EL RAP and S.C.A.Q.M.D., VOC determinations differ between the South Coast District's lab and the Paint Manufacturer's lab. Mr. Haanstra noted that there is a tremendous amount of difference regarding the VOC number, depending who runs the tests. Margil Wadley, head of the Laboratory Dept., at South Coast District is proposing to the Executive Officer that the formula for VOC be changed to eliminate the complex denominator. Mr. Haanstra expressed pessimism regarding the formula change but noted that it would favor the industry. A discussion will take place between Ray Robinson, certain industry people, and the South Coast Executive Officer to see if it would be advisable for each paint company to seek the variance on the VOC or whether something can be done to cover the whole industry.

Rule 1107 was also discussed by Mr. Haanstra. The South Coast District, under the leadership of Monty Price, soon will conduct workshops to change this rule. The changes are similar to those of the Bay area. An industry meeting will be scheduled prior to the workshops to organize a stand.

A Technical Committee report was delivered by Dodwell De Silva, of Major Paint Co. He noted that there are presently 14 members on his committee. Three projects are active: Spontaneous Combustion of Surface Coatings—Bud Jenkins; Crystalline Silica as a Grinding Aid in High Speed Dispersion—Kirk Oakes; and Evaluating Block Resistance Using the BYK Mallinckrodt Block Tester. Our Society has presented a paper at the last four FSCT Annual Meetings, said Mr. De Silva, and the Committee is hopeful that at least one of the active projects can be presented in Atlanta in 1986. This will take a great deal of work, so volunteers for either laboratory or library research would be helpful, he stressed.

John Plant, of John K. Bice Co., Inc., reported on the Employment Committee. He explained that he receives calls from all over the western states for prospective employees. His committee works only with those individuals presently unemployed, not those working and interested in changing positions. No fee is involved for either the prospective employee or employer. In 1985, the Committee removed 26 people from the unemployment list. Of the 26, eight secured jobs in the Adhesives, Inks, Aeronautical, and Plastics field; three obtained factory jobs; and 15 found employment as Quality Control and Formulators, and Retail and Raw Materials Sales. He mentioned that some found jobs out of the state.

Society Secretary Melinda Rutledge, of Allo Chemical Co., reported that the New England Society will be conducting a spring symposium, "Launching the New Revolution—Compliance in the 21st Century," May 15-16, 1986, at the Sheraton Lexington, Lexington, MA.

Richard Benton, of Spencer Kellogg Products/NL Chemicals, spoke on "CLOSING THE GAP WITH HIGH SOLIDS."

Mr. Benton discussed the role of high solids coatings in meeting current air quality regulations. He provided data on the differences between calculated and determined VOC of baked high solids coatings noted some of the recent advances in this area.

He concluded his presentation by offering some approaches for VOC conforming air dry coatings and suggesting some formulation tips.

Q. What kind of dryers would you recommend for the overnight hardness development of chain stopped alkyd?

A. Our general recommendation is cobalt, calcium, and zirconium combinations.

Q. Can you achieve adequate film thickness control with high solids coatings and current application equipment?

A. I would say, yes. We have gone to places that manufacture rotary equipment, airless electrostatic, and various types of equipment like that. We sprayed our baking enamels and kept our film thickness to about 1½ mils or under 2 mils, which we consider satisfactory.

MELINDA K. RUTLEDGE, *Secretary*

LOUISVILLE .... APR.

"Legal Liability"

Louis Holzknecht, of Devoe & Raynolds, was elected incoming Secretary of the Society.

Society President Joyce St. Clair, of Porter Paint Co., announced the May 20, 1986, meeting would be a joint one with LPCA.

Ronald R. VanStockum, Jr., an Environmental Attorney, gave a presentation on "LEGAL LIABILITY."

Mr. VanStockum spoke on recent court cases involving legal liability of the corporate manager and employee in environmental matters. He gave several examples of managers and employees being sued and found criminally guilty of improperly disposing of hazardous wastes. He noted that juries and courts are not very sympathetic with violators, even though the improper disposal may not have been intentional.

LARRY F. PITCHFORD, *Secretary*

MONTREAL .... APR.

"Hyper Dispersants"

J.H. Hampton, of ICI America spoke on "HYPER DISPERSANTS."

The presentation began with an explanation of the dispersion process. Mr. Hampton stated that the object of the process is to break pigment agglomerates to a finer particle size. Pigment particles are not produced smaller than one micron because the particles experience hydrophilic aggregation forces which bring particles together to form aggregates of particle size of around fifty microns. To achieve maximum tinctoral strength, it is necessary to break down the aggregates to a finer particle size. The dispersion process proceeds in the following stages: wetting (air around pigment particles must be replaced by the medium); agglomeration size reduction (done by mechanical action); and stabilization (balancing the Van Der Waals forces. The new surface should be wetted out).

Mr. Hampton defined surfactants as compounds that lower the interfacial tension between solids and liquids. They are available in two forms: oil-loving (nonpolar) and water-loving (polar). The ratio between these two forms or the HBL value in any surfactant composition determines its behavior. The higher the HBL value, the more water soluble the surfactant is going to be. The lower the HBL value, the more solvent soluble it will be.

Hyper dispersants are composed of anchoring groups and polymeric solvatable chains, Mr. Hampton told the audience. In media containing organic pigments which are less polar or even non-polar synergistic hyper dispersants tend to enhance their polarity. Hyper dispersants with weak anchoring groups tend to absorb effectively to organic pigments such as carbon blacks. He then mentioned that a carbon chain which is too short is not effective, particularly with organic pigments. However, if the polymeric chain is too long it may cause destabilization. When the polymeric chain is wetted by the polymeric medium, it should be compatible with the polarity of the solvent.

Finally, the speaker listed the benefits of the hyper dispersants includng major viscosity reduction, reduction of solvent content, increase in tinctorial strength; reduction of milling time; better rheological properties; dispersion in solvent alone; dispersion in common solvent and let down in different paint systems; reduction of stock holding, and increase in production by a factor of 2 or 3.

L.N. ISSA, *Secretary*

NEW ENGLAND........... APR.

"Zircoaluminate Coupling Agents"

Society Secretary Gail Pollano, of Polyvinyl Chemical Industries, read the nominations for officers for the 1986-87 year: President—Maureen Lein, Davidson Rubber Co.; Vice-President—Kevin Mulkern, Truesdale Co.; Treasurer—Gail Pollano; and Secretary—Roger Woodhall, California Products Co.

President Charles Hoar, of Union Chemicals Div., informed the membership of the upcoming questionnaire from the Professional Development Committee which will be distributed to each FSCT member. He urged everyone to fill it out. He then mentioned the upcoming events: the Cleveland Society's "Advances in Coatings Technology" Annual Technical Conference, April 29 to May 1, 1986, and the Federation's Symposium on "Automotive Color Control" to be held June 3-4, 1986.

Ms. Lein, Society Program Committee Chairman, reported that all plans are proceeding along smoothly for the symposium "Launching the New Revolution-Compliance for the 21st Century" to be held May 15-16, 1986, at the Sheraton Lexington.

Larry Cohen, of Cavedon Chemical Co., spoke on "THE CHEMISTRY OF ZIRCOALUMINATE COUPLING AGENTS AND THEIR APPLICATIONS."

Dr. Cohen began his presentation by stating that zircoaluminate coupling agents are an entirely new approach for surface modifiers. With the synergistic use of both zirconium and aluminum, he explained that the coupling agents are considered more inorganic, and metal and pigment reactive than either their silane or titantate counterparts.

The components of zircoaluminates include a zirconium building block, an aluminum building block, and an organofunctional group. They are supplied at 20-25% active matter in one of the following types of solvents: lower alcohols, methylether of propylene glycol, and propylene glycol. He added that certain products are stable in water.

Benefits of the coupling agents were also discussed by the speaker. He noted that the zircoaluminate surface modifiers are able to undergo reaction with virtually all inorganic pigments and filler, attain viscosity reductions exceeding 80% of 63 weight % dispersion, improve color strength, and reduce settling as well as chalking and pigment separation in applied coating.

In conclusion, Dr. Cohen stressed mixing is critical, incorporation of the zircoaluminates into coating systems requires high shear agitation for 10-15 minutes.

Q. After mixing under high shear, will the material form a two phase system eventually?

A. With high shear mixing, you will get a one phase, stable system.

Q. Are the zircoaluminates effective at reducing the viscosity of reactive pigments such as zinc phosphate or zinc chromate?

A. With zinc phosphate, we have found compatible chemistry; we can't speak for the chromates.

GAIL POLLANO, *Secretary*

NORTHWESTERN......... APR.

"Polyester Resin Synthesis Techniques" and "Economic Outlook"

Honored guests in attendance included Federation President-Elect Carlos E. Dorris, of Jones-Blair Co., and Editor of the JOURNAL OF COATINGS TECHNOLOGY, Robert Ziegler.

Mr. Dorris stressed the importance that the Federation places on manufacturing, technical progress, and education. He explained that the Federation consists of 7000 members, all volunteers, and that the foremost function of the Federation is to disseminate information gathered from the Societies, JCT, newsletters, seminars, and Annual Meeting.

Mr. Ziegler stressed the Federation's emphasis on education, especially continuing education. One way in which the Federation assists in education is through seminars, he explained. Two upcoming seminars are "Special Purpose Coatings" to be conducted in Pittsburgh, PA, May 13-14, 1986, and "Symposium on Automotive Color Control" to be held in Southfield, MI, June 3-4, 1986.

The Federation also promotes education through its publications. Mr. Ziegler then told of the new Federation Series on Coatings Technology. Three units are scheduled for publication this summer: "Film Formation," "Polymers and Resins," and "Radiation Cured Coatings."

Mr. Ziegler then announced that Dr. Zeno W. Wicks had been selected as the 1986 Mattiello Lecturer at the Federation's Paint Industries' Show and Annual Meeting to be held November 5-7, at the Georgia World Congress Center, Atlanta, GA.

Lastly, Mr. Ziegler noted that the Professional Development Committee is sending out a survey to obtain a concept of who the members are, what their needs are, and what the Federation can do for them. He urged the membership to complete the survey form.

Dr. Frank N. Jones, Professor of Polymers & Coatings at North Dakota State University, thanked the Society for the donation of $1000 to NDSU, stating that 40 scholarships are now available. He reported that the Society scholarship program was very much appreciated and that NDSU has 25-30 individuals completing coating courses each year. He also told that NDSU is hiring a new professor this year. The University will conduct two courses in June of 1986. "Coatings Science" will be held June 16-27, and "High Solids and Radiation Curable Coatings" will be held June 2-6.

The first speaker of the evening was James Hood, of Eastman Chemical Products, Inc. He explained "POLYESTER RESIN SYNTHESIS TECHNIQUES FOR ACHIEVING LOWER VOC AND IMPROVED COATING PERFORMANCE."

High solids systems of today will not meet tomorrow's demanding VOC requirements, Mr. Hood told the members. One feasible approach to higher solids coatings is lowering the molecular weight of the polyester resins. He stressed that there is an optimum point reached in lowering the molecular weight below which the VOC of the enamel actually increases.

Mr. Hood discussed staging next. Typically, one-stage resin cooks are used, leading to high levels of unreacted monomers and oligomers which are volatile during VOC determinations, he explained. Work was done on several resins to determine the effect of staging the addition of the branching monomers. In all cases, two-staging the TMP monomer resulted in a more narrow molecular weight range and it minimized the amount of low-molecular weight fractions in the resin. He explained that 90% of what is to be accomplished can be completed in two stages.

In closing, he stated that better coatings resins must be designed and built, resins that are made from the quality building blocks that we have available today. They must be combined to make cleaner, neater, and purer resins that will do a better job in the end product.

Peter Glanville, of Dain Bosworth, delivered the second presentation, "ECONOMIC OUTLOOK: WHERE THE STOCK MARKET,

INTEREST RATES, AND INFLATION ARE HEADED."

Mr. Glanville told of four factors affecting the economy: disinflation, cheap money, declining dollar, and consumer remaining in good shape. Capital spending has been sluggish, he reported, but we are looking for corporate profits to show a good rebound this year. Interest rates are down and expected to drop even further.

The speaker concluded by listing guidelines for personal stock investment: take advantage of periods of maximum pessimism and maximum optimism, sell greed/buy fear; learn to be patient, don't expect overnight riches; sell losers, keep winners; and be a bargain hunter.

JOAN B. LAMBERG, *Secretary*

PIEDMONT . . . . MAR.

"Complying High Solids Coatings"

Society Past-President Phil Wong, of Reliance Universal, Inc., announced that Society and Federation Honorary member Dr. Edmund O. Cummings was selected as the recipient of the "Dave Boulder Outstanding Service Award."

Society President Michael S. Davis, of Byk-Chemie, made an announcement concerning the Southern Society seminar. He also reported that a letter was received from the Federation indicating that the Society membership is up 11 members from 1985.

Educational Chairman, Bob Matejka, of Reliance Universal, Inc., reported that attendance at the "Mini-Symposium" reached 27. He also mentioned that Dr. Hurwitz is once again the coordinator of summer employment of students and requested that all companies hire students if possible. He then explained that Dr. Hurowitz is working on a course for "Organic Chemistry of Coatings" hopefully to be given in the fall of 1986.

President Davis reported that the Technical Committee which had no chairman, will be co-chaired by Lee Guiney, a student, and retired member Jim Boulder. These two men will work on the "Words and Phrases for the Furniture Industry" project, explained Mr. Davis.

The guest speaker was Jacqueline Reynolds, of Exxon Chemicals. She provided a presentation on "SOLVENTS POINT THE WAY TO COMPLYING HIGH SOLIDS ACRYLIC COATINGS."

Through the use of slides, Mrs. Reynolds discussed transfer efficiency of solvents vs molecular weight of the resins. She also addressed the relationship various solvents have with electrostatic spray systems.

CHARLES T. HOWARD, *Secretary*

Constituent Society Meetings and Secretaries

BALTIMORE (Third Thursday—Martin's Market Square, Towson, MD). ED COUNTRYMAN, Bruning Paint Co., 601 S. Haven St., Baltimore, MD 21224. Virginia Section—Fourth Wednesday, Ramada Inn-East, Williamsburg, VA.

BIRMINGHAM (First Thursday—Strathallan Hotel, Birmingham, England). D.M. HEATH, Holden Surface Ctgs. Ltd., Bordesley Green Rd., Birmingham B9 4TQ England

CHICAGO (First Monday—meeting sites vary). EVANS ANGELOS, Kraft Chemical Co., 1975 N. Hawthorne Ave., Melrose Park, IL 60160.

CDIC (Second Monday—Sept., Jan., Apr., June in Columbus; Oct., Dec., Mar., May in Cincinnati; and Nov., Feb. in Dayton). SAMUEL KRATZER, Potter Paint Co., P.O. Box 265, Cambridge City, IN 47327.

CLEVELAND (Third Tuesday—meeting sites vary). RICHARD ELEY, Glidden Coatings & Resins, Div. of SCM Corp., D.P. Joyce Research Center, P.O. Box 8827, Strongsville, OH 44136.

DALLAS (Thursday following second Wednesday—Executive Inn, near Lovefield Airport). FREDERICK T. BEARD, Glidden Coating & Resins, Div. of SCM Corp., 1900 North Josey Ln., Carrolton, TX 75006.

DETROIT (Fourth Tuesday—meeting sites vary). JOANNE CEDERNA, Inmont Corp., 26701 Telegraph Rd., Southfield, MI 48086.

GOLDEN GATE (Monday before third Wednesday—Alternate between Sabella's Restaurant on Fisherman's Wharf and Francesco's in Oakland, CA). KARL SAUER, Pfizer, Inc., MPM Div., 776 Rosemont Rd., Oakland, CA 94610.

HOUSTON (Second Wednesday—Sonny Look's, Houston, TX). JAMES TUSING, PPG Industries, Inc., P.O. Box 1329, Houston, TX 77251.

KANSAS CITY (Second Thursday—Cascone's Restaurant, Kansas City, MO). STEVEN JOHNSON, Cook Paint & Varnish Co., P.O. Box 389, Kansas City, MO 64141.

LOS ANGELES (Second Wednesday—Steven's Steak House, Commerce, CA). MELINDA RUTLEDGE, Allo Chemical Co., P.O. Box 443, Ontario, CA 91761.

LOUISVILLE (Third Wednesday—Breckinridge Inn, Louisville, KY). LARRY F. PITCHFORD, Reynolds Metals Co., P.O. Box 3530, Plant III, Louisville, KY 40232.

MEXICO (Fourth Thursday—meeting sites vary).

MONTREAL (First Wednesday—Bill Wong's Restaurant). W WILDE, Hoechst Canada, Inc., 4045 Cote Vertu, Montreal, Que., Canada H4R 1R6.

NEW ENGLAND (Third Thursday—LeChateau Restaurant, Waltham, MA). GAIL POLLANO, Polyvinyl Chemical Industries, Inc., 730 Main St., Wilmington, MA 01887.

NEW YORK (Second Tuesday—Landmark II, East Rutherford, NJ). JOHN W. BURLAGE, Pacific Anchor Chemical, 14 Ridgedale Ave., Cedar Knolls, NJ 07927.

NORTHWESTERN (Tuesday after first Monday—Jax Cafe, Minneapolis, MN). JOAN B. LAMBERG, Horton-Earl Co., 750 S. Plaza Dr., St. Paul, MN 55120.

PACIFIC NORTHWEST (Portland Section—Tuesday following second Wednesday; Seattle Section—the day after Portland; British Columbia Section—the day after Seattle). JOHN DALLER, McCloskey Corp., 4155 N.W. Yeon, Portland, OR 97210.

PHILADELPHIA (Second Thursday—Dugan's Restaurant, Philadelphia, PA). THOMAS L. PETA, J.C. Osborne Chemicals, Inc., P.O. Box 1310, Merchantville, NJ 08109.

PIEDMONT (Third Wednesday—Howard Johnson's, Brentwood Exit of I-85, High Point, NC). CHARLES HOWARD, DeSoto, Inc., P.O. Box 22105, Greensboro, NC 27420.

PITTSBURGH (First Monday—Montemurro's, Sharpsburg, PA). MARK TROUTMAN, Bradley Paint Co., 608 W. Crawford St., Connellsville, PA 15425.

ROCKY MOUNTAIN (Monday following first Wednesday—Bernard's, Arvada, CO). MARCY S. BAUGH, Hutson Industries, 60 Tejon St., Denver, CO 80223.

ST. LOUIS (Third Tuesday—Engineers Club). JAMES N. MCDERBY, F.R. Hall & Co., 6300 Bartmer Ind. Dr., St. Louis, MO 63130.

SOUTHERN (Gulf Coast Section—Third Thursday; Central Florida Section—Third Thursday after first Monday; Atlanta Section—Third Thursday; Memphis Section bi-monthly on Second Tuesday; Miami Section—Tuesday prior to Central Florida Section—R. SCOTT MCKENZIE, Southern Coatings & Chemicals, P.O. Box 2688 Sumter, SC 29150.

TORONTO (Second Monday—Cambridge Motor Hotel). HANS WITTMAN, BASF Canada Ltd., 10 Constellation Ct., Rexdale, Ont., Canada M9W 1K1.

WESTERN NEW YORK (Third Tuesday—meeting sites vary). JEAN L. LUCK, Pratt & Lambert Inc., Powder Coatings Div., P.O. Box 22, Buffalo, NY 14240.

PIEDMONT .... APR.

"Zircoaluminates for Enhanced Adhesion"

Announcements from Federation headquarters were made concerning the "Automotive Color Control" Symposium to be held June 3-6, 1986, and the Southern Society "Alfred Hendry Award" for the best student papers on coatings technology. The award is a $1,000 cash prize and will be administered and judged by the Federation Education Committee.

A Society Education Committee report was given by Chairman Bob Matejka, of Reliance Universal, Inc. With respect to the summer employment program, 13 students have filed applications and their potential for industry has been assessed. In regard to the "Organic Chemistry of Coatings" course scheduled for the fall in 1986, there have been some added delays and when these problems are resolved, they will be reported, stated Mr. Matejka.

The technical speaker Larry Cohen, of Cavedon Chemical Co., discussed "CHEMISTRY AND THE USE OF ZIRCOALUMINATES FOR ENHANCED ADHESION OF METAL SUBSTRATES."

Mr. Cohen explained how to increase the adhesion of various products to metallic surfaces by retarding corrosion. He noted that enhancement of adhesion to metal surfaces increases with improved salt spray resistance and by retarding corrosion.

Using a slide presentation, Mr. Cohen showed how to incorporate the zircoaluminates into various systems and cited performance advantages.

CHARLES T. HOWARD, *Secretary*

PITTSBURGH............. APR.

"Blocked Isocyanates"

The Nominating Committee, headed by Society Past-President Clifford Schoff, read its nominations for the officers of the 1986-87 year: Vice-President—Mark D. Troutman, Bradley Paint Co.; Secretary—Rich Marci, Royston Laboratories; and Treasurer—Ed Threlkeld, Ashland Chemical Co.

An Education Committee report was given by Secretary Mark Troutman, in the absence of Chairman Don Boyd. On March 24, 1986, John Dahl, of Matthews International, and Gerry Ward, attended the Buhl Science Fair to act as judges for the award to be given to the project which they felt best exemplified a project related to the coatings industry.

Mr. Troutman also reported that a volunteer is needed to attend a dinner sponsored by the Hugh O'Brien Youth Foundation in conjunction with the Western Pennsylvania Leadership Seminar.

Cliff Schoff is scheduled to make another presentation at Chatham College. He will address the members of the American Chemical Society Student Affiliates.

Lastly, Mr. Troutman discussed the Committee's program of sponsoring undergraduate research projects at local universities. He reported that Don Boyd had sent a letter to FSCT headquarters requesting matching funds for the monies allocated by the Society for the projects during the 1986-87 year.

James W. Rosthauser, of Mobay Chemical Corp., provided the technical presentation. Dr. Rosthauser discussed "BLOCKED ISOCYANATES IN COATINGS."

He began by defining a blocked isocyanate, noting that the main requirement is that the bond of an isocyanate adduct, upon heating, will break apart, regenerating isocyanate and blocking agents. They came into being because their predecessor, the two component polyurethane coatings, were moisture sensitive and had a limited pot life.

Dr. Rosthauser continued by describing the materials from which isocyanates are made. He included isocyanurate compounds and aliphatic biurets. They are typically mixed with polyol coreactants such as acrylics, esters, polyethers, and are used to help alkyds dry a bit faster. Unlike the diisocyanates themselves, the products made from these raw materials have low vapor pressure and are relatively ecologically harmless. The diisocyanate monomers are known to cause lung irritation.

The different types of blocking agents, their chemistry, and application were also addressed by Dr. Rosthauser. The first of these was the phenol blocked isocyanate, the original blocked isocyanate to be used by the industry. It was readily accepted on the market place, cured at reasonable temperatures, and exhibited more flexible type coatings. It proved to be an advantage in the winding of wire onto a spool where cracking had been a problem.

The second type of blocking agent is the caprolactam isocyanates. He explained that these materials react with polyols at a relatively high temperature of 160°C. The coatings are used in the powder coatings sheet metal finishing operations as well as coatings for gas cylinders. They are also being used to coat glass bottles in order to make them shatter-proof. The auto industry uses the coatings to formulate chip-resistant coatings for the lower parts of the auto body.

The third type of compound, described by Dr. Rosthauser is the Meldrum's acid blocked polyisocyanate, also called isopropylidene malonate. These react at low temperatures with alcohols and amines and have been useful in the development of water reducible materials.

In conclusion, Dr. Rosthauser described how the blocked isocyanates provide a solution to the problem of curing electrodeposited films. He stated that crosslinking could not be accomplished with the use of a conventional type melamine or urea formaldehyde since they require the addition of a strong acid catalyst necessary to cure a formaldehyde mechanism. Since the resin itself is cationic, he explained, it will become basic as it is baked. In the end, acid is driven off and what is left behind is amine functionality which is ideal for use with blocked isocyanates since they cure with basic compounds.

MARK D. TROUTMAN, *Secretary*

ST. LOUIS................ MAR.

"Education Night"

Society Manufacturing Committee Chairman, Elliot Lanson, of Lan Chem Inc., announced that May 20, 1986, would be Manufacturing Day. A mailing with full details will soon be sent.

Educational Committee Chairman James N. McDerby, of F.R. Hall & Co., welcomed everyone to the Society's Eleventh Annual Education Night. Nine teachers were in attendance.

Mr. McDerby announced that Rich Okragly, of Carboline Co., and Denny Cahill, of Archway Chemical & Supply, Inc., would be attending the Science Fair on April 18 to award cash prizes. Mr. McDerby asked the teachers present to help in promoting coatings related projects to their students.

Next, Mr. McDerby thanked Drs. Stoffer, Collier, and Van De Mark for their effort in making the technical seminar a huge success.

On March 29, 1986, 13 individuals took a test based on the seminar to determine the winner of the Ralph Gatti Award. Society Treasurer Howard Jerome, of Spatz Paints, Inc., and Eileen Gatti, Mr. Gatti's widow, presented checks to the following winners: First Place—Allen Thorpe, of Thermal Science was awarded $300; Second Place—John Ladage, of Carboline Co., was awarded $150; and Third Place—Jane Dove, of Dow Chemical Corp., was awarded $50.

The technical presentation for the evening was given by Drs. Jim Stoffer, Harvest Collier, and Mike Van De Mark, of the University of Missouri-Rolla. They described "COATINGS PROGRAMS AT THE UNIVERSITY OF MISSOURI-ROLLA."

Course requirements and opportunities available to Rolla graduates were highlighted by Dr. Stoffer. Challenges being addressed by Rolla students which have an immediate impact on the industry were described by Dr. Collier. Data from a student project on an acrylic polymer, was presented by Dr. Van De Mark.

JAMES N. MCDERBY, *Secretary*

Elections

KANSAS CITY

Associate

Bonnell, Ronald—S.C. Johnson & Son, St. Louis, MI.

Retired

Tucker, John H.—Leawood, KA.

LOS ANGELES

Active

Alilhan, Shahid—Mattel Toys, Hawthorne, CA.
Lunzer, David L.—Union Carbide Corp., Torrance, CA.
Sandoke, Alpheus—Cardinal Industrial Finishes, So. El Monte, CA.

NEW ENGLAND

Active

Simkus, Rooney—Ipso, Inc., Mansfield, MA.
Waack, Richard—Ceramics Process System, Lexington, MA.

Associate

Franklin, Gene—Byk-Chemie USA, Palisades Park, NJ.
Kilelee, Kevin E.—Union Carbide Corp., Somerset, NJ.
Mullin, Richard C. II—C.K. Mullin Inc., Braintree, MA.

NEW YORK

Active

Sugerman, Gerald—Kenrich Petrochemicals, Inc., Bayonne, NJ.

Associate

Armbruster, David C.—Armbruster Associates, Summit, NJ.
Legnetti, Paul A.—CIBA GEIGY Corp., Ardsley, NY.

NORTHWESTERN

Active

Burrows, Benjamin E.—Rexnord Chemical Prod., Minneapolis, MN.

Associate

Wright, Michael D.—American Hoechst, Wood Dale, IL.

PACIFIC NORTHWEST

Associate

Jakosh, Bob—NL Chemicals, Bellevue, WA.
Williamson, F. Dale—Olympic Home Care Prod., Seattle, WA.

PIEDMONT

Associate

Coulston, Mike—Megachem, High Point, NC.
Davis, Donald L.—Chemarco, Greenville, SC.
Scheick, David L.—Sun Chemical Corp., Matthews, NC.
Walsh, James P. Jr.—Kinsmen Corp., Atlanta, GA.

Educator/Student

Bowkley, Herbert L.—Appalachian State Univ., Boone, NC.
Herman, Harvey B.—UNC-Greensboro, Greensboro, NC.

TORONTO

Associate

McDermott, Terry—International Pigments & Colours, Toronto, Ontario.

AFFILIATED

Cirisoglu, M. Can—Dewilux A.S., Bornova/Izmir, Turkey.

AN INFRARED SPECTROSCOPY ATLAS

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896 Pages—Over 1,400 Spectra—Over 1,500 References

This revised and expanded 896-page book (by the Chicago Society for Coatings Technology, 1980) contains a compilation of 1433 spectra, fully indexed, of materials commonly used in the coatings industry. Spectra of many recently marketed materials are included, as well as examples of Fourier transform infrared spectra.

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Birmingham B31 3PG, England

People

Gary A. Welp has been named Vice-President—Corporate Technical Manager for the McCloskey Corp., Philadelphia, PA. He will be based in Philadelphia and will have overall responsibility for the company's research and development, technical and laboratory personnel, and community and quality assurance programs. Mr. Welp is member of the Pacific Northwest Society.

Hitox Corporation, Corpus Christi, TX, has appointed **Sara M. Robinson** to the post of Vice-President and Sales Manager for the firm. Ms. Robinson will continue with the duties she performed as National Sales Manager, a position she has held since joining the company in 1984. She is a Past-President of the Piedmont Society.

William A. Boyd, President of Vail Rubber Products Corp., has been elected to a one-year term as President of the National Coil Coaters Association. He succeeds **James S. Smith,** President of Roll Coater Inc.

Also elected Vice-Presidents were **Francis D. O'Neill,** of Teledyne Rodney Metals and **Robert W. Moorman,** of Glidden Coatings and Resins Div., SCM Corp. Re-elected Secretary/Treasurer was **Robert C. Parsons** of Reynolds Metals Co. Elected to three-year terms as Directors were **Walter Culin,** Pre Finish Metals, Inc.; **George A. Fletcher,** Metal Koting; **James C. Schwartz,** Parker Chemical Co., and **John H. Geyer,** Total Tech Associates.

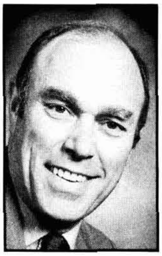
Glenn S. Peacock has been named Laboratory Director for Jamestown Paint & Varnish Co., Jamestown, PA.

Union Carbide Corp., Danbury, CT, has announced the appointment of **Dr. Nathan L. Zutty** as President of its Solvents and Coatings Materials Div. Currently Chairman of Union Carbide Europe, Dr. Zutty is replacing **H.W. Lichtenberger**, who was appointed President of the firm's Chemicals and Plastics Business Group. Dr. Zutty has served in various management positions in research and development, operations, and as a division Vice-President. He became President of the Coatings Materials Div. in 1979 and of the Specialty Chemicals Div. in 1982. He has been Chairman of Union Carbide Europe since 1984.

G.A. Welp

S.M. Robinson

D.P. Leipold



J. Bernie

Dianne P. Leipold has been named Technical Service Representative for the Water Soluble Polymers Group of Hercules Incorporated, Wilmington, DE. Ms. Leipold most recently served as Senior Chemist for the firm. She is the author of several technical articles, and her recently awarded gel toothpaste patent is for a transparent dentifrice composition containing hydrophobically modified hydroxyethyl cellulose, a water-soluble thickener.

As a result of the recent realignment of the Coatings and Additives Group of its Specialty Chemicals Co., Hercules Incorporated, Wilmington, DE, has announced a series of changes. The sales organization, directed by **John P. Strode,** has been divided into three regions. They are headed by: **Hanspeter Esslinger,** Midwest Sales Manager; **K. Allen Groh,** Southern and Western Sales Manager; and **Peter J. Wilson,** Northeastern Sales Manager. Product management is directed by **John E. Montgomery.** Product Managers are **Nobal E. King** for nitrocellulose and **John E. Plowright** for peroxides, hydroperoxides, lubricants, plasticizers, and polyols. Product Supervisors are **Maurice J. Sadowsky** for EC/EHEC and flatting agents and **Melinda L. Zwickert** for specialty elastomers, rubber additives, and companion products.

In addition, market development programs are directed by **Dr. Norman C. MacArthur.** Technical sales service, including laboratory programs and related activities, is managed by **John P. DeVido.** Export Sales Manager is **Hans O. Esser.**

Angus Chemical Co., Northbrook, IL, has appointed **Robert J. Frederick** to the position of Vice-President of sales. He formerly served as Vice-President of planning and development.

The Paint Research Association, Middlesex, England, has appointed **John Bernie** to the post of Managing Director. For the past three years, he has served as Head of the National Corrosion Service with responsibility for maintaining this government advisory service to industry and for the development of major collaborative research programs.

Tnemec Company, Inc., Kansas City, MO, has elected **Albert C. Bean, Jr.** to the position of Chairman. **Peter F. Cortelyou** was named President and Chief Operating Officer; **Harold Neu** was named Vice-President, finance; and **Robert M. Bauer** was appointed Vice-President, research and development. In addition, **George M. Fay** was named Special Projects Manager for the company.

James N. Elliott, Field Secretary of the National Paint and Coatings Association, has retired after more than 21 years with the association. Mr. Elliott received a Master's Degree in Business from Georgia Institute of Technology. He will be succeeded by **Ken Zacharias,** Manager of Safety and Chemical Regulations.

DeSoto, Inc., Des Plaines, IL, has appointed **Dick Thomas** to the position of Senior Chemist for the Appliance Group. In his new position, Mr. Thomas will be responsible for the research and development of new electrocoat systems for the appliance industry. He is a member of the Chicago Society.

H.D. Wenstrup has been elected President of Chemcentral Corporation, Chicago, IL. He succeeds **R.T. Hough,** who will continue as Chairman of the Board and Chief Executive Officer.

Kenneth C. Scott has joined A.E. Staley Manufacturing Co., Decatur, IL, as Director of Chemicals Research and Development. Prior to joining the firm, he was Director of Performance Chemicals and Chemical Engineering Research for BASF Wyandotte Corp.

Eugene Elzy has been appointed President of the Emulsion Polymers Div. of Reichhold Chemicals, White Plains, NY. He formerly served as Executive Vice-President of the division.

AZS Corporation, Atlanta, GA, has appointed **Talmadge Murphey** to the position of Vice-President of its Lakeland, FL, operations. Mr. Murphey has been employed with AZS for 17 years.

In addition, AZS Corporation has appointed **Lawrence Wasowski** to the position of Technical Manager of the Coatings and Adhesives Div. Mr. Wasowski will be responsible for managing the research and development efforts relating to epoxy hardeners, polyisocyanate curatives, and trade sales latex polymers for paints, caulks, and adhesives.

Allen Thorpe, of Thermal Science, Inc; **John Ladage,** of Carboline Co.; and **Jane Dove,** of Dow Chemical Co., were awarded the St. Louis Coatings Society's Ralph Gatti Award at the "Education Night" meeting of March 26. Nine local high school teachers attended the meeting to hear Drs. Jim Stoffer, Harvest Collier, and Mike Van DeMark discuss the coatings program at the University of Missouri-Rolla. The Gatti Award commemorates the name of the St. Louis Past-President and is for outstanding technical contributions to the coatings industry. Each participant is given a test on coatings technology. The prizes are $300, $150, and $50.

Wally Meyer, President of McWhorter, a wholly-owned subsidiary of the Valspar Corporation, Minneapolis, MN, has also been named a Vice-President of Valspar. Mr. Meyer joined the firm in 1978 and was promoted to President of McWhorter upon its acquisition in 1981.

George C. Todd has joined the Color Division, Ferro Corp., as a Sales Representative for the Inorganic Pigments Group. He will be responsible for the sale of inorganic pigments (mixed metal oxides, cadmium and camouflage) in the midwest region.

John S. Babiec, Jr. has been appointed Director of Performance Minerals, Research and Development, for the Engelhard Corp., Iselin, NJ. His responsibilities include developing new products for the paper, plastic, rubber, and paint industries.

Stephen G. Pinney, President of S.G. Pinney & Associates, Inc., Port St. Lucie, FL, was elected Chairman of ASTM Committee D-33 on Protective Coating and Lining Work for Power Generation Facilities. He will serve a two-year term.

Lisa J. Rowe has joined Daniel Products Co., Jersey City, NJ, as Director, New Business Development. Ms. Rowe will develop and implement diversification strategies including programs for expanded commercial development of current product lines and acquisition of new technologies, products, and businesses.

Meetings/Education

18th Biennial Symposium & Show to Be Sponsored By the Western Coatings Societies, Feb. 23-25

The Western Coatings Societies will hold the 18th Biennial Symposium and Show from February 23-25, at the Monterey Convention Center, in Monterey, CA. Jointly sponsored by the Los Angeles, Golden Gate, Pacific Northwest, and Rocky Mountain Societies, the theme of the program is "Technical Excellence and Innovations for '87."

The event is the largest regional paint industry show, with exhibits of raw materials and equipment. Exhibits Chairman Barry Adler, of Royell, Inc., has announced those exhibitors who have contracted for space to date. They include: A.J. Lynch & Co., Arco Chemical Co., Armenco, Ashland Chemical Co., BASF Corp., Beltron Corp., Berol Chemicals, Brown Boxenbaum Co., Buckman Laboratories, Byk-Chemie, U.S.A., Cabot/Cab-O-Sil Div., Cargill, Inc., Celanese Specialty Resins, CEM Corp., Chicago Boiler Co., Clawson Tank Co., Cosan Chemical Corp., Daniel Products Co., Diamond Shamrock Corp., Disti, Inc., Drew Chemical Co., E.I. du Pont de Nemours & Co., E.T. Horn Co., Eastman Chemical Products, EM Chemicals, Engelhard Min. & Chem. Div., Epworth Mfg. Co., Inc., Exxon Corp., Fawcett Co., Inc., Grefco, IBNC., Halox Pigments, Harrisons & Crosfield, Heubach, Inc., Hitox Corporation, Ideal Mfg. & Sales Co., J.M. Huber Corp., Liquid Controls Corp., Lorama Chemicals Inc., Miller Paint Equipment, Milton Roy Co./Diano Color, Minolta Corp., Mobay Chemical Corp., *Modern Paint and Coatings,* Morehouse Industries, Inc., McCloskey Varnish Co., Netzsch Inc., NL Industries, Inc., Norton Containers, P.T. Hutchins Co., Ltd., Pacific Coast Chemical Co.

Also exhibiting at the Show will be Pacific Dispersions Inc., Pacific Micro Software, Pfizer Minerals, Pigments & Metals, Polyvinyl Chemical Co., Premier Mill Corp., Progressive Recovery Inc., Reichhold Chemicals Inc., Rohm and Haas Co., Rosedale Products, SCM Pigments, Sylvachem Corp., Transwestern, Triad Sales Co., Union Carbide Corp., United Catalyst Co., Vortisiv Div./M&M Machine, W.R. Grace Co./Davison Chem. Div., and Witco Chemical Corp.

Serving as General Chairman for the Symposium and Show is Ted Favata, of T.L.T., Inc. Assisting Mr. Favata are: *Co-Chairman*—Patricia Shaw, of Davlin Paint Co.; *Treasurer*—Barry Adler, of Royell, Inc., *Advisor*—Bud Harmon, of Borden Chemical Co.; *Exhibits*—Mr. Adler, Bob Minucciani, of Glidden Coatings & Resins, and Mr. Favata; *Entertainment*—Mel Lipscomb, of Lipscomb Chemical Co., *Publicity*—Patricia Stull, of Pacific Coast Chemical Co.; *Registration*—Tom Dowd, of E.T. Horn Co.; *Spouse Program*—Shirley Lipscomb; and *Technical Program*—Gordon Rook, of Nuodex/Huls.

Rochester Institute of Technology Establishes Graduate Program in Color Science

A Master of Science degree in Color Science, Appearance, and Technology will be offered beginning in the Fall, 1986, at the Rochester Institute of Technology through the Munsell Color Science Laboratory.

Designed to give students a broad exposure to the field of color and an opportunity to specialize in a particular area appropriate for their background and interest, this is the only graduate program devoted to this discipline in the U.S. The curriculum is designed for students whose undergraduate majors are in imaging science, photography, printing, textiles, physics, chemistry, psychology, physiology, graphic arts, fine arts, or any discipline pertaining to the quantitative description of color. Candidates who do not have adequate undergraduate work in related sciences must make up foundation courses before matriculating into the program.

The color science, appearance, and technology major provides graduate level study in both color science theory and its practical application. Color measurement, color appearance, and colorant formulation are stressed. The program revolves around the Munsell Color Science Laboratory, whose activities include providing standardized measurement and calibration of optical radiation, contractual and academic research and development, and industrial seminars and symposia.

For more information, contact Dr. Roy S. Berns, Coordinator of the Program at Munsell Color Science Laboratory, Rochester Institute of Technology, P.O. Box 9887, Rochester, NY 14623-0887.

EMU Is Recipient of ASARCO Donation

The Polymers and Coatings Program of Eastern Michigan University's College of Technology recently received a generous donation from the ASARCO Zinc Oxide Div., Columbus, OH.

The gift of paint testing instruments, laboratory processing machines, analytical apparatus, coatings evaluation supplies, and an extensive coatings reference library, was made possible by Marvin Coulter and other ASARCO employees through conversations with Lewis P. Larson, retired from ASARCO and a member of the EMU Polymers and Coatings Industry Advisory Committee.

"The processing, testing, and evaluating equipment and supplies will strengthen the work being done at EMU in industrial finishes and will open up new capabilities in architectural specialty coatings," said Paul Kuwik, Chairman of the Dept. of Interdisciplinary Technology.

He added that the excellent reference library, with many volumes no longer in print, will supplement the library and provide background to guide student research projects.

Pacific Northwest Society Symposium Attracts 260 Registrants to Portland

Two hundred and sixty people attended the 39th Annual Spring Symposium of the Pacific Northwest Society, May 1-3, in Portland, OR. There were 166 full-time registrations, 27 one-day and specials; and 67 spouses.

The program sessions featured the following papers:

(1) "New Extender Pigments for High Solids Compliance Coatings"—W. Meadows, of Cyprus Industrial Minerals Co.

(2) "In and Out of the Courtroom, a Primer for the Expert Witness"—A.E. Shenker, Attorney.

(3) "Effect of Molecular Weight on Performance of Cellulosic Thickeners in Latex Paint"—D.M. Blake, of Dow Chemical Co.

(4) "Tools and Rules of Adhesion Science"—D. Rahrig, of Johnson Wax.

(5) "Aluminum Crosslinkers for High Solids Coatings"—K. Lakin, of Manchem Ltd.

(6) "Wood Preservatives"—W. Woods, of Nuodex/Huls.

(7) "Buff Colored Titanium Pigments"—S. Robinson, of Hitox Corp. of America.

(8) "Acid Catalyst Trouble Shooting in High Solids and Water-borne Coatings"—R. Baker, of King Industries.

(9) "Formulation of Corrosion Resistant Water-borne Coatings Through Resin, Pigment, Additive, and Drier Selection"—A. Heitkamp, of Cargill, Inc.

The slate of officers for 1986-87, as elected at the business meeting, is: President—Dennis Hatfield, of J.F. Shelton Co.; Vice-President—Yvon Poitras, of General Paint Corp.; Secretary—John Daller, of McCloskey Corp.; Treasurer—Emil Iraola, of Olympic Home Care Products Co.; and Society Representative—Carlton Huntington, of Chemical Distributors, Inc.

At the closing social, Warren Cordano, of Cordano Chemical Co., was presented a plaque commemorating his 50th year in the coatings field. Frank J. Borrelle, Executive Vice-President of the Federation, was elected to Society Honorary Membership.

The Symposium Committee was headed by Mr. Daller. Working with him were: Bill Tuor, of Pacific Coast Chemicals; Jim Riedel, of Rodda Paint Co.; John Mitchell, of Chemical Distributors; Scott Starnes; Steve Rearden, of Imperial Paint Co.; Ken Wenzel, of McCloskey Corp.; Kevin O'Leary; Mr. Huntington; Bill Cordano, of Cordano Chemical Co.; Rick Furmann, of Associated Chemists; and the President of the Society, Gerry McKnight, of Rodda Paint Co.

The 1987 Symposium will be held jointly with the Federation as Spring Week '87, in Seattle, WA, April 29-May 2.

Federation of Societies for Coatings Technology
and
Pacific Northwest Society
for Coatings Technology

present

SPRING WEEK '87

April 29 – May 2
Seattle, Washington
The Westin Hotel

Schedule

Wed., April 29 — FSCT Society Officers Meeting
Thur., April 30 — PNW Golf
FSCT Board of Directors Meeting
PNW Evening Activity
Fri., May 1 — Seminar
Sat., May 2 — Seminar (cont'd)
PNW Sports Competition
Closing Dinner Dance

Special Discount Fares Available from Delta To Annual Meeting

Special arrangements have been made with Delta Airlines to offer discounted fares within the U.S.to/from Atlanta, GA, for the November 5-7 Annual Meeting and Paint Industries' Show, at the World Congress Center. These special fares are available only when you call the unlisted toll-free number 1-800-241-6760. Be sure to ask for the lowest fare available. You must give the FSCT Convention number, which is

U0235

Coatings and Films To Be Explored At Gordon Conference

The 1986 Gordon Research Conferences, designed to foster and promote education and science by organizing informal meetings of research scientists with common interests in the fields of chemistry and related sciences, have been scheduled in various academic locations in New Hampshire.

Among the varied topics to be considered is "Physics and Chemistry of Coatings and Films," to be held August 11-15 at the Plymouth State College (S), Plymouth, NH.

For more information on this and other topics to be presented, contact Dr. Alexander M. Cruickshank, Director, Gordon Research Conferences, Gordon Research Center, University of Rhode Island, Kingston, RI 02881.

Qualifying Coatings Inspectors

A guide for qualifying and certifying coatings inspectors in nuclear facilities has been completed by American Society for Testing and Materials. The guide delineates the requirements for development of procedures for the qualification of personnel who perform inspection of coating work. To order, D 4537, *Standard Guide for Establishing Procedures to Qualify and Certify Inspection Personnel for Coating Work in Nuclear Facilities*, contact ASTM Customer Service Dept., 1916 Race St., Philadelphia, PA 19103.

Solids Analyzer

Applications and features of a new solids analyzer for water- and solvent-borne solids are covered in a recently issued bulletin. The product consists of an electronic balance, a microwave drying system, and a microprocessor digital computer. For more information, contact Judy Arey, CEM Corporation, P.O. Box 9, Indian Trail, NC 28079.

Pearlescent Pigments

A guide which describes pearlescent pigments has been published. The guide offers a comprehensive study of the pearlescent look now available in oil and plastic base paints, and answers many of the questions that a potential new entrant into this market would be interested in exploring. Copies of the guide "Paint Manufacturers' Guide to Pearlescent Pigments," are available from the Pigment Division, EM Industries, Inc., 5 Skyline Dr., Hawthorne, NY 10532.

Resins

A water-white, unsaturated, low molecular weight polyester resin system which is both solvent-free and monomer-free is described in recently released literature. The line is designed for gravimetric or volumetric addition to mastics, molding compounds, gel coatings, and high solids VOC-compliant coatings. For further information, contact Lorraine McNabney, Universal Color Dispersions, 2700 E. 170th St., Lansing, IL 60438.

Color Control System

Information is now available on a new computer color control system which features complete color control software, formula search programs, and formula storage, scaling, and costing. The full color control software package provides best match/least cost color formulations, laboratory and production batch correction calculations, and extensive color quality control capabilities. For further information about the ACS-3300 Computer Color Control System, contact Applied Color Systems, Inc., P.O. Box 5800, Princeton, NJ 08543.

Infrared Dryer

A recently released product bulletin introduces a new infrared dryer that, when mounted on a precision balance, is designed to provide the user with reliable moisture content determinations. For more information on LP16, write Mettler Instrument Corp., Box 71, Hightstown, NJ 08520.

Products Directory

A comprehensive 16-page guide offers information on a company's products, services, trade names, regional sales and customer service offices, and producing locations. To obtain the 1986 "Worldwide Directory of Products and Operations," request brochure number SP-124 from Manville Service Center, 1601 23rd St., Denver, CO 80216.

Detackifier

Information is now available on a solid clay paint spray booth additive for detackifying oversprayed paint in the scrubbing water system. The product is designed primarily for use with solvent-based systems. For more information on GCP® 834, contact Betz Laboratories, Inc., Somerton Rd., Trevose, PA 19047.

Fine Acids

A folder containing brochures about three fine acids was recently made available. The brochures describe applications for specialty aromatic acids including novel high strength fibers and engineering resins. For a copy of this folder, write Amoco Chemicals Co., Mail Code 4002, Dept. FL01-JCT, 200 E. Randolph Dr., Chicago, IL 60601.

Solution to June *"CrossLinks"*

Coming Events

FEDERATION MEETINGS

For information on FSCT meetings, contact FSCT, 1315 Walnut St., Philadelphia, PA 19107 (215-545-1506).

1986

(Sept. 23-24)—Meeting of Technical Advisory Committee with Society Technical Committee Chairmen. Louisville, KY.

(Nov. 5-7)—64th Annual Meeting and 51st Paint Industries' Show. World Congress Center, Atlanta, GA.

1987

(Apr. 29-May 2)—Combined Federation Spring Week and Pacific Northwest Society Symposium. The Westin Hotel, Seattle, WA. FSCT Society Officers Meeting on April 29; FSCT Board of Directors Meeting on April 30; Seminar on May 1-2. Concludes with a dinner dance on May 2.

(Oct. 5-7)—65th Annual Meeting and 52nd Paint Industries' Show. Convention Center, Dallas, TX.

SPECIAL SOCIETY MEETINGS

1987

(Feb. 23-25)—Western Coatings Societies' Symposium and Show, Monterey Convention Center, Monterey, CA. (Barry Adler, Royell, Inc., 1150 Hamilton Ct., Menlo Park, CA 94025).

(Apr. 1-3)—Southern Society. Annual Meeting. Dutch Inn, Lake Buena Vista, FL. (C. Lewis Davis, 802 Black Duck Dr., Port Orange, FL 32019).

(Apr. 29-May 2)—Combined Federation Spring Week and Pacific Northwest Society Symposium. The Westin Hotel, Seattle, WA. April 29—FSCT Society Officers Meeting; April 30—FSCT Board of Directors Meeting; PNW Golf; PNW Evening Activities; May 1—Seminar; May 2—Seminar continued; PNW Sports Competition; Dinner Dance.

1988

(Apr. 13-15)—Southern Society. Annual Meeting. Charleston, SC. (Scott McKenzie, Southern Coatings Co., P.O. Box 160, Sumter, SC 29150).

OTHER ORGANIZATIONS

1986

(July 21-25)—"Cathodic Protection Design" Course offered by Dept. of Engineering Professional Development, The College of Engineering, University of Wisconsin-Madison. (Program Director John T. Quigley, University of Wisconsin-Madison, Engineering Professional Development, 432 North Lake St., Madison, WI 53706).

(Aug. 4-22)—Fifth Annual Program in R&D Management, Sponsored by Battelle Memorial Institute, Columbus, OH. (Dr. William D. Hitt, Battelle Memorial Institute, 505 King Ave., Columbus, OH 43201-2693).

(Aug. 11-15)—"Physics and Chemistry of Coatings & Films" Program. Gordon Research Conference. Plymouth State College (S), Plymouth, NH. (Dr. Alexander Cruickshank, Director, Gordon Research Center, University of Rhode Island, Kingston, RI 02881).

(Sept. 3-4)—Industrial Color Technology Seminar sponsored by Applied Color Systems, Inc. Lancaster, PA. (Ms. Bobbie Deel, ACS, 2848 M Carolina Center, I-85 S., Charlotte, NC 28208).

(Sept. 3-5)—"Estimating for Painting Contractors and Maintenance Engineers" Short Course. Univ. of Missouri-Rolla, MO. (Prof. James O. Stoffer, Dept. of Chemistry, Univ. of Missouri-Rolla, Rolla, MO 65401).

(Sept. 7-12)—Symposium on High Solids Coatings. Sponsored by the ACS Div. of Polymeric Materials: Science and Engineering. Anaheim, CA. (George R. Pilcher, Hanna Chemical Coatings Corp., P.O. Box 147, Columbus, OH 43216).

(Sept. 7-12)—ACS, Div. of Polymeric Materials: Science and Engineering. Anaheim, CA. (T. Davidson, Ethicon, Inc., Route 22, Somersville, NJ 08876).

(Sept. 8-13)—190th National Meeting. American Chemical Society. Chicago, IL. (ACS, A.T. Winstead, 1155 16th St. N.W., Washington, D.C. 20036).

(Sept. 9-11)—RadCure '86—Association for Finishing Processes of the Society of Manufacturing Engineers Conference and Exposition. Baltimore Convention Center, Baltimore, MD. (AFP/SME Public Relations, Society of Manufacturing Engineers, One SME Dr., Dearborn, MI 48121).

(Sept. 15-17)—13th International Naval Stores Meeting. Waldorf-Astoria, New York, NY. (Douglas E. Campbell, Executive Director, Pulp Chemicals Assn., 60 E. 42nd St., New York, NY).

(Sept. 15-19)—53rd Introductory Short Course on "The Basic Composition of Coatings." Univ. of Missouri-Rolla, MO. (Prof. James O. Stoffer, Dept. of Chemistry, Univ. of Missouri-Rolla, Rolla, MO 65401).

(Sept. 18-19)—"Radiation Curing of Polymers" Symposium sponsored by the Royal Society of Chemistry, Industrial Div., Northwest Region. Lancaster University, England. (Dr. D.R. Randell, CIBA-GEIGY Industrial Chemicals, Tenax Rd., Trafford Park, Manchester M17 1WT, England).

(Sept. 21-23)—Canadian Paint and Coatings Association. 74th Annual Convention. Hilton Hotel, Quebec City, Que., Canada. (CPCA, 515 St. Catherine St. W, Montreal, Que., Canada H3B 1B4).

(Sept. 21-26)—XVIIIth Congress of FATIPEC. (Federation of Associations of Technicians in the Paint, Varnish, and Printing Ink Industries of Continental Europe). Venice, Italy. (C. Bourgery, Secretary General of FATIPEC, 76 Blvd. Pereire, 75017 Paris, France-or-Amleto Poluzzi, AITIVA, Piazzale R. Morandi 2,20121 Milano, Italy).

(Sept. 22-25)—"Your Chosen Finish." FINSTRAT Conference and Exposition sponsored by the Association for Finishing Processes of the Society of Manufacturing Engineers. Long Beach, CA. (Gerri Andrews, SME, Public Relations Dept., One SME Dr., P.O. Box 930, Dearborn, MI 48121).

(Sept. 23-25)—"Industrial Painting Processes" clinic sponsored by AFP/SME. Indianapolis, IN. (Diane Korona, SME Special Programs Div., SEM Dr., P.O. Box 930, Dearborn, MI 48121).

(Sept. 29-Oct. 3)—13th Introductory Short Course on "Paint Formulation." Univ. of Missouri-Rolla, Rolla, MO. (Prof. James O. Stoffer, Dept. of Chemistry, Univ. of Missouri-Rolla, Rolla, MO 65401).

(Oct. 1-2)—Industrial Color Technology Seminar sponsored by Applied Color Systems, Inc. Minneapolis, MN. (Ms. Bobbie Deel, ACS, 2848 M Carolina Center, I-85 S., Charlotte, NC 28208).

(Oct. 8-10)—SPI/SPE Plastics Show and Conference—South. Georgia World Congress Center, Atlanta, GA. (Jeffrey A. Forger, Conference and Programs Director, SPE, 14 Fairfield Dr., Brookfield Center, CT 06805-0403).

(Oct. 13-17)—"Physical Testing of Paints & Coatings" Short Course. Univ. of Missouri-Rolla, Rolla, MO. (Prof. James O. Stoffer, Dept. of Chemistry, Univ. of Missouri-Rolla, Rolla, MO 65401).

(Oct. 27-28)—Industrial Color Technology Seminar sponsored by Applied Color Systems, Inc. Dalton, GA. (Ms. Bobbie Deel, ACS, 2848 M Carolina Center, I-85 S., Charlotte, NC 28208).

(Oct. 27-31)—"Modern Instrumentation for the Polymer & Coatings Industry" Short Course. Univ. of Missouri-Rolla, Rolla, MO. (Prof. James O. Stoffer, Dept. of Chemistry, Univ. of Missouri-Rolla, Rolla, MO 65401).

(Nov. 3-4)—Industrial Color Technology Seminar sponsored by Applied Color Systems, Inc. Atlanta, GA. (Ms. Bobbie Deel, ACS, 2848 M Carolina Center, I-85 S., Charlotte, NC 28208).

(Nov. 3-5)—Paint Research Association. Sixth International Conference, Sheraton Hotel, Brussels, Belgium. (D. Dasgupta, PRA, 8 Waldegrave Rd., Teddington, Middlesex TW11 8LD, England).

(Nov. 3-5)—Annual Meeting of National Paint and Coatings Association. Hilton Hotel, Atlanta, GA. (Karen Bradley, NPCA, 1500 Rhode Island Ave., Washington, D.C. 20005).

(Nov. 21-23)—39th Annual Show and Convention of National Decorating Products Association. Cervantes Convention Center, St. Louis, MO. (Lillian Smysor, NDPA, 1050 N. Lindbergh Blvd., St. Louis, MO 63132).

(Dec. 3-5)—Industrial Color Technology Seminar sponsored by Applied Color Systems, Inc. Orlando, FL. (Ms. Bobbie Deel, ACS, 2848 M Carolina Center, I-85 S., Charlotte, NC 28208).

1987

(Feb. 4-6)—"Formula" Forum on Chemical Specialties sponsored by the Societe Francaise de Chimie, Nice. (Societe Francaise de Chimie, Departement Congres, 250 rue Saint Jacques 75005 Paris, France).

(Feb. 8-11)—Inter-Society Color Council. Williamsburg Conference on "Geometric Aspects of Appearance." The Lodge, Colonial Williamsburg, VA. (Dr. D.H. Alman, Du Pont Co., P.O. Box 2802, Troy, MI 48007).

(Mar. 17-19)—Powder Coatings '87. G-MEX Exhibition Center, Manchester, England. (Mervyn W.K. Little, Specialist Exhibitions Ltd., Grantleigh House, 14-32 High St., Croydon, Surrey CRO 1YA, England).

(Mar. 26-29)—Colour 87—the International Exhibition for Painting Techniques and Colour Application. Cologne, Germany. (Koln Messe, Postbox 210760, D-5000 Cologne 21, Germany).

(Apr. 5-10)—ACS, Div. of Polymeric Materials: Science & Engineering, Anaheim, CA. (T. Davidson, Ethican, Inc., Route 22, Somersville, NJ 08876).

(May 18-21)—Surface Coating '87. Chemical Coaters Association. Milwaukee, WI. (CCA, Box 241, Wheaton, IL 60189).

(May 31-June 5)—Sixth International Meeting on Radiation Processing. Skyline and Holiday Inn Hotels, Ottawa, Ont., Canada. (Mrs. E. Golding, International Meeting on Radiation Processing, P.O. Box 13533, Kanata, Ont., Canada K2K 1X6).

(June 17-19)—"Chemically Modified Surfaces" Conference cosponsored by Colorado State University and Dow Corning Corp. Holiday Inn, Fort Collins, CO. (Ward T. Collins, Mail Stop C41C00, Dow Corning Corp., Midland, MI 48686-0994).

(June 17-20)—Oil and Colour Chemists' Association Biennial Conference. Eastbourne, England. (Mr. R.H. Hamblin, Director & Secretary, OCCA, Priory House, 967 Harrow Rd., Wembley, Middlesex HA0 2SF, England).

(July 13-16)—SUR/FIN '87 Chicago—International Conference & Exhibit of Electroplating and Surface Finishing. McCormick Place, Chicago, IL. (AESF, 12644 Research Parkway, Orlando, FL 32826).

(Aug. 23-28)—"Copolymerization" Symposium. Sponsored by the Polymer Div. of the Royal Australian Chemical Institute and the Div. of Polymer Chemistry of the ACS. Sydney, Australia. (Prof. D. Tyrell, Polymer Science & Engineering, Univ. of Massachusetts, Amherst, MA 01003).

(Sept. 15-18)—XVIIth Congress of AFTPV (French Association of Paint and Varnish Technicians) and Eurocoat. Nice, France. (J. Roire, 5, Rue Etex, 75018 Paris, France).

(Nov. 7-11)—10th International Congress on Metallic Corrosion sponsored by Central Electrochemical Research Institute on behalf of International Corrosion Council. Madras, India. (Dr. V.I. Vasu, Chairman, ICMC Organizing Committee, Director CERI, Karaikudi 623006, Tamil Nadu, India).

1988

(Oct. 18-21)—12th World Congress on Metal Finishing, INTERFINISH 88. Palais des Congres, Paris, France. (SEPIC INTERFINISH), 17 rue d'Uzes, 75002 Paris, France).

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'Humbug' from Hillman

Carl Huntington has written from the Pacific Northwest that his 89-year-old mother recently passed away and left some interesting diary notes and fascinating memorabilia in the family attic. Among them was noted under the heading, "Approaching Age"—

"Everything is farther away than it used to be. It's twice as far to the corner and they've added a hill, I notice. I've given up running for the bus; it leaves faster than it used to. It seems to me that they are making stairs steeper than in the old days and have you noticed the unusually small print they now use in the newspapers?

There is no sense in asking anyone to read aloud. Everyone speaks in such a low voice, I can barely hear them. The material in dresses is so skimpy now—especially around the waist and hips.

Even people are changing! They are so much younger than they used to be when I was their age. On the other hand, people my age are so much older than I am. I ran into an old classmate the other day and she had aged so much that she didn't even recognize me. I got to thinking about it when I was combing my hair this morning and in doing so, I glanced at my reflection. Confound it, they don't even make mirrors like they used to."

And also—

This is an authentic "receipt" in its original spelling as it was written for a bride four generations ago.

Grandma's Recipe for Doing the Family Wash

1. Build a fire in the back yard to heat kettle of rain water.
2. Set tub so wind won't blow in the eyes if the wind is pert.
3. Shave one whole cake of lye soap in bilin water.
4. Sort clothes. Make three piles; 1 pile white, 1 pile cullard, 1 pile britches and rags.
5. Stur flour in cold water to smooth and then thin down with bilin water.
6. Rub dirty spots on board, scrub hard, then bile, scrub cullard but don't bile—just rench and starch.
7. Take white things out of kettle with broom stick handle, then rench, blew and starch.
8. Spread tee towels on grass.
9. Hang old rags on fence.
10. Pore rench water on flower beds.
11. Scrub porch with hot soapy water.
12. Turn tubs upside down.
13. Go put on clean dress. Smooth hair with side combs. Brew cup of tee. Set and rest. Rock a spell and count your blessings.

Bruce Schirm, an avid reader of "Dear Abby" and other important literature, found the following in one of Abigail Van Buren's columns. I can't imagine how I missed it.

DEAR ABBY: I'll bet you are going to get mounds of mail on this one! "Peeling Paint in Dayton" said his wife's deathbed wish was to be cremated. She wanted her ashes mixed with paint to be used in the bedroom. Obviously, the wife had hoped that this would prevent her husband from entertaining other women.

You advised the man to honor her request but to entertain elsewhere. Abby, no way! That letter had to be a joke! No woman in her right mind would make such a request. And if there's no law against it, there should be.

If a ghost would be looking for a place to live, that bedroom would be it.

—Harmony on Eastlake, Ohio

DEAR ABBY: The letter in your column signed "Peeling Paint in Dayton" inspired the following poem. If you think it's worth printing, be my guest.

—Arnold T. Schwab, Calif.

DEAR ARNOLD: I do and here it is:

MIXED REACTION

Hubby, hubby, promise me.
When alive, I ain't
You'll sift my ashes carefully
Into a can of paint.
Stir me well, and then apply,
Under proper light,
A patch to test that when I'm dry
I'm just a shade off white.
Brush me thickly overhead—
Finish every ounce—
Coat the ceiling round the bed
On which we used to bounce.
If you bring a hussy there,
Watch it; When I feel
A sudden heating of the air,
I'll blister, crack and peel.

—Herb Hillman
Humbug's Nest
P.O. Box 135
Whitingham, VT 05361

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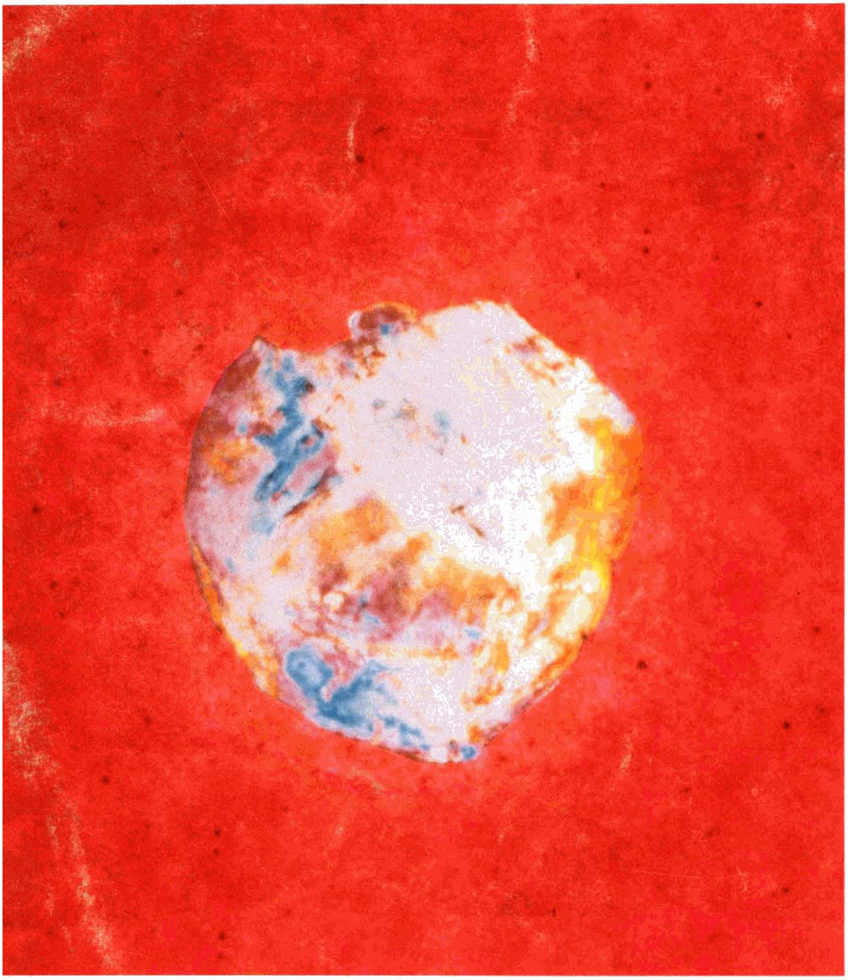

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