jct

JOURNAL OF COATINGS TECHNOLOGY

Volume 48   Number 621

pigmented microvoid coatings II

Arolon® X801 Emulsion.
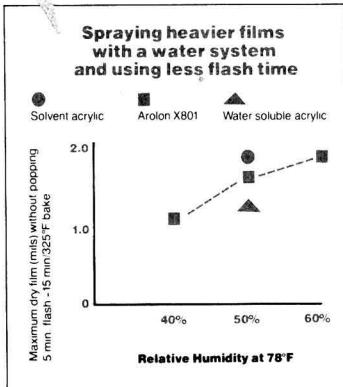# The water-thinned way to a solvent-like gloss.

AROLON X801—an acrylic emulsion resin system that offers the economy, energy saving, and ecological benefits of water-based coatings with performance that compares favorably with solvent-thinned systems.

This higher solids, acrylic emulsion resin system provides a good combination of gloss, resistance to popping (minimum flash off), film thickness, flow, chemical resistance, hardness, durability and flexibility.

Coatings formulated with Arolon X801 offer important benefits to the user in terms of:

- easier application to obtain higher film build
- energy savings with lower bake and cure temperatures
- better ecological position because of lower cosolvent requirements
- durability and flexibility

Easier Application.

Spraying heavier films with a water system and using less flash time

Maximum dry film (mils) without popping
5 min flash - 15 min 325°F bake

Relative Humidity at 78°F

Ordinary water solubles generally will blister or pop on baking at over 1.25 mils with a 5 minute flash period. Similar solvent systems will allow application of almost 2.0 mils. Arolon X801 delivers a film thickness approaching solvent acrylics without the popping problems associated with other water reducible systems, and with better film characteristics.

Low Temperature Bake Saves Energy.

Arolon X801 works in low temperature bakes to conserve energy			
Bake Schedule	15 min 275°F	15 min 250°F	20 min 225°F
Pencil hardness	H	H	H
MEK (double rubs)	>100	>100	80
Reverse impact pass	30	10	10
Salt Fog resistance	¹300	250	150
Humidity resistance	²500	500	48

(1) Hours to develop ⅛ inch creep at score on zinc phosphated metal (steel).
(2) Hours without blistering on zinc phosphate steel.

The table shows that good hardness and cure was obtained with a bake schedule of 15 minutes at 250°F. By selecting fast curing melamine crosslinkers, Arolon X801 may be formulated for baking in the range of 225-275°F with minimal bake time. Force dry lacquer formulas may be compounded by replacing the melamine with a water soluble acrylic such as Arolon 557.

Less Cosolvent/Higher Volume Solids.

Arolon X801 formulates into water-thinned enamels with less cosolvent and higher volume solids than conventional water reducible systems. As low as 4% solvent in the effluent has been obtained, but is not common practice. As the table shows, water reducible acrylics need all the organic solvent allowable by EPA standards. Plus it has lower solids. The solvent systems shown vary in solids content but both would require afterburners to meet EPA regulations.

Arolon X801 bake enamels give less organic solvent			
	Arolon X801	Water Soluble Acrylic	Solvent Acrylic	Short Oil Alkyd
% weight solids	50.4	37.8	57.6	38.9
% volume solids	38.8	26.2	42.1	25.1
% solvent in effluent by volume	13.0	20.0	100.0	100.0

(above enamels all have P/B 0.7 and are reduced to 20-25 sec./#4 Ford cup viscosity.)

The Water Base Way To Gloss Bake Enamels.

Water reducible resins make excellent coatings, and one of the best is Arolon X801. This new acrylic emulsion resin system bridges the gap between solvent system film properties and water-base advantages and simplicity.

And with Ashland's 20 years of technical experience in water reducible systems, you've got the world's best technical advice at your beck and call. Contact us for more detailed data on Arolon X801, or on any other of our many water reducible resin systems. Resins & Plastics Division, P.O. Box 2219, Columbus, Ohio 43216.

Organic reds and yellows

They are durable, light fast, bleed resistant replacements for cadmiums or chromes in paints or plastics. To help meet the requirements you face under ASA specification 266.1-1964.

BASF Wyandotte Corporation
100 Cherry Hill Rd., P.O. Box 181
Parsippany, NJ 07054
(201) 263-0200

Colors

BASF

jct JOURNAL OF COATINGS TECHNOLOGY

Features

Federation Activities

Departments

THE FUTURE OF OXYGENATED SOLVENTS WILL MAKE GREAT HISTORY.

We couldn't be more serious.

In fact, we expect the coatings industry's demand for oxygenated solvents to remain in excess of 2,000,000,000 pounds a year through 1980. That's big business. And we're committed to it.

Today, these exempt solvents provide an economical and efficient answer to environmental controls. Coatings of the future —like High Solids and Water-borne—will continue to depend on these same oxygenated solvents.

We know because we've been in this business a long time.

In fact, we've just celebrated our 50th Anniversary in glycol ethers. And we're looking forward to celebrating our 100th Anniversary in 2025.

Our commitment to oxygenated solvents is a major factor in making us the leading supplier to the industry. And we intend to continue providing both our technical assistance and our broad line of products.

You see, we expect the commitments we make today to make very good history tomorrow.

PEOPLE PLANNING THE FUTURE.

Comment

Getting Together Helps

On September 17, the Federation sponsored simultaneous but separate meetings of Society Educational and Society Technical Committee Chairmen. The meetings were held in Cleveland and the Federation reimbursed the transportation expense of all who attended.

Purpose of the meetings was to assemble these key committee chairmen in an across the table situation where they could discuss their problems, relate their experiences, and contribute new ideas.

It was the third such national meeting of Society Educational Chairmen; the first for the Technical Chairmen. Presiding were the Chairmen of the Federation Committees: Harry Scott—Educational; and Sid Lauren—Technical Advisory.

I sat in on the Technical meeting and it was one of the most inspiring sessions I have ever attended. The agenda — which was never completed — was devoted to a rundown of each Society's current projects, management support (or lack of it) for Technical Committee work, role of the Chairman, and how to select good projects.

Although there is claimed to be a drop in volunteer effort for Technical Committee work, you would have never known this from the enthusiasm shown by the 21 Chairmen who were present. They are most eager to get on with their tasks and the meeting gave them a bag full of ideas to help them achieve their goals.

During the course of the meeting, Jan Grodzinski, Chairman of the Toronto Society Technical Committee, went to the blackboard and wrote what he called, "Positive Action by Technical Committee Chairmen":

(1) Push.
(2) Make efficient use of telephone.
(3) Develop spirit of curiosity in committee membership.
(4) Talk to management of local paint companies and suppliers for manpower assistance.
(5) Concentrate on young newcomers to industry.
(6) Seek cooperation from local learning centers.
(7) Use personal contacts and influence.
(8) Ask for personal comments from prospective members re Technical Committee work.
(9) Push.

Those are some pretty good tips which would apply equally as well to Society Educational and Manufacturing Committees.

The Federation has been pleased to sponsor the Cleveland meetings and is gratified at the acceptance that they have received.

It does help to get people together and, as the Federation moves ahead, you will see more of these meetings in the future.—FJB

Performance is just another facet of experience.

The more experience you can put into a resin, the better the performance you can expect to get out of it. Developmental resin XU 214, our new solid-flake epoxy for powder coatings, is a good example.

From our experience with resins for powder coatings we knew that improved flow would be needed, so XU 214 was developed.

CIBA-GEIGY technical expertise has endowed this new high-performance resin with both low viscosity in the molten state and high melting point in the solid state.

Because of this unusual combination of desirable properties, users enjoy a rare level of performance.

Developmental resin XU 214 produces powder coatings noted for a unique combination of flow and leveling during cure and anti-blocking properties during storage. These properties are essential to the *thinner films, lower cure temperatures, and higher pigment contents* now required by the powder coatings industry.

Bottom line: exceptionally versatile powder coatings, distinguished by outstanding adhesion and resistance to impact and chemicals.

When you want to get a lot out of an epoxy, look to a company with a lot of know-how to put in.

For data and samples, write: Section JPT, ARALDITE; Resins Department, CIBA-GEIGY Corporation, Ardsley, New York 10502.

CIBA—GEIGY
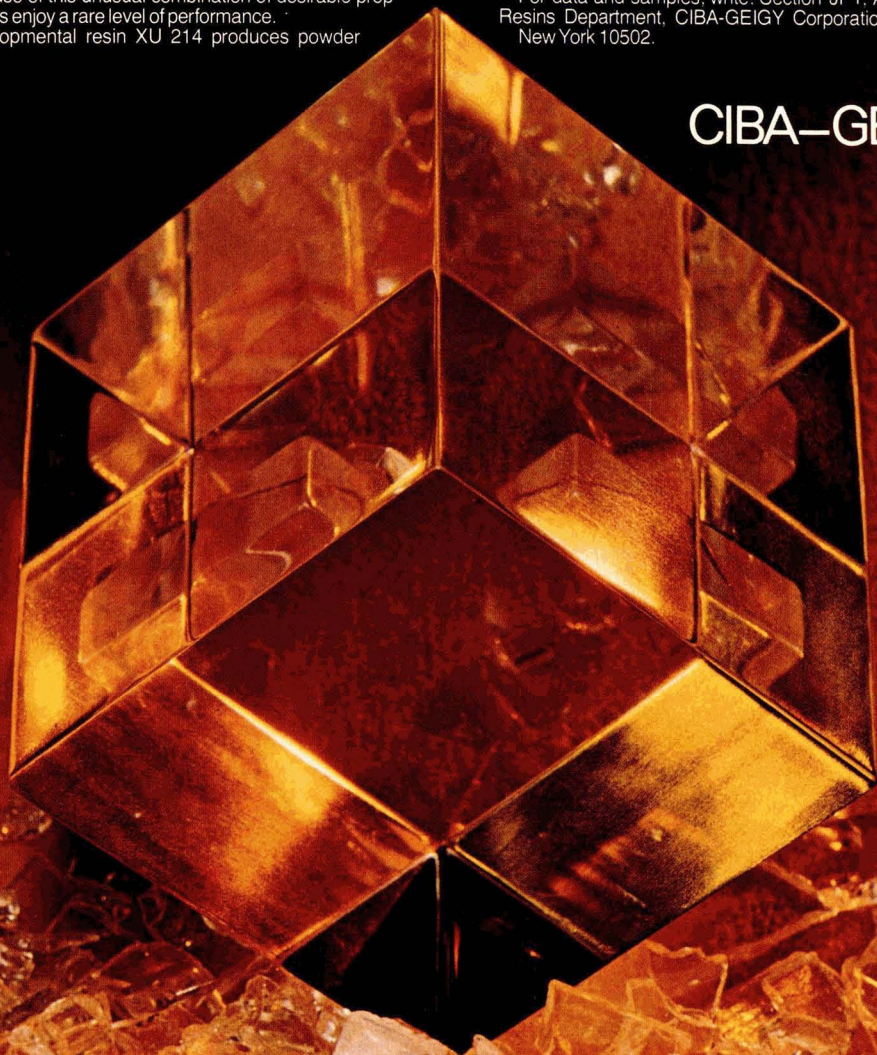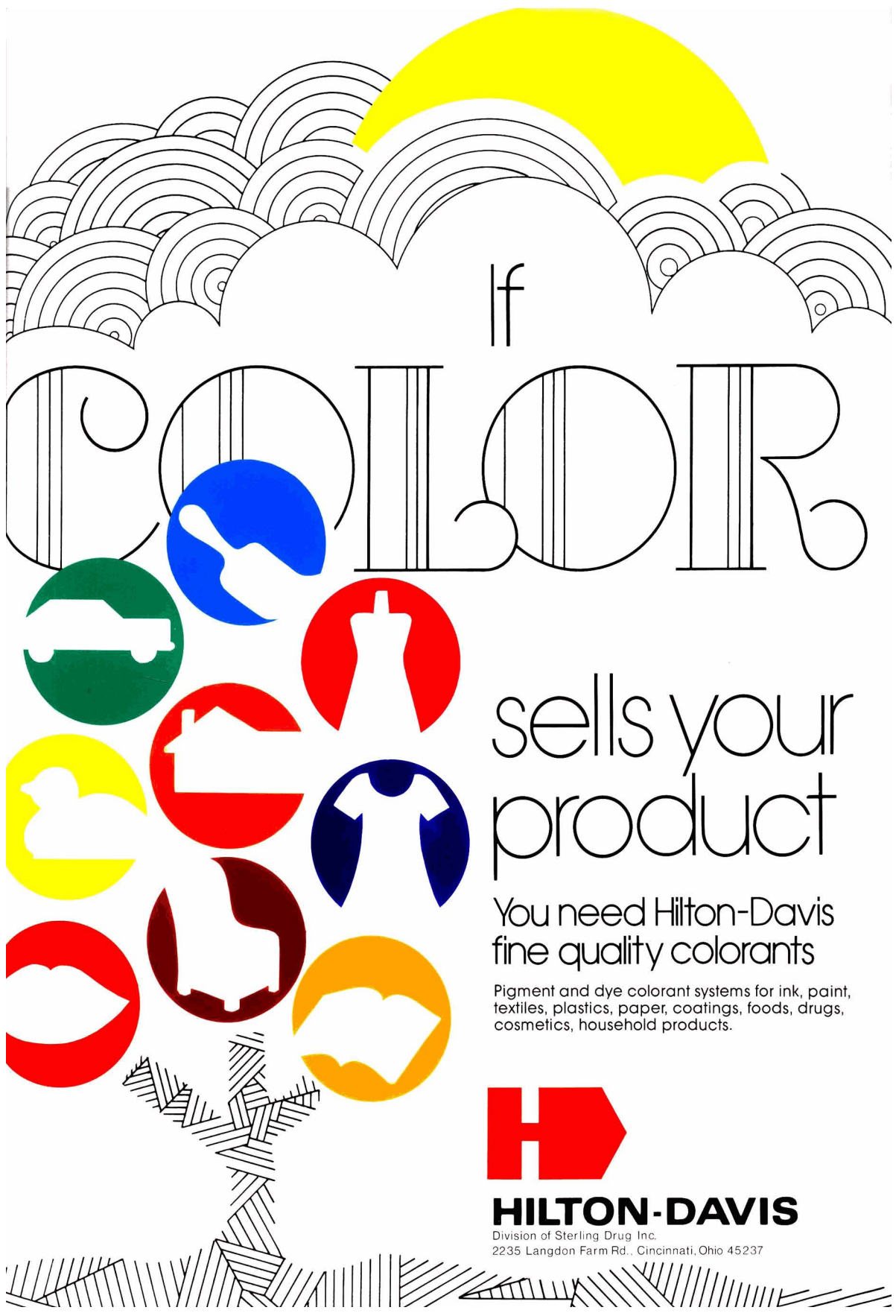
PIGMENTED MICROVOID COATINGS II. LUMINANCE AND COLOR OF THE CONCENTRIC SPHERE MODEL—M. Kerker and D. D. Cooke

This theoretical calculation explores, for the concentric sphere model, the effect of particle size distribution upon the luminance and color of an optically thin pigmented microvoid film on a black background. The luminance and color are obtained from the tristimulus values of the Kubelka-Munk scattering coefficient.

In this model, the film consists of a resin containing a logarithmic distribution of rutile spheres, each positioned at the center of a microvoid sphere.

For a particular distribution of rutile spheres, the effect of increasing the size of the microvoid is to decrease the luminance to a minimum value as well as to shift the color toward spectrally pure violet. Beyond this minimum, further increase of the microvoid results in increased luminance and decreased spectral purity. For sufficiently small rutile particles (radius from 0.03 to $0.09 \mu m$) the reduction in luminance upon initial addition of microvoid may be quite dramatic, e.g. more than 2 to 3 orders of magnitude, with a corresponding decrease in the hiding power of the film, and increase in its transparency.

MODEL FOR THE CORRELATION OF RHEOLOGICAL MEASUREMENTS WITH THE LEVELING AND CURE OF THERMOSETTING POWDER COATINGS— M. J. Hannon, D. Rhum, and K. F. Wissbrun

Measurement of the dynamic viscosity of a powder paint as a function of time at various temperatures can be used by means of a simple model to predict the nonisothermal viscosity changes which occur when a powder-coated panel is baked at various oven temperatures. The Orchard theory then predicts, using parameters from this model, the change of profile irregularity and wavelength with baking conditions and film thickness. Average roughness and gloss can be correlated by the same parameters. The rub resistance or cure of the films is also correlated by the nonisothermal viscosity model.

The parameters of the model are the temperature dependent initial viscosity of the resin and its temperature dependent cure rate, and the heating rate of the panel. The use of a computer to evaluate the effects of varying any of these parameters independently should be useful in minimizing the experimental effort in optimizing formulations.

ANALYSIS AND MEASUREMENT OF FOAMING PHENOMENA IN WATER-BASED COATING SYSTEMS—P. D. Berger and J. A. Gast

Studies were conducted to establish scientific principles for the analysis of foaming phenomena in trade sales and industrial coatings. The fundamental thermodynamics that produce foam were considered. Five factors were found to stabilize foaming phenomena in water-based coatings. They were surface potential, surface transport, surface state, surface viscosity, and bulk viscosity. Theoretical formulas were established and measurement techniques were devised to evaluate these conditions and to develop defoamers that could counteract foaming phenomena. These principles make it possible for defoamer specialists to develop effective control agents without a knowledge of the exact product formulation under study. This information can be extended to coating technologists so they may minimize foaming tendencies in their formulations by choosing surface active ingredients wisely.

ARTIFICIAL WEATHERING OF COATINGS ON ORGANOLEAD-TREATED SOUTHERN YELLOW PINE—H. M. Barnes

The performance of three coatings on organolead-treated southern pine was investigated. Accelerated weathering tests indicated no discernible difference in coating durability between treated and untreated samples in any coating group. Wood treated with this class of preservatives should offer the advantage of paintability in addition to increased service life in exterior exposure.

semi-gloss

AC-490

AC-25

For Satisfied
Customers...
Use ACRYLIC

Announcing two new Carboset® resins for coatings you can pound harder and soak more.

Hard coatings, made from formulations using Carboset resins, can be made even harder with new Carboset XL-11. And newly developed Carboset XL-19 will provide coating formulations with exceptional water resistance.

Like all Carboset resins, XL-11 and XL-19 resins are water-soluble acrylic polymers for temporary or permanent coatings. Both protective and decorative. On metal, paper, plastics and wood. Ideal for industrial coatings, paints, paperboard coatings, printing inks and floor finishes.

Carboset XL-19 resin is also acceptable for use under FDA regulation 121.2526 "Components of Paper and Paperboard in Contact with Aqueous and Fatty Foods."

For additional information on any of the Carboset resins in formulations for coatings, including the new XL-11 and XL-19 resins, contact B.F.Goodrich Chemical Company, Dept. JP-35, 6100 Oak Tree Boulevard, Cleveland, Ohio 44131.

B.F.Goodrich Chemical Company

High grade
coatings with excellent
properties –
VEBA epoxy
curing agents
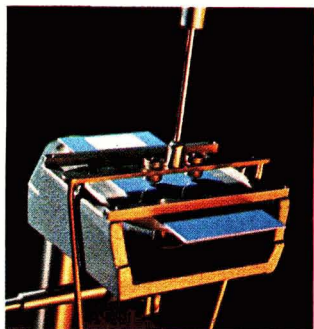
VEBA-CHEMIE AG supplies for hot and cold curing diamines and anhydrides.

VEBA Diamines

IPD and **TMD** as well as the hardeners **V 214** and **V 215** are clear rather than colorless, low viscosity liquids. They are of aliphatic or cycloaliphatic structure.

VEBA Anhydrides

HHPA, THPA, MTHPA, PMDA are solid, pure white products, **MHHPA** is of low viscosity and liquid.

VEBA Special Hardeners

B 31, B 55 enable manufacture of highly reactive and matt powder coating systems. Try how the VEBA epoxy curing agents can improve your products. If you wish we will give you additional information, free samples and technical advice.

HHPA	=	Hexahydrophthalic anhydride
THPA	=	Tetrahydrophthalic anhydride
MTHPA	=	Methyl tetrahydrophthalic anhydride
PMDA	=	Pyromellitic dianhydride
MHHPA	=	Methyl hexahydrophthalic anhydride

VEBA-CHEMIE AG

Dept. EP 103 , P.O. Box 45, D-4660 Gelsenkirchen-Buer, F. R. Germany, Phone: (02 09) 366-39 16 , Telex: 824 647 vebc

Society Educational/Technical Committee Chairmen Meet

Simultaneous but separate meetings of Society Educational and Technical Committee Chairmen were hosted by the Federation on September 17 in Cleveland.

It was the third such event for Society Educational Committee Chairmen, the first for Technical Committee Chairmen. Purpose of the meetings was to provide each group the opportunity to discuss mutual problems, relate and compare experiences, and contribute new ideas for programs at both the local and national level.

Sid Lauren, of Coatings Research Group, Inc. (Chairman of the Federation Technical Advisory Committee), presided at the meeting of the Technical Committee Chairmen. Federation Treasurer John J. Oates, of Troy Chemical Corp., and Phil Heiberger, of E. I. du Pont de Nemours & Co., Inc. (Vice-President of the Paint Research Institute) also were in attendance and addressed the group, along with Federation Executive Vice-President Frank J. Borrelle. Major items of discussion were the reports on current projects by each Society, means of increasing membership involvement and management support for Technical Committee work, selection of projects, and the role of the Technical Committee Chairman.

Presiding at the meeting of the Society Educational Committee Chairmen was Harry Scott, Jr. of Glidden-Durkee Div. (Chairman of the Federation Educational Committee). Michael W. Malaga, of Glidden-Durkee Div. (Council Representative of the Cleveland Society), welcomed the group. Also in attendance was Thomas A. Kocis, Federation Director of Meetings and Communications. This was the third annual meeting of the Society Educational Committee Chairmen (who make up the Federation Educational Committee), and their agenda covered the major areas of current interest nationally, as well as an update of local programs. Topics discussed included the Federation scholarship program, Audio/Visual productions, proposed coatings correspondence course, and programming for an educational session at the 1977 Annual Meeting in Houston. Chairman Scott announced the appointment of three new members of the Educational Steering Committee: Don Brody (New York); Carl Knauss (Cleveland); and Bob Hopkins (Baltimore). They join Charles Miyada (Los Angeles) and Richard Gohman (Dallas)

as representatives of the five geographical areas into which the Federation's 24 U. S. and Canadian Societies have been divided for educational purposes. Chairman Scott and Federation Executive Vice-President Frank J. Borrelle are also on the Steering Committee.

Members Attending Educational/Technical Committee Meetings

Educational Committee Chairmen

ROBERT HOPKINS (Baltimore)—Glidden-Durkee Div. of SCM Corp.
ARTHUR DALTON (Chicago)—Dow Chemical Co.
CARL KNAUSS (Cleveland)—Kent State University
RICHARD GOHMAN (Dallas)—Jones-Blair Co.
BOHDAN MELNYK (Detroit)—Chrysler Corp.
KEN PROBST (Golden Gate)—San Jose Regional Vocational Center
JOHN GAST (Houston)—Wittco Chemical Co.
WILLIAM SMITH IV (Kansas City)—Conchemco, Inc.
CHARLES MIYADA (Los Angeles)—Reichhold Chemicals, Inc.
LLOYD BROWNING (Louisville)—Guardsman Chemical Coatings, Inc.
WALTER KOLANITCH (Montreal)—Sherwin-Williams Co. of Canada Ltd.
DONALD BRODY (New York)—M & T Chemicals, Inc.
PAUL PAYNE (Pacific Northwest)—Reliance Universal, Inc.
BEN CHATZINOFF (Philadelphia)—Quaker City Chemicals, Inc.
PETE TEAGUE (Piedmont)—Eastman Chemical Products, Inc.
JOHN DAHL (Pittsburgh)—J. H. Matthews Co.
J. D. MULLEN (Rocky Mountain)—J. D. Mullen Co.
HERMAN LANSON (St. Louis)—Polychem Resins, Inc.
DAN DIXON (Southern)—Freeport Kaolin Co.
JAMES PROVAN (Toronto)—Chemetron of Canada Ltd.

Presiding:

HARRY SCOTT (Cleveland)—Glidden-Durkee Div., SCM Corp. — Chairman of Federation Educational Committee

Welcoming Remarks:

MICHAEL W. MALAGA (Cleveland)—Glidden-Durkee Div., SCM Corp. — Council Representative of Cleveland Society for Coatings Technology

Technical Committee Chairmen

ED COUNTRYMAN (Baltimore)—Baltimore Paint & Chemical Corp.
RON DADE (Chicago)—Sherwin-Williams Co.
CHARLES KUMINS (Cleveland)—Tremco Mfg. Co.
RAY PIERREHUMBERT (Dallas)—Jennat Corp.
JOHN DICKMAN (Golden Gate)—Reichhold Chemicals, Inc.
JIM CAVE (Louisville)—Celanese Coatings Co.
BOB WARREN (New England)—Waterlac Industries, Inc.
THOMAS GINSBERG (New York)—Union Carbide Corp.
RICHARD JOHNSON (Northwestern)—Cargill, Inc.
JIM RIEDEL (Pacific Northwest)—Rodda Paint Co.
STAN LeSOTA (Philadelphia)—Rohm and Haas Co.
EDWARD TROUSIL (Rocky Mountain)—Kohler-McLister Paint Co.
RAY TACKETT (St. Louis)—P. D. George Co.
GARY REYNOLDS (Southern)—Color Wheel Paint Mfg. Co., Inc.
JAN GRODZINSKI (Toronto)—Dominion Colour Corp. Ltd.
ROBERT MILLER (Western New York)—Jamestown Finishes, Inc.

Other Society Attendees

CHESTER STAHL (C-D-I-C)—Yenkin-Majestic Paint Co.
JAMES VICK (Houston)—Shell Development Co.
JOHN GORDON (Los Angeles)—AMSCO Div. of Union Oil Co. of Calif.
HORACE PHILIPP (Montreal)—Sherwin-Williams Co. of Canada Ltd.
DENNIS ADAMS (Northwestern—Winnipeg)—Sherwin-Williams Co. of Canada Ltd.
JOHN LUCAS (Piedmont)—The Lilly Co., Inc.

Technical Advisory Committee Members

SID LAUREN-*Chairman* (Cleveland)—Coatings Research Group, Inc.
MORRIS COFFINO (New York)—D. H. Litter Co., Inc.
R. DREW BAKER (Detroit)—Reichhold Chemicals, Inc.
THAD BROOME (Southern)—Precision Paint Corp.
BERNARD KRANTZ (Los Angeles)—BASF-Wyandotte Corp.
LEON KUTIK (Chicago)—DeSoto, Inc.

SPECIAL DELIVERY

TROYSAN POLYPHASE ANTI-MILDEW

Here just when you need it.

At a time when you are deciding whether to go with a non-mercurial or to stay with mercury.

It's Troysan Polyphase Anti-Mildew, the most effective liquid non-mercurial fungicide developed to date.

Available now in full production quantities.

It provides protection from mildew and mold growth that comes closer to mercury than anything we've seen... certainly surpassing any non-mercurial fungicide on the market today.

What's more, Polyphase Anti-Mildew works beautifully in a wide range of water and oil-based paints. It's low in toxicity. And it's resistant to sulfide staining.

We've proved its effectiveness over years of testing. And major paint companies have put it through its paces too.

We have data available on request. And samples if you like to prove things for yourself.

Troysan Polyphase Anti-Mildew. Special delivery to manufacturers who prefer not using mercury.

troy chemical corp.

One Avenue L, Newark, New Jersey 07105
(201) 589-2500

The NL Rheologist has a whole stack of answers to your product performance problems.

NL BENTONE® 34
NL BENTONE® 38
NL BEN-A-GEL® EW
NL M-P-A®
NL RHEOTONE™ SA-38
NL THIXCIN® R
NL THIXATROL® ST
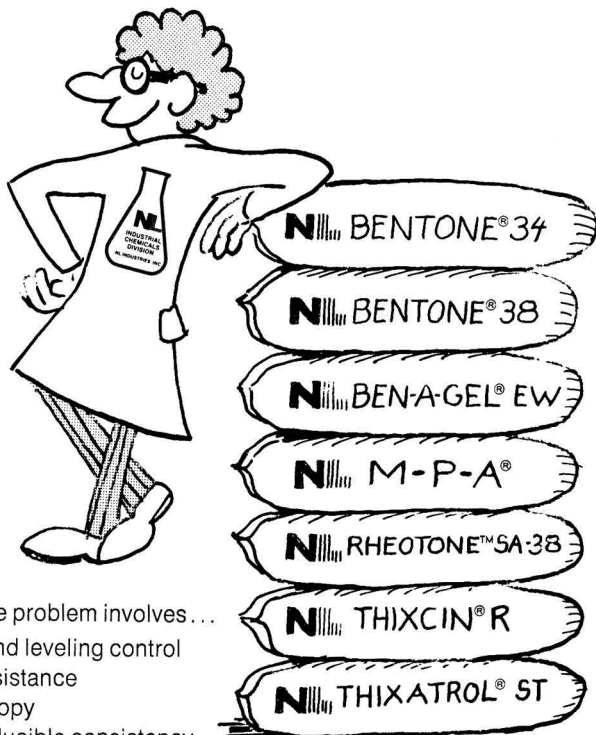
The NL Family of Rheological Additives

Bentone® 34
Designed for low and intermediate polarity organic liquids.

Bentone® 38
For non-polar and intermediate polarity organic liquids.

Ben-a-gel® EW
Specifically designed for water-based systems.

M-P-A®
For anti-settling control in non-aqueous paints.

Rheotone™ SA-38
Self-activating for non-polar and intermediate polarity organic liquids.

Thixcin® R
For gelling hydrocarbon, vegetable and silicone oil systems.

Thixatrol® ST
For low to medium solubility parameter (aliphatic and aromatic) organic systems.

When the problem involves...
- Flow and leveling control
- Sag resistance
- Thixotropy
- Reproducible consistency
- Flooding and floating of colors
- Particle suspension
- Penetration control
- Viscosity stability
- Gelling efficiency
- Film reinforcement

...that's the time to talk to your NL Rheologist. He's a specialist and can tell you which of the broad line of NL Rheological Additives will do the best job of helping you produce a better product, more easily, more economically. He's easy to reach:

Atlanta, Ga. 30318
Beta Bldg Two Northside 75
404/352/3224

Bayonne, N.J. 07002
40 Avenue A
201/436/8800

Deerfield, Ill. 60015
104 Wilmot Road, Suite 302
312/948/9550

Newport Beach, Calif. 92660
1300 Quail Street, Suite 207
714/752/0951

Canada: Enelchem Products

Industrial Chemicals Division
NL Industries, Inc.
P.O. Box 700
Hightstown, New Jersey 08520

NL Industrial Chemicals
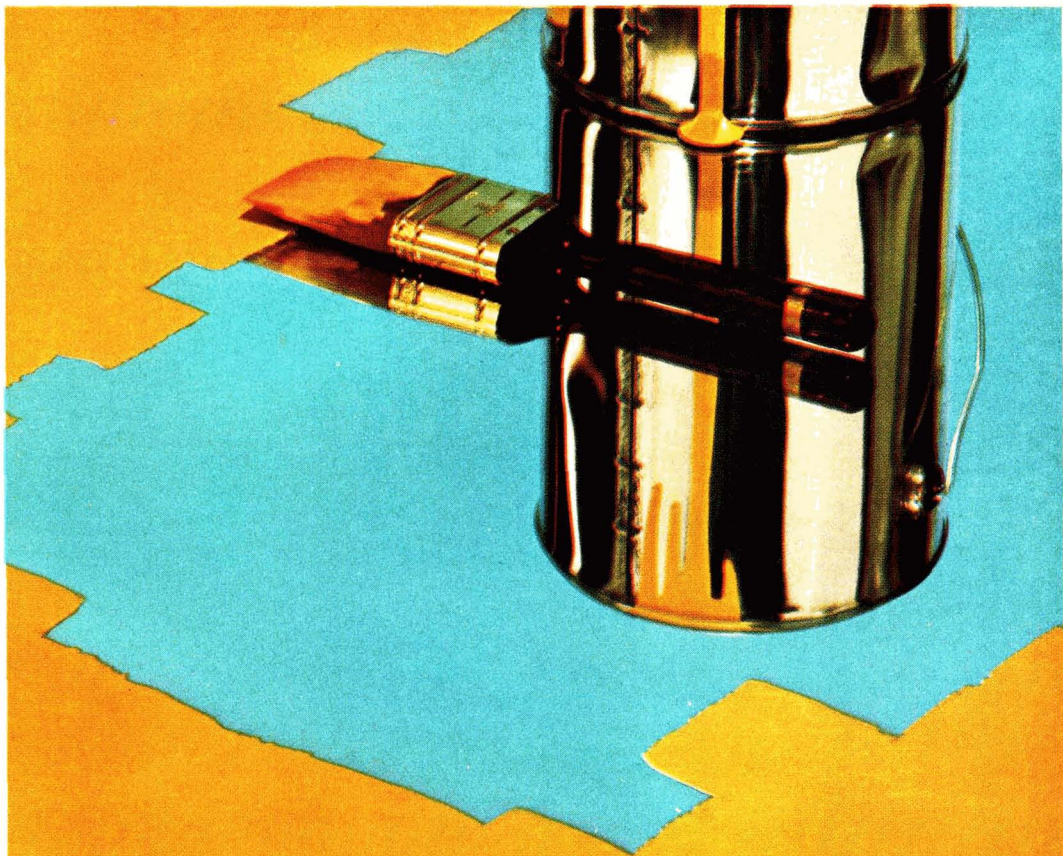
Introducing new Arctic Mist™ from Johns-Manville. Now one functional extender can improve your paint 12 ways.

We developed Arctic Mist functional extender as a flatting agent to control gloss and sheen, but depending on your needs, you can also use it to add bulk and increase pigment volume. To prevent sagging. To reinforce paint film and reduce checking. To improve leveling characteristics.

To control paint viscosity. To improve paint "tooth". For "stir-in" batch adjustment in both oil and water base paints. To extend the prime pigments which provide opacity. And to help prevent wear on machinery.

Arctic Mist is so pure that it requires no OSHA caution label. And our manufacturing facilities are close to major paint markets.

To get complete technical information about this revolutionary new extender, call Frank Buck, (303) 979-1000, or write him at Johns-Manville, Box 5108-FIM, Denver, CO 80217.

JM

Johns-Manville

A crowning achievement in vinyl acrylic emulsions...

AMSCO-RES® 3077

Your best latex paints are suddenly better than ever — with AMSCO-RES 3077.

AMSCO-RES 3077 is a versatile polymer designed for use in both interior and exterior trade sales coatings. In comparative tests, AMSCO-RES 3077 outperformed other vinyl acrylic copolymers. It exhibits exceptional low temperature coalescence, enamel holdout, scrub, and gloss. By any comparison, AMSCO-RES 3077 is truly outstanding.

Turn the page to read the "specs" and comparison test results. Then call your AMSCO man for samples.

You're the director...
tell us what you want!

union 76
AMSCO

Comparison Tests prove superiority of AMSCO-RES® 3077

A crowning achievement

The unique combination of desirable properties makes AMSCO-RES 3077 a major advance in vinyl acrylic paint emulsions. This versatile new copolymer improves the quality of a wide range of interior and exterior coatings — without increasing your raw material costs. It is the result of intensive research and development — backed by years of leadership in vinyl acrylic emulsions.

AMSCO-RES 3077 was designed specifically to meet the growing demand for improved latex paint systems. It has been tested in comparison with a number of leading competitive vinyl acrylic copolymers. Test results prove the outstanding versatility of the AMSCO-RES 3077. All of the competitive products showed some outstanding properties, but the AMSCO-RES 3077 ranked with the best in all of the properties tested. And it proved clearly superior in most of them!

Outscrubs them all!

The exceptional pigment binding capacity of AMSCO-RES 3077 was proved in "one-to-one" scrub tests matching the AMSCO copolymer against twelve leading competitive vinyl acrylics. The test results shown below were achieved with a 60% PVC interior flat paint.

	Scrubs* to 80% Removal
AMSCO-RES 3077	1315
Copolymer B	912
AMSCO-RES 3077	1495
Copolymer C	732
AMSCO-RES 3077	1225
Copolymer D	415
AMSCO-RES 3077	1212
Copolymer H	362
AMSCO-RES 3077	1032
Copolymer I	479

Highest quality all the way!

Exceptional scrub resistance is just one of the many outstanding properties of AMSCO-RES 3077. When you formulate paints with this remarkable copolymer, you never have to sacrifice one property in order to achieve another. AMSCO-RES 3077 has all the properties you want in a latex paint polymer. The following ratings are based on rigid test comparisons with leading competitive products.

Touch-up. AMSCO-RES 3077 proved superior to all competitive copolymers in both room temperature touch-up and cold temperature touch-up.

Gloss. AMSCO-RES 3077 was compared with all leading competitors in a 23% PVC semi-gloss formula. With a 60° gloss reading of 72 and an 85° sheen reading of 90, the AMSCO-RES 3077 ranked highest.

Color acceptance and uniformity. AMSCO-RES 3077 was rated equal or superior to all competitive products.

Enamel holdout. The performance of AMSCO-RES 3077 was rated excellent — superior to most of the competitors.

TYPICAL EMULSION PROPERTIES

Type (Copolymer) _____ Vinyl Acetate-Acrylic
Solids Content, % w_____ 54–56
Viscosity, cps_____ 1500-2500
Particle Size, Microns _____ 0.2–0.4
Weight/Gallon _____ 9.1 lbs.
Borax Stability_____ Stable
pH_____ 4.5–5.5

Run your own tests. It's the best way to get acquainted with AMSCO-RES 3077. Call your AMSCO man for detailed product data, starter formulas, and generous test samples.

*TEST METHOD

The paints were tested in pairs as shown above. Test panels were made by casting the paint films with a six-mil doctor blade on Leneta black plastic scrub panels. The panels were air-dried for 3 days at ambient temperature and then scrubbed on a Gardner Straight Line Scrub Tester using a 1-pound bristle brush. A 10% suspension of Ajax Cleanser in water was used as a scrub medium. A reading was taken of the number of scrub cycles when 80% of the film was removed.

union 76
AMSCO

Amsco Division
Union Oil Company of California
Palatine, Illinois 60067

Resource

Indusmin resources brought you Minex, a proven extender for the paint industry... resources that include technical capability, production capacity and precision quality control.

These, plus vast ore reserves, make Indusmin a raw material source you can count on.

Minex is available from a network of distributors across Canada and the U.S.A. For information, please contact:

indusmin limited

365 Bloor St. East, Suite 200, Toronto, Canada M4W 1H7 Telephone: (416) 967-1900 Telex: 06-22607
U.S. Subsidiary: American Nepheline Corporation, P.O. Box 14445, Columbus, Ohio 43214. Telephone: (614) 451-1525

Nominees to Be Elected to Three Positions On the Federation Board of Directors

The Nominating Committee has presented two sets of nominations for the Federation Board of Directors: Four nominees for two positions, 3-year terms each, as members-at-large (John A. J. Filchak, Howard Jerome, Ruth Johnston-Feller, and Horace Philipp); and two nominees for one position — 2-year term to fill the unexpired term of Treasurer-Nominee James A. McCormick — as a member-at-large (Donald J. Fritz and Dr. Thomas J. Miranda). Elections will be held on October 26, during the Federation Council Meeting at the Sheraton Park Hotel in Washington, D. C.

JOHN A. J. FILCHAK
(Pacific Northwest)

has a B. S. Degree from the University of Puget Sound, and is Director of Quality Control Div., Region 10, General Services Administration. A Past-President of the Pacific Northwest Society, he is its current Council Representative. He was a founding member of that society's Specifications Committee and has served as Chairman for 16 years. He has been Chairman of the Federation's Specifications Committee since 1967 and was a member of the Board of Directors, 1973-76.

RUTH JOHNSTON-FELLER
(Pittsburgh)

is former Manager of the Coatings and Colorimetry Laboratories, Pigments Div., CIBA-GEIGY Corp., and is now a Consultant. She is currently serving her fifth year chairing the Inter-Society Color Council Committee. Other Federation committee service includes Bruning Award (which she received in 1970), Program and Publications. She is graduate of the University of Illinois with a B. S. Degree in Chemistry. She has contributed 450 definitions to the Paint/Coatings Dictionary.

DONALD J. FRITZ
(Philadelphia)

is Plant Manager for Synres Chemical Corp., Kenilworth, N. J. and holds a Chemical Engineering Degree from Drexel University. He is a Past-President of the Philadelphia Society and recipient of its Liberty Bell Award. His Federation activities include chairmanship of the Golden Anniversary Meetings Committee, and service on the Host, By-Laws, Corrosion, and Program Committees.

DR. THOMAS J. MIRANDA
(Chicago)

is Staff Scientist at the Elisha Gray II Research and Engineering Center, Whirlpool Corp., Benton Harbor, Mich. He is a graduate of California State College and holds a Ph. D. from the University of Notre Dame. A former President of the Chicago Society, he has served since 1973 as Technical Editor of Journal of Coatings Technology, and Chairman of the Federation's Publications Committee.

HOWARD JEROME
(St. Louis)

is Technical Director and Operations Manager for Vane-Calvert Paint Co., St. Louis, Mo., and is Council Representative of the St. Louis Society. He is a Past-President and Honorary Member of the New England Society (where he also served as Council Representative), and was Chairman of the Federation Technical Advisory Committee from 1969-70. He is a graduate of Northeastern University.

HORACE S. PHILIPP
(Montreal)

received his B. S. and B. A. Degrees from Sir George Williams University, and is a Chemist with Sherwin-Williams Co. of Canada Ltd. He is a Past-President of the Montreal Society, has served as Chairman of its Program Committee, and is currently Membership Committee Chairman and Society Council Representative. He is Chairman of the Federation Membership Committee (a position also held from 1967-72).

One of our nine grades of Amorphous Silica, including three grades of IMSIL® which is the ultimate in Micronized Amorphous Silica, can accomplish about 99% of all filler/extender jobs. And, do it better for less cost. Inert Amorphous Silica is the ideal filler/extender for almost everything. You may think your product is one of the 1% that cannot use Amorphous Silica profitably. Don't make up your mind until you have experimented.

FREE SAMPLES & BROCHURE
Write for our brochure and prices which gives complete chemical and physical properties for all 9 grades…send for it now.
Free samples always available.

im
ILLINOIS MINERALS CO.
2035 WASHINGTON AVE. CAIRO, ILLINOIS 62914
(618) 734-4172

SPECIFYING ILLINOIS MINERALS AMORPHOUS SILICA FILLER/EXTENDERS IS LIKE HITTING PAY DIRT

IF YOUR YELLOW TRAFFIC PAINT DOESN'T CONTAIN ONCOR®Y47®A PIGMENT, YOU'RE MISSING SOME BIG EXTRAS.

The pigment used in your yellow traffic paint can make a telling difference. It can mean miles of extra economy, months of extra durability.

The pigment with these characteristics is ONCOR® Y47®A. Field performance under the toughest highway traffic conditions has proven its ability to provide traffic paints with a long, useful service life.

So when you and your paint supplier discuss specifications for your next order of yellow traffic paint, be clearly specific about the pigment—ONCOR Y47A.

If you would like further information about ONCOR Y47A, contact: Industrial Chemicals Division, NL Industries, Inc., P.O. Box 700, Hightstown, N.J. 08520.

IF YOU MAKE YELLOW TRAFFIC PAINT...

You'll be interested in what we're saying to your customers in that market. This advertisement is currently appearing in American City & County Magazine.

NL Industrial Chemicals

Thiokol UVITHANE™ oligomers offer flexibility in radiation curable coatings and inks.

Because the world isn't flat.

The real world, with all its bends and folds, curves and corners, demands coatings and inks that are flexible.

And flexibility—plus abrasion resistance, as well as all the time-saving and energy-saving benefits of radiation curing—is amply supplied by three acrylated polyurethane oligomers from Thiokol.

UVITHANE 782 cures to a soft extensible film and UVITHANE 783 to a tough flexible film, both in a matter of seconds. Use them alone or to upgrade more rigid oligomers in coatings for wood, metal, plastics, electronic components, paper and textiles; and in specialty inks and adhesives.

UVITHANE 788 cures to a non-yellowing, tough flexible film which resists *scuffing, wear and cracking.* That makes it an ideal ingredient in coatings for vinyl floor coverings, flexible plastic containers and other applications where yellowing is a factor.

And we have the flexibility to custom-blend our full line of REACTOMER™ acrylic monomers with the UVITHANE oligomers. We'll even custom-manufacture new *monomers or oligomers* for you.

Lynn Kippax, Marketing Manager for Chemical Specialties, is the man with all the information on UVITHANE oligomers and REACTOMER acrylic monomers. He'll be glad to share it with you. Call him at (609) 396-4001. Or write him: Thiokol/Chemical Division, 930 Lower Ferry Road, Trenton, New Jersey 08607.

Thiokol

Specialty Polymers • Off-the-Road Vehicles • Synthetic Fibers • Sprayers • Propulsion • Educational Services
Friction Materials • Ski Lifts • Pyrotechnics • Closures • Rubber and Rubber Chemicals • Radiation Curable Polymers and Coatings

News from Washington

NPCA Proposes Occupational Health Research Program

Details of an occupational research program, to be sponsored by the National Paint and Coatings Association and designed to explore the effects of coatings products and their ingredients on workers and the work environment, were explained to local associations, regional vice-presidents, and Board of Directors representatives at a September 2 meeting in Chicago, Ill.

Association Chairman of the Board John L. Armitage, of John L. Armitage & Co., called the meeting to brief industry leaders on a proposed research program to be conducted over a three-year period (beginning in 1977) and costing in excess of $200,000 annually. The study would be undertaken by Stanford Research Institute, Menlo Park, Calif., or other qualified research organizations, and would involve a general mortality study of workers in paint manufacturing, a medical surveillance program and a general environmental study.

Financing for the program would be through a proposed 15% dues increase recommended by the Executive Committee, which will be voted on by NPCA members at the 1976 Annual Meeting in Washington, D.C., October 26.

Stressing the need for an industry-wide commitment to occupational health, Chairman Armitage called upon the "unique horsepower" group to carry information regarding this program back and explain it to their local members and companies because it is vital that "the grassroots — the members — understand the comprehensive nature of the plan."

NPCA President Robert A. Roland also emphasized the importance of the program, noting that "The only way to respond to the government is with facts, and the paint industry needs facts concerning the epidemiology of its workers."

He added, "We need to know how workers are affected by the raw materials used in paint manufacturing and the diseases these materials may cause."

The proposed program was outlined by Francis Gaugush, of The Sherwin-Williams Co. (Mission Manager of the Occupational Health Task Force); Larry Keller, of PPG Industries, Inc. (Mission Manager of the Product Safety Task Force); and Donald W. Smith, of Pratt & Lambert, Inc. (Chairman of the Industrial Research Committee).

The general mortality study is "hypothesis generating," to reveal any long-term effects of worker exposure in paint plants through a study of death records. The program would involve 19 months of studying approximately 60 plants and 150,000 man-years of experience.

The environmental study would characterize worker exposure and recommended controls. This study would take approximately 19 months and would involve 10 plants, ranging in size from those with over 100 workers to those with less than 25.

The medical surveillance program would involve the development of forms and procedures for use by member companies in monitoring occupational health; conducting field tests; and providing complete monographs, as well as designing a possible morbidity (disease or illness) study. This program would also run approximately 19 months.

"We need to gear up to compete under the conditions of social and moral revolutions which are taking place in our country," Mr. Gaugush told the participants. "The Department of Labor and its Occupational Safety and Health Administration (are imposing) upon the industry to provide a safe work place for every worker." He added, "This series of studies will put us in the position of accepting the mantle of industry stewardship. If we don't accept it, it will be put upon us.

Spray Paints Declared Harmless to Ozone Layer

The Chairman of the Spray Paint Manufacturers Committee of the National Paint and Coatings Association, Gus W. Leep (Illinois Bronze Paint Co.), has declared that the hydrocarbon propellants (propane, isobutane, or combinations) used in 95% of consumer spray paint products pose no known threat to the earth's upper atmospheric ozone layer.

Mr. Leep said that hydrocarbon propellants are substantially different from fluorocarbon propellants. Fluorocarbons have been the target of criticism based on the theory that they are rising to the earth's upper atmosphere and depleting the protective layer of ozone which helps filter out the sun's ultraviolet rays. Spray paints, said Mr. Leep, have been unfairly linked to the fluorocarbon/ozone issue.

Mr. Leep's comments followed a September 13 press conference held by the National Academy of Science

at which the Academy recommended up to a two-year delay before regulatory action on fluorocarbons be implemented. The Academy stated that no significant damage to the ozone would result from such a delay.

Expressing satisfaction with the NAS regulatory delay recommendation, Chairman Leep commented, "I am pleased to see that the Academy has chosen to base its recommendations on scientific facts and reasoning, and that time is available for comprehensive research to be conducted."

He observed that the controversial ozone depletion theory made public two years ago has subjected all aerosol products to suspicion, whether or not they contain fluorocarbon propellants. "As far as spray paints are concerned," said Mr. Leep, "the vast majority already are labeled for propellant content, and have been for many years. Labeling helps consumers make product choices."

Where have all the bubbles gone?

Air Release Agent 7219 didn't let them happen.

This walnut veneered panel is one of many that were spray coated with a 2-component polyurethane lacquer applied both with and without Henkel's Air Release Agent 7219 in extensive field tests. The same was done with nitrocellulose lacquers.

Note how the untreated surface at the left is broken by entrapped bubbles and craters, while in the section at the right, which includes Air Release Agent 7219, there were no bubbles when the surface began to dry. Equally good results were obtained with curtain coating, spray and brush application.

That's how Air Release Agent 7219 works. This new silicone-free defoamer is equally effective in all types of solvent paint systems and high solids coatings for wood and metal substrates. It is suitable for nitrocellulose lacquers, air- and oven-drying acrylic resin systems and cold hardening epoxy resin paints.

Start off your paint system to a bubble-free finish with Air Release Agent 7219. We'll gladly help with application suggestions and samples. Write, or call 201-659-1200.

Chemical Specialties Division

Henkel **Henkel Inc.**
1301 Jefferson St., Hoboken, N.J. 07030
Teaneck, N.J. • Charlotte, N.C. • Chicago, Ill. • Los Angeles, Cal.

Thorough Analysis of Lead Issue Urged by NPCA

The Consumer Product Safety Commission has been urged by the National Paint and Coatings Association to engage in a thorough risk-benefit analysis on the question of a safe level of lead in residential paint products.

In testimony before CPSC Commissioners on September 13, NPCA President Robert A. Roland stated that the Commission should make its final decision on whether to lower the 0.5% level of lead in paint to 0.06% "based on reliable evidence and founded on a sufficient scientific base."

If Limit Is Lowered, "No Lead Added" Standard Recommended

"If the Commission finds that it must lower the level of lead in paint below 0.5%," he said, "then we recommend that it adopt a standard which specifies that no lead may be *intentionally* added to residential paint formulations, and a specific regulatory standard of 0.2%."

This 0.2% level would make allowance for the trace contaminants found in raw materials, manufacturing equipment, and the general environment, and could minimize the product liability burden of the smaller manufacturer, which would be great at the 0.06% level.

Mr. Roland urged a very careful analysis of all the data and evidence on the issue of a safe level of lead in residential paints, noting that the "Commission's own data show that the majority of residential paint products presently do not use lead driers or any other lead components in their formulations. Thus, the total environmental exposure to lead in modern paints is far less than some may believe, under the existing standard, because of voluntary industry action."

The NPCA President pointed out that much of the data used by the National Academy of Sciences and others to justify a lower lead limit is based on research using pure lead salts and not the lead compounds used in paints.

He said that the reason the Lead Based Paint Poisoning Prevention Act, as amended by Public Law 93-151, specifically instructed the CPSC Chairman to "conduct appropriate research on multiple layers of dried paint film, containing the various lead compounds commonly used, . . . is because *research on pure lead*

compounds such as lead acetate was not sufficient to make such a determination." (emphasis added)

"If this responsibility is fairly exercised and the Commission determines that the risks involved outweigh the benefits," Mr. Roland said, "then not only will NPCA do everything it can to aid its members in complying with a lower lead standard, it will fully support such a standard. This has always been and continues to be NPCA's position.

Need Standard Test Method To Determine Amount of Lead In Paint

NPCA also recommended that the CPSC thoroughly examine the current practices of the paint industry with respect to the use of lead in modern paints, and adopt a standard test method as a means of identifying the amount of lead contaminants in paints.

"A truly critical question, which must be answered before a standard as low as 0.06% is adopted, is, Can a paint manufacturer, utilizing good manufacturing practices, meet such a standard even though no lead is deliberately added to his products?" Mr. Roland said.

If the Commission decides to lower the current lead standard for paint, it is critical that the problem of contaminants is adequately resolved, he stated, and that it is imperative that an accurate, standard test method be adopted as a part of the regulations relating to lead content in paint. The lack of accuracy and the inability to achieve reproducible results with many test methods raise "the spectre of tremendous and unnecessary statutory and product liability risk," he added.

If the Commission decides to lower the lead level, Mr. Roland asked that the possibility of a phase-down of the current level be considered. This phase-down could be in the form of either a general exemption for a specific period of time or a specific exemption for individual companies with special problems.

This phase-down would reduce the impact on those manufacturers who must find ways to reformulate their products which still need lead driers or revise their product mix.

He also asked that any new standard make a reasonable allowance for trace contaminants of lead which cannot be precluded from paint

products under good manufacturing practices.

The CPSC hearings were required under S. 1466, the National Health Education and Disease Prevention Act of 1976. As enacted, Title II of this legislation required that the five Commissioners of the Consumer Product Safety Commission determine by majority vote within six months of the date of enactment (December 23, 1976) whether a level of lead in paint greater than 0.06%, but not in excess of 0.5%, is safe. If CPSC determines that such a level is safe, that level then would become the maximum permissible amount of lead in paint six months after the date of CPSC's determination. If CPSC fails to make the required determination within the specified six-month period, the maximum permissible level of lead in paint then would be 0.06% twelve months after the date of enactment (June 23, 1977).

May 16-18 Conference at NBS To Discuss Corrosion Of Metals in Building

A conference designed to promote dialogue between corrosion engineers and members of the building industry concerned with corrosion of metals is scheduled to be held at the National Bureau of Standards in Gaithersburg, Md., May 16-18, 1977.

The conference is being sponsored by NBS, the National Association of Corrosion Engineers, and the Construction Specifications Institute.

The first day of the conference will be devoted to presentations on the fundamentals of corrosion and corrosion control. The remaining day and a half will deal with specific corrosion problems, including socio-economic concerns, encountered by the building industry.

A preliminary announcement of the conference will be mailed in November. Those wishing to receive this announcement, should contact Dr. Jerome Kruger, Chief, Corrosion and Electrodeposition Section, Room B252, Materials Bldg., or Dr. Geoffrey Frohnsdorff, Chief, Materials and Composites Section, Center for Building Technology, IAT, Room B348, Building Research Bldg., National Bureau of Standards, Washington, D. C. 20234.
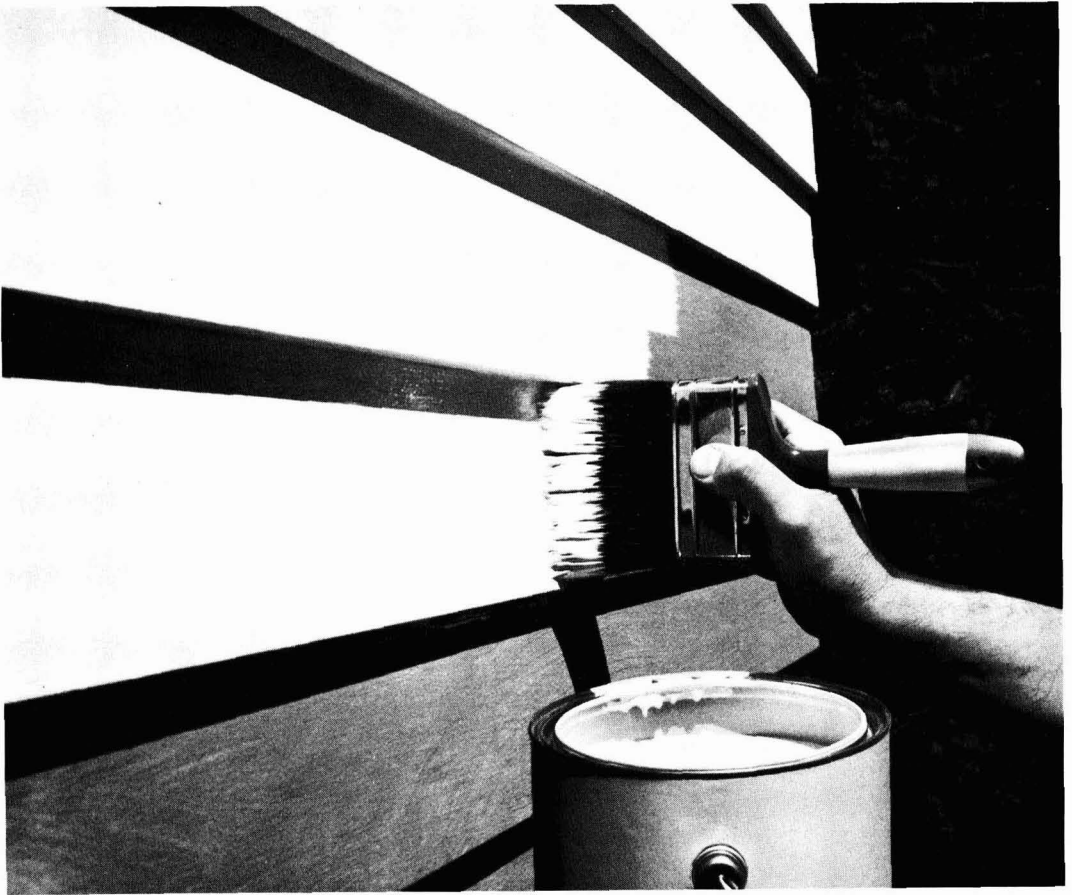
Mold is remembered.
A premium price is not.

Add VANCIDE® PA to your premium solvent based paints and their mold resistance will match or surpass every other high standard you have achieved. The reason: VANCIDE PA is the most effective fungicide there is, pound for pound. And it has been since 1963. It's as simple as that.

VANCIDE PA costs 30¢ to 50¢ per gallon for optimum loading, depending on formulation. Not a big investment for you or your customer – considering its superior performance. Actually, VANCIDE PA is more economical to use than other mold inhibitors on a cost effectiveness basis. You get more of what you pay for with VANCIDE PA. VANCIDE PA is available in powder and dispersion form.

For complete information write to Paint Department, R. T. Vanderbilt Company, Inc., 30 Winfield Street, Norwalk, CT 06855 (203) 853-1400. 6279 East Slauson Avenue, Los Angeles, CA 90040 (213) 723-5208.

Ⓥ R. T. Vanderbilt Company, Inc.
INDUSTRIAL MINERALS AND CHEMICALS
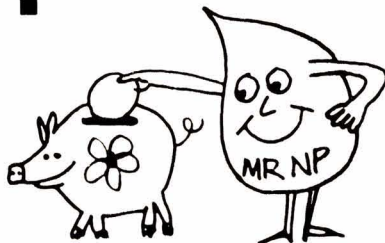
Pigmented Microvoid Coatings II.

Luminance and Color
Of the Concentric Sphere Model*

MILTON KERKER and DERRY D. COOKE
Clarkson College of Technology†

This theoretical calculation explores, for the concentric sphere model, the effect of particle size distribution upon the luminance and color of an optically thin pigmented microvoid film on a black background. The luminance and color are obtained from the tristimulus values of the Kubelka-Munk scattering coefficient.

In this model, the film consists of a resin containing a logarithmic distribution of rutile spheres, each positioned at the center of a microvoid sphere.

For a particular distribution of the rutile spheres, the effect of increasing the size of the microvoid is to decrease the luminance to a minimum value as well as to shift the color toward spectrally pure violet. Beyond this minimum, further increase of the microvoid results in increased luminance and decreased spectral purity. For sufficiently small rutile particles (radius from 0.03 to 0.09 μm) the reduction in luminance upon initial addition of microvoid may be quite dramatic, e.g. more than 2 to 3 orders of magnitude, with a corresponding decrease in the hiding power of the film, and increase in its transparency.

KEY WORDS: Microvoids; Pigment; Kubelka-Munk scattering function; Polarization; Rayleigh scatterers; Luminance; Chromaticity.

INTRODUCTION

Incorporation of small bubbles, or *microvoids*, into white pigmented films may affect the hiding power and brightness in striking ways, including a syn-

ergism, such that an appropriate mixture of pigment and microvoids may provide greater opacity than an equal particulate volume comprised only of pigment particles. Thus, if enhancement of hiding power is the goal, there may be an advantage to replacing part of the pigment by microvoids.

Following a suggestion by Seiner and Gerhart,[1] the possibility was explored, theoretically, that this synergism might arise from encapsulation of pigment particles within the microvoids. The model is depicted in *Figure* 1. A spherical core with radius a and refractive index m_1 is surrounded by a microvoid concentric shell with radius b and m_2, which in turn is encased within a uniform continuous medium with m_3. Of course, this is not a realistic model since it depicts the particle suspended at the center of the microvoid. The justification for this oddity is that calculations can be carried out for such a pair of concentric spheres,[2] and hopefully any interesting effects might carry over into the more realistic case where the pigment particle sits on the floor of the microvoid.

Although microvoids are considered in this particular analysis, the phenomena which will be described occur *whenever the surrounding medium has a refractive index intermediate between the core and the shell*. Indeed, there are systems such as phase separated glasses for which this model is quite realistic.[3] The inverse configuration, where the microvoid (or constituent of lower refractive index) is enclosed within a spherical shell of the pig-
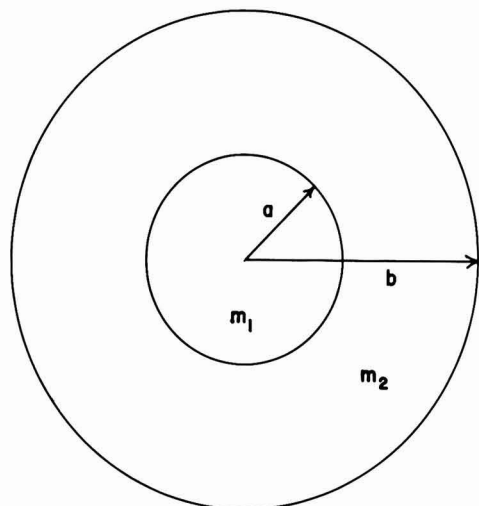
Figure 1—Concentric sphere model. In this paper refractive dices correspond to rutile m1, microvoid m2 and resin m3. Fraction of rutile f = (a/b)³ where a and b are radii of rutile particle and microvoid, respectively

ment material (or constituent of higher refractive index) all encased in a continuous medium (of intermediate refractive index), gives rise to comparable effects. These effects will also occur for combinations of confocal ellipsoids,[4] and quite possibly for other nonspherical configurations.

MICROVOID COATINGS

Preliminary calculations carried out for *monodisperse* dispersions illuminated with *monochromatic* light did show positive synergisms for certain configurations.[5] For example, the hiding power in light with $\lambda = 0.534\mu$m of a dispersion of particles with radius 0.30μm is doubled when an outer shell of each particle, equivalent to 15% of the volume, is replaced by a microvoid shell. This is illustrated in parts (a), (b), and (c) of *Figure 2*.

However, in many other cases quite the opposite effect was obtained, and more frequently films comprised of pigment particles encased in microvoids exhibited lower hiding power than films consisting only of pigment particles with the same total size. Indeed, when the particles are sufficiently small, this effect becomes quite dramatic. The Kubelka-Munk scattering function drops virtually to zero; the particles become nearly *invisible;* the films become nearly *transparent.* Thus, for a particle with radius $a = 0.017\mu$m and wavelength $\lambda = 0.534\mu$m, the hiding power will drop by a factor of about 40,000 when part of the pigment material is replaced by a microvoid concentric shell (pigment 42% of the volume, inner radius 0.013μm, outer radius 0.017μm). The smaller the particle, the greater is this effect. Even for $a = 0.09\mu$m, the size for which

this pigment exhibits maximum hiding power, there is a 400 fold decrease in hiding power when part of the pigment material (pigment 29% of the volume, inner radius 0.059μm, outer radius 0.090μm) is replaced by a microvoid concentric shell. These effects are also depicted in *Figure 2*.

Obviously, this model does not predict the kind of synergism that had initially been anticipated. Quite the opposite!

In retrospect, the effect is not too difficult to understand. Small particles scatter light as if the particle were replaced by an oscillating dipole.The intensity of the scattering is related to the *dipole moment* and this in turn depends upon the *polarization* of the particle by the electromagnetic field. When the refractive index of the particle is greater than that of the medium in which it is immersed, the polarization is positive; when the refractive index is less, the polarization is negative. The compound particles considered above consist of one part with positive polarization (e.g., the pigment cores) and one part with negative polarization (e.g., the microvoid coating). Apparently, the nearly invisible particles have a configuration for which the polarization of the positive region annuls that of the negative region so that the effective dipole moment (and
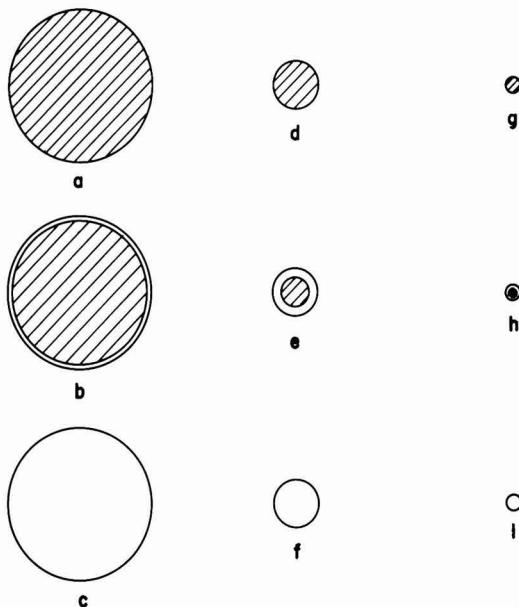
Figure 2—Effect of microvoid coating on the volume normalized Kubelka-Munk scattering coefficient (*vide* Reference 5; this is the hiding power); pigment m1 = 2.97, microvoid m2 = 1.00, resin m3 = 1.51, wavelength λ = 0.534 μm
Inner radius 0.28 μm; outer radius 0.30 μm
    S = 1.8, 3.3, 0.9 for a, b, c, respectively
Inner radius 0.059 μm; outer radius 0.090 μm
    S = 31, 0.075, 1.33 for d, e, f, respectively
Inner radius 0.013 μm; outer radius 0.017 μm
    S = 0.19, 5.1 x 10⁶, 0.036 for g, h, i, respectively

hence the scattering) is close to zero. The conditions which must be satisfied in order to obtain the effect are given in the earlier cited work.[4,5]

Subsequent analysis has shown some additional curious features.[6] The particles approach truly zero light scattering only in the limit of zero size. For finite, albeit small particles, there is some *residual* scattering, even in those cases for which the scattering is drastically reduced by the presence of the microvoid (or other) spherical shell. It is this residual scattering which we find curious.

Rayleigh Scatterers

Scattering by uniform small particles, so-called Rayleigh scatterers, is proportional to λ^{-4} where λ is the wavelength. Lord Rayleigh derived his famous theory (the dipole theory) in order to account for the blue color of the sky. He demonstrated that the particular hue of the sky was a consequence of the λ^{-4} dependency. Our analysis indicates that the residual scattering, which occurs after the dipole scattering has been suppressed, follows a λ^{-8} law. The consequences of this are shown in the results presented below. Actually, such λ^{-8} scattering had been observed in phase separated glasses by a number of workers and a model quite comparable to the one considered here had been proposed to account for this effect.[3]

Another feature of Rayleigh scattering is the symmetry between scattering into forward and backward half-spaces. For dielectric particles larger than Rayleigh scatterers, there is preferential scattering into the forward half-space. However, the residual scattering from the concentric spheres studied here, for which the dipole scattering has been suppressed, shows preferential scattering into the backward half-space. This effect had also been observed in the phase separated glasses.

COMPUTATIONS

In this paper we extend the computations to more realistic conditions than had been treated in the earlier paper[5] by asking the following question: What is the visual appearance in white light of a resinous film, upon a black background, containing polydisperse rutile spheres each encased within a microvoid sphere? More specifically, we calculate for each wavelength in the visible spectrum the Kubelka-Munk scattering coefficient defined below as S'. This quantity is proportional to the reflectance of an optically thin layer of the dispersion viewed against a black background. The visual appearance is characterized by the luminosity and chromaticity of this reflected light and these in turn are obtained by calculating the tristimulus values of the Kubelka-Munk scattering coefficient as given by[7]
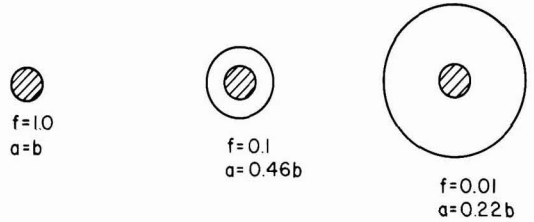
Figure 3—Procedure for incrementing microvoid coating. Fraction of particle comprised by core, f = 1, 0.10 and 0.01; a is inner radius, b is outer radius

$$S' = (1 - < \overline{\cos \theta} >) \, \overline{C}_{SCA} \tag{1}$$

where $\overline{C}_{SCA}$ is the scattering cross section and $< \overline{\cos \theta} >$ is the asymmetry factor, each averaged over the normalized size distribution. Thus

$$\overline{C}_{SCA} = \int_{-1}^{1} \int_{0}^{\infty} I \, f(a) \, da \, d \cos \theta \tag{2}$$

and

$$< \overline{\cos \theta} > = \frac{\int_{-1}^{1} \int_{0}^{\infty} I \, f(a) \cos \theta \, da \, d \cos \theta}{\overline{C}_{SCA}} \tag{3}$$

where I, the scattered intensity for unpolarized unit irradiance, is a function of wavelength, radius, refractive index, and scattering angle θ. This is calculated from the Aden-Kerker theory as shown elsewhere.[2,8] It should be recognized that the S' is different from the scattering into the back hemisphere, or at 180°. Of course $(1 - <\overline{\cos \theta}>)$ is one factor required in going from C_{SCA} to the Kubelka-Munk S'.[5]

The tristimulus values, X, Y, Z, are calculated by inserting S' into the usual equations as if it were a reflectance using the 1931 CIE standard observer and the relative spectral irradiance of the CIE standard source C, each as tabulated by Judd and Wyszecki.[9] The reason for doing this is that $R_o = Sx/(Sx+1)$ approaches Sx as the thickness of the layer x becomes small. The luminosity is proportional to Y and the chromaticity coordinates are given by $x = X/(X + Y + Z)$ and $y = Y/(X + Y + Z)$.

The wavelength range was 0.400 to 0.770 μm. The real part of the refractive index of the particles was obtained by averaging the values given by de Vore[10] for rutile, weighting those for the ordinary ray twice and those for the extraordinary ray once. This ranged from 3.131 to 0.400 μm to 2.618 at 0.770 μm. Cronemeyer's[11] values of the imaginary part of the refractive index for rutile were used. These varied from 3.1 $\times$ 10^{-3} at 0.400 μm to 5.0 $\times$ 10^{-6} at 0.430 μm. Values for longer wavelengths were obtained by extrapolation, although these were so small that they did not influence the results. The re-

fractive index of the medium was taken from values for a thermosetting acrylic resin computed by E. L. Cairns of the E. I. duPont de Nemours & Co., Inc. Pigments Dept. from Fresnel reflectance measured in a Cary 14 spectrophotometer.[12] This varied from 1.534 at $0.400\mu m$ to 1.493 at $0.770\mu m$.

The particle size distribution was described by a logarithmic distribution normalized so that the two parameters in the distribution were the modal radius, a_M, and a breadth parameter, σ_0, which for the relatively narrow distributions used here is approximately equal to the coefficient of variation.[13] Calculations were carried out for $a_M = 0.03$, 0.06, 0.09, 0.12, and 0.15, each with $\sigma_0 = 0.01$, 0.10, and 0.20; also for $a_M = 0.20$, $\sigma_0 = 0.01$; $a_M = 0.25$, $\sigma_0 = 0.01$, and 0.10; and $a_M = 0.30$, $\sigma_0 = 0.01$. Commercial grades of rutile pigments generally have number mean radii in the range 0.05 to $0.10\mu m$. The coefficient of variation in real pigment system ranges

from about 0.2 to 0.3, somewhat broader than calculated.

In the calculations, we start with a distribution of pigment spheres and then proceed to add on to each of these a concentric microvoid shell, such that each configuration is comprised of the same volume fraction of pigment. The shells are incremented in this way until the volume fraction of pigment is 0.01, which corresponds to the radius of the pigment particle in each microvoid being about 22% of the total radius. The incrementing procedure is illustrated in *Figure* 3. Obviously, this is an arduous calculation.

A comment is in order regarding the normalization of S'. A measure of the hiding power is usually obtained by dividing the Kubelka-Munk scattering function by the particle volume. However, we have used the backward scattering function as defined above, so that the luminances reported here are not

Figure 4—Luminance Y versus f, fraction of each particle comprised of rutile for $a_M = 0.03\ \mu m$ and $\sigma_0 = 0.01$ and 0.20

Figure 5—Luminance Y versus f, fraction of each particle comprised of rutile for $a_M = 0.06\ \mu m$ and $\sigma_0 = 0.01$ and 0.20

normalized with respect to particle volume but rather relative to numbers of particle. There is the question, if these results are to be normalized relative to volume, whether to select for the particle volume that of the rutile, the microvoid, or the sum of the two. In order to normalize in this way, it would be necessary to divide each luminance by the average volume per particle of rutile, microvoid, or microvoid spherical shell.

The limitations of these calculations should be clearly kept in mind. They apply accurately only to low concentrations, with the PVC of the composite particles (solid pigment and void combined) less than 0.1. It is well known that in white enamels, as the concentration of TiO_2 is increased, its scattering efficiency decreases substantially. We cannot calculate this loss rigorously from theory. Perhaps the loss would be less when air is combined with the

Figure 7—Chromaticity diagram (x = X/X + Y + Z and Y = Y/X + Y + Z, where X, Y, Z are tristimulus values) for $a_M = 0.03, \sigma_0 = 0.01$. Numbers alongside the elliptical curve are values of volume fraction of rutile, S represents the source, A the bare rutile particle (f = 1) and B the configuration for which the luminance is minimum (f = 0.43). Numbers along the outer curve indicate wavelengths (nm) of spectrally pure colors

TiO_2, as in the present picture. Perhaps as bubbles displace resin, the dispersion will indeed behave more like TiO_2 in air, as we originally thought. But that is beyond the reach of present theory.

LUMINANCE

Figure 4 shows how the luminance (in arbitrary units) varies as increasingly larger microvoid shells are added to two distributions of rutile spheres with breadth parameters $\sigma_0 = 0.01$ and 0.20, each with modal radius $a_M = 0.03$ μm. For the nearly monodisperse system ($\sigma_0 = 0.01$) the luminance drops by a factor of 3,000 as the microvoid shell increases to the point where the volume fraction of pigment drops to about 0.43. The effect is slightly smaller for the more polydisperse system, reflecting the somewhat greater number of larger particles present in this positively skewed size distribution. Similar results are shown in *Figure 5* for a = 0.06 μm, and in *Figure 6* for a = 0.09, 0.12, 0.15, 0.20, 0.25, and 0.30 μm.

The effect of the microvoid in sharply decreasing the luminance becomes less with increasing pigment particle size. This is consistent with the fact that the dipolar scattering accounts for a lesser
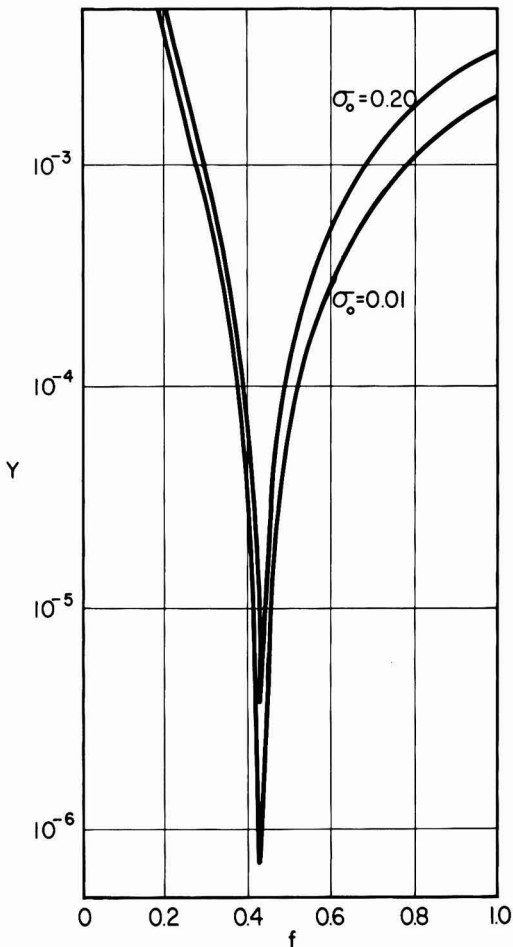

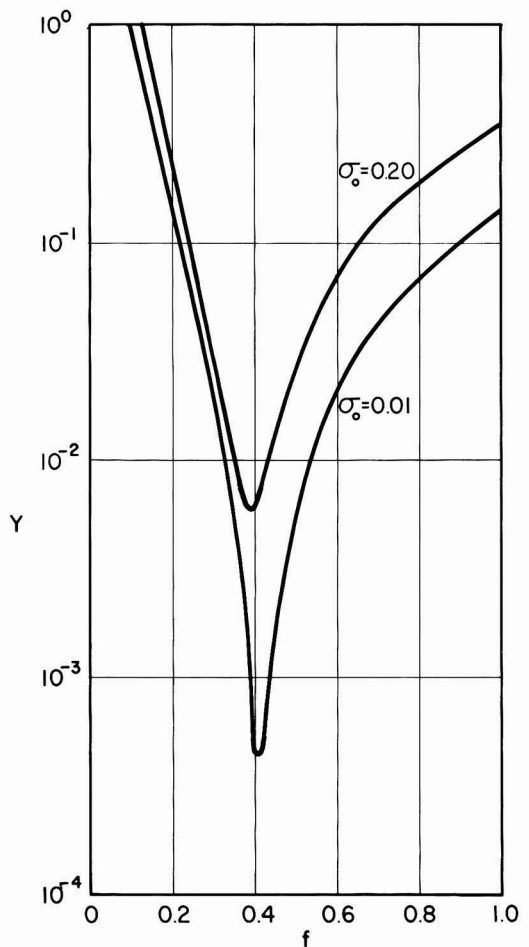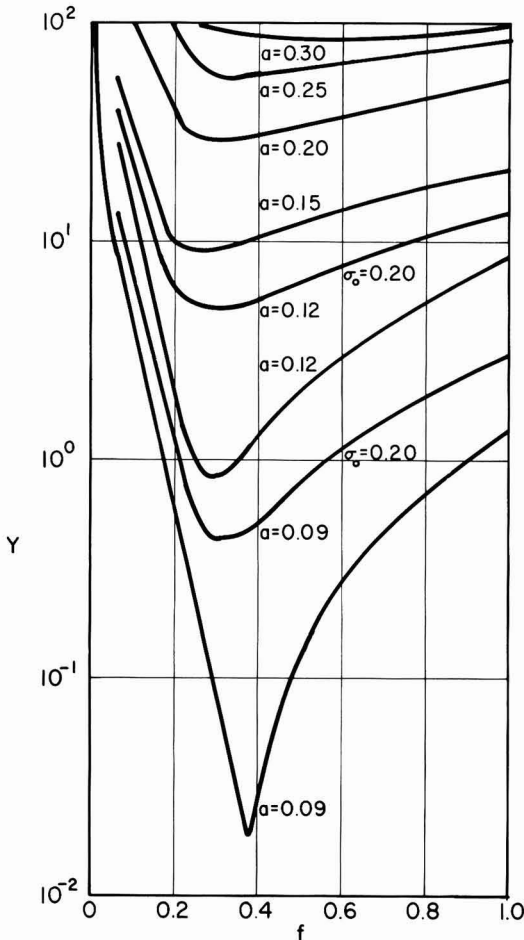Figure 6—Luminance Y versus f, fraction of each particle comprised of rutile for $a_M = 0.09, \sigma_0 = 0.01$ and 0.20; $a_M = 0.12, \sigma_0 = 0.01$ and 0.20; $a_M = 0.15, 0.20, 0.25, 0.30$ each for $\sigma_0 = 0.01$ (only $\sigma_0 = 0.20$ is indicated)
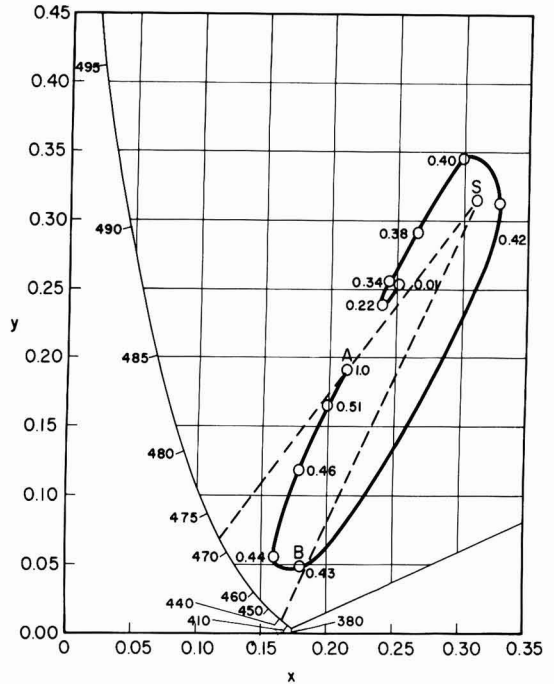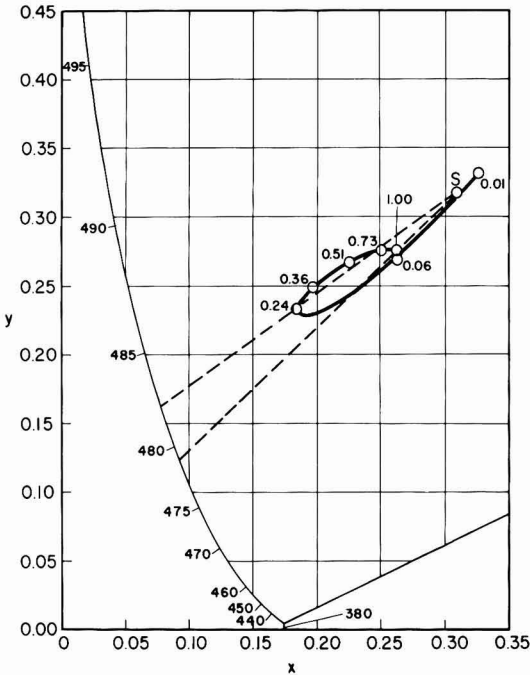
Figure 8—Chromaticity diagram for $a_M = 0.15$, $\sigma_o = 0.01$

fraction of the scattering as the size becomes larger. The mechanism described above, in which the negative polarization of the microvoid annuls the effect of the positive polarization of the pigment moiety no longer applies to the same extent. Yet even for particles as large as $a = 0.30\mu$m, there is a significant decrease in scattering as a microvoid shell is added; a trend quite opposite to what might be intuitively inferred were one to think about this process in terms of reflection-refraction of geometrical optical rays.

One can conclude quite definitively that this particular model for inclusion of microvoids into pigmented coatings does not provide for enhancement of luminosity or of hiding power in this particle size range. Indeed, the opposite is true. It offers, instead, a particularly powerful mechanism for rendering such a film more transparent.

CHROMATICITY

We now turn to a consideration of the chromaticity of the reflected light. *Figure 7* is quite typical for the smaller size cores ($a_M = 0.03\mu$m, $\sigma_o = 0.01$). The inner curve, in the shape of a partially closed ellipse, is the locus in the chromaticity plane of the Kubelka-Munk scattering function, which in turn is proportional to the reflectance. The numbers on this curve indicate the fraction of the particles which are comprised of the rutile cores. Thus the point designated A is for the distribution of bare

rutile particles. Point B is where the rutile cores comprise 43% of the total volume of each particle. This represents the configuration of pigment encased in microvoid having the minimum luminance.

The color coordinates of the light source are indicated by S. The spectral colors are given by the outer boundary, the numbers indicating the wavelength (in units of μm). The linear bottom portion of this curve indicates the nonspectral colors. The scale is such that the diagram shows only the lower left corner of the chromaticity diagram. The hue of a particular point is the intercept obtained by extending the line from the source to this point through to the spectral curve. Thus for the bare pigment particle (point A), the hue is 0.475 μm. The purity is given by the ratio of the length of the line segment AS to the total length, in this case 50%.

The blue color of the film containing the bare pigment particles is quite consistent with expectations since particles of this size (radius about 0.05 the wavelength) are Rayleigh scatterers and follow a λ^{-1} dependence. Interestingly, the color becomes more violet and much purer as the microvoid shell surrounding the rutile particles is expanded. Indeed for volume fraction $f = 0.43$ the color has shifted into the violet, $\lambda = 0.440\mu$m, and the purity has increased to 88%. But, referring back to *Figure 4*, $f = 0.43$ corresponds precisely to the configuration for which the luminance goes through a deep minimum. And for this so-called *residual scattering*, the theoretical analysis referred to earlier (6) indicates a λ^{-8} dependence. This higher order wavelength dependence accounts for the shift to the violet. The cut-off of visual sensitivity at $\lambda = 0.380\mu$m accounts for the greater spectral purity.

The chromaticity sweeps around very rapidly into the achromatic region as the microvoid increases beyond the size for which the luminance is minimal. This is because the weak residual scattering is now swamped by "higher order" scattering, which in turn is essentially achromatic (6).

The chromaticity diagrams for somewhat larger sizes ($a_M = 0.06$, and 0.09, and 0.12μm), and for somewhat broader distributions ($\sigma_o = 0.10$ and 0.20), resemble that in *Figure 7*, although the chroma of the residual scattering is not as great, and so these will not be discussed further. For still larger rutile particle sizes ($a_M = 0.15$, 0.20, 0.25, and 0.30μm) high chroma no longer appear. This is illustrated in *Figure 8* for $a_M = 0.15$; $\sigma_o = 0.01$. In this case the luminance of the bare rutile particles is still blue (0.479μm), but the purity is only 19%. As the microvoid shell increases, the luminance decreases to a minimum value at $f = 0.24$ of about one-half the initial value, at which point the chromaticity exhibits a principal wavelength of $\lambda = 0.482$ and a purity of 55%. The mechanism of scattering in this case involves higher order terms and is no longer
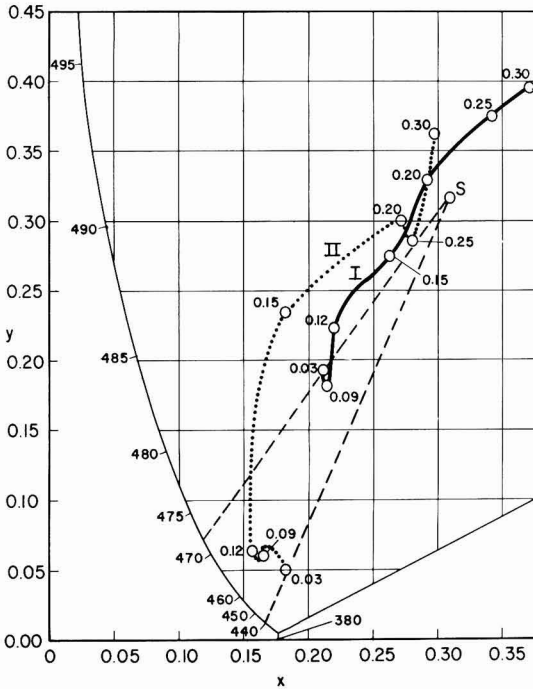
Figure 9—Chromaticity diagrams—I. Rutile particles. II. Rutile particles in microvoid sphere for values of f where luminance is minimum. Numbers on curves indicate values of a_M; $\sigma_0 = 0.01$

amenable to the simple interpretation applicable to the smaller particles. Yet the film does become decidedly bluer with the initial growth of the microvoid.

Figure 9 provides an alternative view of these results. Curve I represents the chromaticity of bare rutile particles for $a_M = 0.03$ to 0.30μm with $\sigma_0 = 0.01$. These are quite monodisperse distributions, but the results are not greatly different for distributions which have been calculated with $\sigma_0 = 0.10$ or 0.20.

Curve I shows just how the chromaticity changes from the rather blue of the Rayleigh scatterers (hue — 0.472μm; purity 50%) to the slightly yellowish tinge of the largest particles (hue — 0.580μm purity 30%). The "whitest" films occur for $a_M = 0.20\mu$m, where the purity of the greenish-blue light is only about 5%. This is about twice the radius normally used for paints.

Curve II represents the chromaticity for those configurations where the luminance is minimal (see *Figures* 4-6). We have already seen how this residual scattering for $a_M = 0.03$ is shifted into the violet and how the purity is enhanced. This condition persists up to $a_M = 0.12$ and, although the scattering at the minimum continues to be "bluer" for the larger sizes, the effect is smaller.

CONCLUSION

Interesting luminance and color effects have been calculated for thin films consisting of rutile spheres encapsulated in microvoid spheres all embedded in a resin. The rutile spheres are in the size range of 0.3 μm or less, with coefficient of variation of 0.20 or less.

The luminance decreases by orders of magnitude to a minimum value as the microvoid shell becomes larger. With still larger microvoid shell (volume fraction of rutile about 40%), the luminance increases in what might be considered the normal fashion.

The decreasing luminance is accompanied by a shift in color towards the violet and to higher purity. Beyond the configuration for which the luminance is minimum, the color rapidly becomes achromatic. □

References

(1) Seiner, J. A. and Gerhart, H. L., *Ind. Eng. Chem. Prod. Des. Develop., 12,* 98 (1973). Also see American Chemical Society Meeting, Chicago, Ill., Aug. 27, Abstracts of Papers ORPL 10-24.
(2) Aden, A. L. and Kerker, M., *J. Appl. Phys., 22,* 1242 (1951).
(3) Goldstein, M., *J. Appl. Phys. 34,* 1928 (1963).
(4) Kerker, M., *J. Opt. Soc. Am. 65,* 376 (1975).
(5) Kerker, M. Cooke, D. D., and Ross, W. D., JOURNAL OF PAINT TECHNOLOGY, *47,* No. 603, 33 (1975).
(6) Chew, H. and Kerker, M., *J. Opt. Soc. Am. 66,* 440 (1976) In Press.
(7) Ross, W. D., JOURNAL OF PAINT TECHNOLOGY, *43,* No. 563, 49 (1971).
(8) Kerker, M., "The Scattering of Light and Other Electromagnetic Radiation," Chapter 5, Academic Press, New York, 1969.
(9) Judd, D. B. and Wyszecki, G., "Color in Business, Science, and Industry," 2nd Edition, Wiley, New York, 1963.
(10) de Vore, J. R., *J. Opt. Soc. Am. 41,* 416 (1951).
(11) Cronemeyer, D. C., *Phys. Rev. 87,* 876 (1952).
(12) Ross, W. D., private communication, 6 May 1975.
(13) Espenscheid, W. F., Kerker, M., and Matijevic, E., *J. Phys. Chem. 68,* 3093 (1964).

Model for the Correlation
Of Rheological Measurements
With the Leveling and Cure
Of Thermosetting Powder Coatings

M. J. Hannon, D. Rhum, and K. F. Wissbrun
Celanese Research Company*

Measurement of the dynamic viscosity of a powder paint as a function of time at various temperatures can be used by means of a simple model to predict the nonisothermal viscosity changes which occur when a powder-coated panel is baked at various oven temperatures. The Orchard theory then predicts, using parameters from this model, the change of profile irregularity and wavelength with baking conditions and film thickness. Average roughness and gloss can be correlated by the same parameters. The rub resistance or cure of the films is also correlated by the nonisothermal viscosity model.

The parameters of the model are the temperature dependent initial viscosity of the resin and its temperature dependent cure rate, and the heating rate of the panel. The use of a computer to evaluate the effects of varying any of these parameters independently should be useful in minimizing the experimental effort in optimizing formulations.

KEY WORDS: Thermoset; Isothermal process; Test panels; Gloss; Crosslink density; Elastic modulus; Viscosity; Orchard theory; Rheology; Wavelength.

INTRODUCTION

Two fundamental requirements of commercial coatings are good appearance and good physical properties. The formulation variables which are responsible for these two characteristics are often in conflict; one that enhances one property diminishes the other. Appearance is strongly affected by the rheological characteristics of the paint, and the rheology in turn is strongly affected by the formulation constituents. This is particularly true of powder paints, in which solvents are totally absent from the formulation. In powder coatings the appearance, largely controlled by viscosity and the time available for leveling, must be primarily achieved via resin formulation. The flow necessary to form the smoothest surfaces is obtained with low viscosity formulations, but strong films are obtained from high molecular weight resins, which have high viscosity. With thermosetting formulations the viscosity varies from an initial value to infinity as the material cures, and the flow must occur well before the gel point. The final physical properties strongly depend on proper cure; development of crosslink density cannot be short-changed excessively in order to enhance appearance development. As another example of conflicting requirements, good flow requires as low a glass transition temperature (Tg) as possible, while stability of the powder requires a Tg well above room temperature.

An understanding of the process in which a deposited powder paint is converted to a cured film requires the integration of several disciplines into a coherent theory. These disciplines are surface characterization, rheology, and cure characterization. With such a theory, the rheological and physical parameters can, in turn, be related back to the chemical structures of resin and curing agent and other formulation parameters of the paint system, permitting one to limit surface defects and maximize physical properties.

Various attempts at analyzing the leveling properties of paints have been reviewed by Quach.[1] Most of the review deals with leveling in solvent and latex paint systems. Recently several authors have attempted to refine leveling measurements. Dodge,[2] and later Hansen,[3] and Quach and Hansen[4] used

drawdown bars to simulate brush marks, and profilometers to measure the surface profiles of the dried films. One of the early attempts to apply a theoretical analysis of leveling to a powder paint system was made by Wolpert and Wojtkowiak,[5] using a thermoplastic acrylic powder. These authors used the Orchard-Rhodes analysis and found qualitative agreement with the theory. Subsequent work by Wolpert[6] elaborated on the previous work and in addition purported to demonstrate the importance of a yield phenomenon in the paint in causing leveling to stop. Additional work by Nix and Dodge[7] qualitatively showed the importance of pigment dispersion, particle size, and particle size distribution upon leveling of powder paints. Finally, Spitz[8] applied the Orchard-Rhodes theory to the leveling of a thermoplastic epoxy powder paint and found excellent agreement with the theory.

The application of a theory to the leveling of a thermoset powder paint has not been made. The relationship of final physical properties to the rheological changes during curing of a thermoset powder paint also has not been investigated.

The purpose of the present work is to present a model for the leveling and cure of a thermoset powder paint system. The theory of leveling used is that of Smith and Orchard,[9] Orchard,[10] and Rhodes.[11] This is combined with a model of the cure of a thermoset system similar to that of Roller,[12] who investigated the viscosity-time-temperature interactions that relate to the curing of a thermoset system during a lamination process. The model is intended to correlate leveling performance, gloss, and cured film properties with rheological measurements made on a paint formulation before it is converted to powder form. Once such correlations are established for a given coating type the task of optimizing the formulation should be aided by use of the model to analyze the reasons for any deficiencies. Hypothetically improved formulations can be screened rapidly and inexpensively by computer simulation. Actual experimental formulations having the properties predicted to be desirable by the computer can then be prepared on a small scale and their rheological and curing parameters tested experimentally. The expensive and tedious necessity of preparing large quantities of a formulation, converting it to powder and spraying, baking, and evaluating test panels can be restricted to formulations that have passed the computer and laboratory tests.

THEORY
Leveling

The development of the theory relevant to the leveling process is amply reviewed by Quach.[1] The most widely accepted expression for the time dependent decay of sinusoidal brush marks was first given by Orchard[10] and subsequently verified by Rhodes.[11]

$$\ln \frac{A}{A_o} = -\frac{\pi}{\lambda} \, f\left(\frac{2\pi h}{\lambda}\right) \int_0^t \frac{\sigma}{\eta} \, dt \qquad (1)$$

Where A_o = initial amplitude of the brushmarks at time zero

A = amplitude of the brushmarks at time t

λ = wavelength of the sinusoidal brushmarks

h = mean film thickness

σ = surface tension, assumed constant

η = viscosity

$f\left(\frac{2\pi h}{\lambda}\right)$ = a function whose value is given in equation (2).

$$f\left(\frac{2\pi h}{\lambda}\right) = \frac{\tanh\left(\frac{2\pi h}{\lambda}\right) - \frac{2\pi h}{\lambda} \cdot \text{sech}^2\left(\frac{2\pi h}{\lambda}\right)}{1 + \left(\frac{2\pi h}{\lambda}\right)^2 \cdot \text{sech}^2\left(\frac{2\pi h}{\lambda}\right)} \qquad (2)$$

For a film thickness, small compared with the wavelength of the disturbances (which is usually the case in the coatings which were considered), the function becomes:

$$f\left(\frac{2\pi h}{\lambda}\right) = \frac{2}{3} \cdot \left(\frac{2\pi h}{\lambda}\right)^3 \qquad (3)$$

and the expression for the amplitude becomes:

$$\ln \frac{A}{A_o} = \frac{-16\pi^4 h^3 \sigma}{3\lambda^4} \int_0^t \frac{dt}{\eta} \qquad (4)$$

This expression has been verified many times for paint systems, as mentioned in the introduction. However, in most of these cases it was assumed that the polymer was at constant temperature and had a constant viscosity, independent of time, so that equation (4) simplified to equation (5).

$$\ln \frac{A}{A_o} = \frac{-16\pi^4 h^3 \sigma t}{3\lambda^4 \eta} \qquad (5)$$

In this work, however, the viscosity is not time independent, because the powder paint is thermosetting, and its temperature varies during baking. The integral expression of equation (4) must be calculated explicitly for each curing system according to the kinetics of that system, as detailed below.

Of interest, is the term in the Orchard equation, $\frac{h^3 t}{\eta}$, or, when dealing with time dependent viscosity,

$h^3 \int_0^t \frac{dt}{\eta}$. Later in this paper, this is abbreviated as

$h^3 F$, where F is the time integrated fluidity. Use of this term permits grouping of measurements made at different film thicknesses into a single function or plot.

From the same theory of Orchard the maximum shear stress, τ, on the paint is:

$$\tau_{max} = 8\pi^3 \cdot \frac{\sigma A h}{\lambda^3} \qquad (6)$$

For many paint systems, this stress will be sufficiently large to cause continuous leveling according to the above equations. However, it has been shown by Patton[13] and others that for systems with a significant yield stress, leveling will stop when the stress becomes equal to this yield value. Beyond this point no further leveling is possible.

A theory relating the specular reflectance (gloss) to surface roughness has been derived by Bennett and Porteus[14] from the basic theory of optics. The theory predicts that there is an exponential decrease of reflectance with increasing surface roughness,[14,15] which provides a theoretical basis for the relationship between gloss and surface irregularities observed by Dodge.[2] Combining the above considerations, a relationship between the rheological characteristics of the coating and final film appearance is expected.

Curing

The sequence of events involved in the curing reaction of a thermoset resin system is described in detail by Flory.[16] In the early stages of cure, the crosslinking reaction produces branches which increase the molecular weight of the polymer. At a certain point, approximately one crosslink per molecule, the polymer is converted into a three-dimensional gel structure. With increasing crosslink density, there is a reduction in the soluble content of the polymer.

According to classical rubber elasticity theory[16] the elastic modulus of the network is directly proportional to the crosslink density:

$$G \propto \phi RT \tag{7}$$

where G = elastic modulus
ϕ = crosslink density
R = universal gas constant
T = absolute temperature.

It will be through this theory that the viscoelastic measurements are related, by means of the model for curing behavior, to final film properties.

Rheology: Model for Nonisothermal Viscosity Variation

In order to predict the results of the nonisothermal process of baking an initially cold powder coated object, a model is needed to translate the results of the isothermal tests that are experimentally convenient to run. Such a model was constructed, making what was considered to be reasonable assumptions, and they are here stated explicitly in the form of equations. First, define

$$X(t, T) \equiv ln \, \eta^* \tag{8}$$

This transformation simplifies the fitting of the theory to the experimental results. Then, in a time

interval, Δt, there is a change of temperature, ΔT. Now assume that X will change both because of the increased cure in the time, Δt, and because of the change in temperature, ΔT.

$$\Delta X = \frac{\partial X}{\partial t}\bigg)_T \Delta t + \frac{\partial X}{\partial T}\bigg)_t \Delta T \tag{9}$$

$$= \frac{\partial X}{\partial t}\bigg)_T \Delta t + \frac{\partial X}{\partial T}\bigg)_t \frac{dT}{dt} \Delta t \tag{10}$$

where the subscripts indicate parameters kept constant.

In integral form:

$$X(\tau) = \int_0^\tau \left[\frac{\partial X}{\partial t}\bigg)_T + \frac{\partial X}{\partial T}\bigg)_t \frac{dT}{dt} \right] dt \tag{11}$$

If the activation energy for viscous flow, E_v, is assumed to depend only on temperature, then integration of the second term of equation (11) can be evaluated, and one arrives at the expression proposed independently by Roller[12] for curing of epoxy resins in lamination processes. This assumption has been made, and is stated in equation (12).

$$\frac{\partial X}{\partial T}\bigg)_t = \frac{E_v}{RT^2} \tag{12}$$

The experimental results also suggest the assumption that the cure rate depends only on temperature,

$$\frac{\partial X}{\partial t}\bigg)_T = k(T) = Ae^{-E_p/RT} \tag{13}$$

where E_p = activation energy for the cure rate.

Finally, it has been experimentally determined that the heating rate of a panel, whose instantaneous temperature is T, has an exponential dependence on time.

$$T = T_b - (T_b - T_o)e^{-st} \tag{14}$$

$$\frac{dT}{dt} = s(T_b - T_o)e^{-st} \tag{15}$$

where T_o is the initial panel temperature and T_b the bake oven temperature.

Equations (11) to (15) then allows the calculation of X (t, T) numerically, using the experimentally determined parameters, namely the Arrhenius parameters for the initial viscosity and for the cure rate, and the final and initial oven temperatures.

The Orchard theory of leveling states that for nonisothermal processes the term t/η is replaced by the time integrated fluidity, $F(t_b)$, as described previously in the development of the model.

$$F(t_b) \equiv \int_0^{t_b} \frac{dt}{\eta(t)} \tag{16}$$

where t_b = baking time.

Knowing $\eta(t)$ from equation (11), $F(t_b)$ can also be calculated by numerical integration.

Finally, it is also of interest to calculate the vis-

cosity at the end of the baking process, adjusted to permit comparison of results at different baking temperatures. Therefore, a cure parameter, C, is defined in equation (17):

$$C \equiv [\eta(t_b)] \; e^{-E_v/RT_b} \qquad (17)$$

A computer program to perform these operations has been written in the APL language, and is available from the authors.

EXPERIMENTAL

Rheological Measurements

The powder paint used in this work was a commercial white, TiO_2-pigmented, epoxy powder. The time and temperature dependence of the viscosity was measured on a Rheometrics Mechanical Spectrometer.[17] Sample discs were prepared by compressing 3.8 g of the powder in a 5 cm diameter plug mold at 50 ton force for about 10 min. Pressing was done at room temperature in order to avoid premature curing of the resin before the measurements were made. The rheometer oven and fixtures were equilibrated at the desired temperature which was measured by a thermocouple embedded in the upper fixture. The sample disc was then inserted and the gap closed immediately. Sample residence time was counted from the time of insertion, although it is estimated that about 2 min are required for the sample to reach the oven temperature. When the sample was sufficiently soft, the excess material squeezed out from the plates was trimmed off, and the oven was closed again. The measurement was started at this point, 4 to 5 min after sample insertion.

Paint Application

The following materials were used in the powder painting part of the work:

(1) Panels — 3″ × 6″ × 1/16″ steel panels, Bonderite® 1000 treatment.

(2) Paint — The epoxy powder coating used was a conventional epichlorohydrin-bisphenol A condensation polymer with an accelerated dicyandiamide curing agent and pigmented with TiO_2.

(3) Spray Equipment — De Vilbiss electrostatic powder spray gun, model EHP-5101 and power supply EPS-507.

The panels were painted while mounted in a spray booth. Gun voltage was 90 KV; main air pressure 60 psig; material feed air pressure 10 psig, vortex air pressure 15 psig. The paint was dispensed from a fluid bed. The panels were coated with a multiple-pass back-and-forth sweeping movement

Bonderite is a registered trademark of Hooker Chemical Co.

Table 1—Baked Film Thicknesses

Nominal Thickness, mil	Mean Thickness	S.D.	Range
1	1.07	0.11	0.3
2	2.15	0.08	0.3
3	3.02	0.13	0.4

to give baked film thicknesses of approximately 1, 2, or 3 mils. Twenty-nine panels were sprayed at each of the three film thicknesses. The average values, standard deviations, and ranges for the three film thicknesses, measured to the nearest 0.1 mil, are shown in *Table 1*.

Baking

The panels were baked in a horizontal position in a forced air oven. They were kept in the oven for various time intervals to permit different extents of flow to take place.

The temperatures of the panels after being placed in the oven were determined by a thermocouple taped to the powder coated panels. Two techniques were used:

(1) The thermocouple was taped to the panel and then it was sprayed with powder before placing in the oven; and

(2) the panel was sprayed with powder and the thermocouple was inserted through the powder into contact with the panel.

Good agreement was obtained between these two methods of thermocouple placement. The oven was maintained at 182° ± 2°C for the heat-up rate determination. The rate of temperature increase of the panel was proportional to the temperature difference between the panel and the oven, i.e., the rate law for heating was:

$$\log (T_b-T) = \log (T_b-T_o) - \frac{st}{2.303} \qquad (18)$$

where T_b = Bake temperature
T = Instantaneous panel temperature
T_o = Initial panel temperature (23°C)
t = Time
s = Rate Constant

Table 2 shows the results of the rate constant determination.

Table 2—Heatup Rate of Panel

Description	$t_{1/2}$ sec[a]	s, sec^{-1}
Panel painted, then thermocouple attached	33	0.0212
Thermocouple attached, then panel painted	32	0.0219
Bare panel	27	0.0260
Thermocouple alone	5.9	0.118

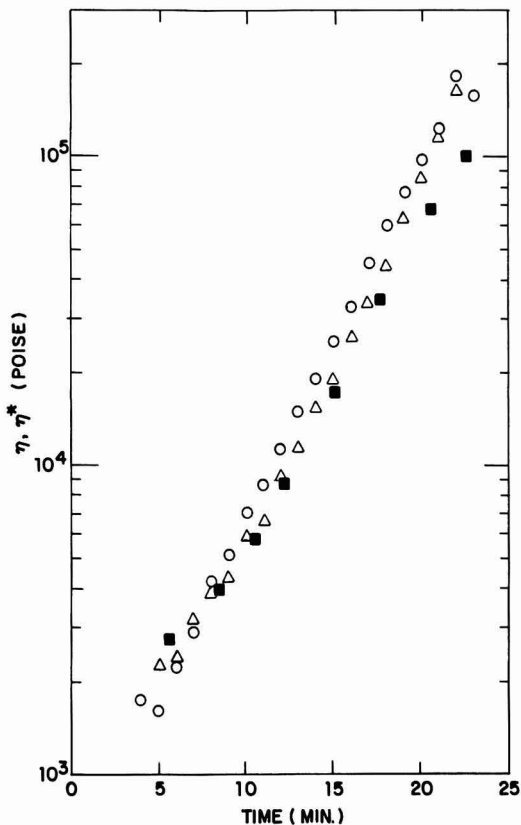(a) $t_{1/2}$ represents the time for the temperature difference to halve.

Figure 1—Viscosity change of a thermosetting powder paint at 120°C (circles & triangles = duplicate runs, steady shear; squares = complex viscosity)

Gloss and Cure Evaluation

The extent of flow was evaluated by glossiness of the panels. Using a Hunterlab D16 glossmeter, 20° gloss was determined on all panels. The degree of cure was evaluated by rubbing the panels with an MEK-saturated cotton swab in a back-and-forth motion using a moderate amount of pressure. One cycle was called a double-rub. The number of double-rubs required to expose the metal under the paint was noted.

MEK rub hardness is a complex qualitative test for degree of crosslinking. The greater the degree of crosslinking, the smaller the amount of soluble fraction in the film and the lower the amount of swelling which occurs in the nonsoluble fraction. Hence, it is reasonable to expect a correlation between the MEK rub hardness and the modulus.

Surface Profile And Roughness Measurements

Roughness and wavelength measurements on the coated panels were performed with the Gould

Surfanalyzer 150 system. The advantage of this system is that the short wavelength disturbances due to pigmentation can be filtered out, permitting the longer wavelength disturbances (orange peel) to be measured. A detailed description of the instrument and the description of how it is used to make measurements of this sort has been presented by Hansen.[3] The measurements were performed using the "waviness" setting which gave the wavelength, λ, of the orange peel with the short wavelength "noise" filtered out; and on the "average" setting which gave a centerline-average (CLA) or arithmetric average (AA) reading of the amplitude of the surface irregularities.

RESULTS

General Remarks

Correlations between experimentally obtained property characterizations such as degree of cure as measured by MEK resistance, and extent of leveling as measured by gloss and surface topography, on the one hand, and calculated values of modulus and flow which were obtained with the rheological model, on the other, were obtained. These quantities were related via the Orchard equation. Pertinent
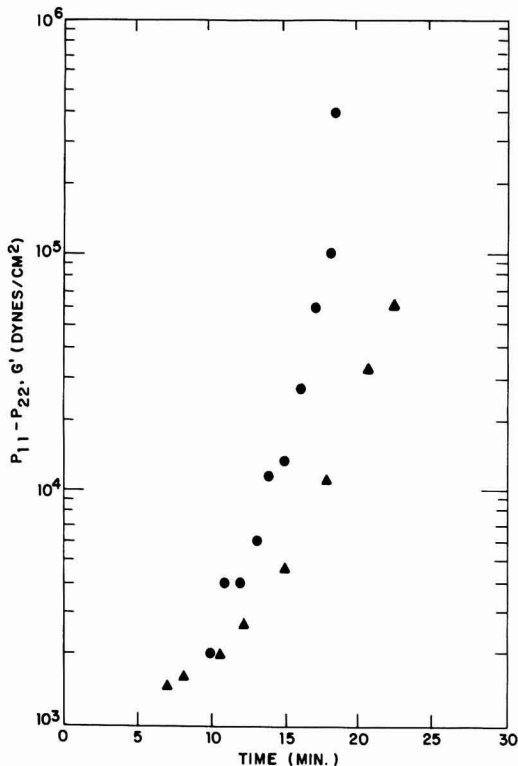

Figure 2—Elasticity change of a thermosetting powder paint at 120°C (circles = normal stress; triangles = dynamic modulus)

data and calculated values are tabulated and plotted as described below.

Rheology

COMPARISON OF STEADY SHEAR AND DYNAMIC VISCOSITY: Initially, viscosity measurements were made in torsional flow between coaxial parallel plates. A far more convenient operation is the "eccentric rotating disc" (ERD) or Maxwell Orthogonal Rheometer (MOR) mode of the instrument.[17] The convenience becomes especially important as the resin cures, producing a highly viscous and elastic melt for which steady shear flow becomes unstable at high shear rates. This problem is not encountered in the ERD mode, which is essentially a small strain oscillatory experiment.

However, it had first to be determined that any gain in operating convenience was not destroyed by a corresponding increase in difficulty of interpretation of the results. The ERD mode results in two quantities, η' and η'', which are the viscosities in-phase and out-of-phase, respectively, with the applied shear, and which are the measures of energy dissipation and of energy storage per cycle of deformation. These are related to the dynamic moduli G' and G'', which are also often used to express the results of oscillatory measurements, by equations (19):

$$\eta' = G''/\omega, \quad \eta'' = G'/\omega \qquad (19)$$

where ω is the frequency of the oscillation. It is well established, theoretically and experimentally,[18] that at low frequencies, ω, and low shear rates, $\dot{\gamma}$, there are relationships between the dynamic viscosity η' and the steady shear viscosity η, and between the dynamic modulus G' and the steady shear first normal stress difference $P_{11} - P_{22}$ as given in equations (20) and (21).

$$\lim_{\omega \to 0} \eta' = \lim_{\dot{\gamma} \to 0} \eta \qquad (20)$$

$$\lim_{\omega \to 0} G' = \tfrac{1}{2} \lim_{\dot{\gamma} \to 0} P_{11} - P_{22} \qquad (21)$$

Furthermore, many continuum models of polymer melt rheology predict that even at non-zero frequency and shear rate the predictions of equations (20) and (21) hold, approximately. Experimentally, it has been found that a relation between the dynamic and steady shear properties, originally proposed by Cox and Merz,[19] holds within the experimental error of the measurements.

$$\eta^* (\omega) = \eta(\dot{\gamma}) \qquad (22)$$

where

$$\eta^* \equiv [(\eta')^2 + (\eta'')^2]^{1/2} \qquad (23)$$

MARTIN J. HANNON is a Research Supervisor at Celanese Research Co. He received his M.S. and Ph.D. Degrees in Polymer Science and Engineering at Case Western Reserve University in 1966 and 1968, respectively. His research interests have been in the rheological and physical properties of polymers as they relate to plastics, fibers, and coatings.

DAVID RHUM holds the position of Research Associate at the Celanese Research Co., where he has been since 1970. His specialty is synthetic polymer chemistry. He obtained his B.S. Degree from Brooklyn College of the University of the City of New York, and his Ph.D. Degree from Columbia University in 1961.

KURT F. WISSBRUN received his M.S. and Ph.D. Degrees in Physical Chemistry from Yale University. He joined the Celanese Corp. in 1957, and is now a Senior Research Associate. His research and development interests have been in the relationships of polymer structure, properties, and processing, especially with regard to rheology of molten polymers.
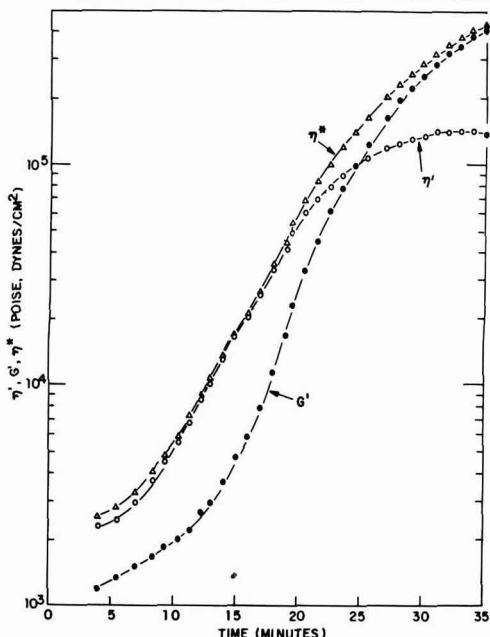
Figure 3—Complex viscosity changes of a thermosetting powder paint at 120°C (at frequency of 1.0 sec⁻¹)
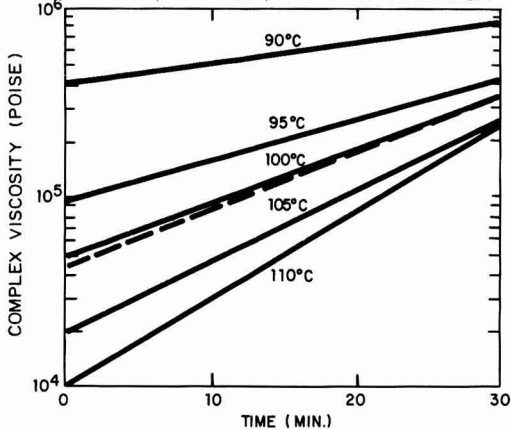
M. J. HANNON, D. RHUM, and K. F. WISSBRUN

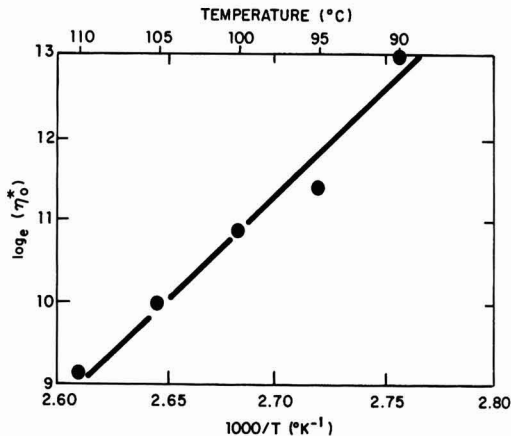Figure 4—Effect of temperature on rate of viscosity change

Figure 5—Effect of temperature on initial viscosity

The applicability of equation (22) to the powder coating during curing was tested experimentally by comparing the shear viscosity from torsional flow with the complex viscosity from the ERD measurement, as shown in *Figure 1*. Evidently, the agreement is quite satisfactory, especially in the earlier stages of the measurement. It is concluded that η^* is an acceptable measure of the time dependent viscosity that should determine leveling.

Figure 2 compares the normal stress from torsional flow with the ERD dynamic modulus. The agreement of these data with the relationship of equation (21) is not quantitative, but clearly both these measures of polymer melt elasticity are changing with time in a similar fashion.

Figure 3 shows how η', G' and η^* individually change with time. Initially, η' is much larger than ωG', which means that the resin is primarily a viscous liquid, with only slight elasticity. As cure proceeds both η' and G' increase, but eventually the curves cross and ωG' becomes larger than η', reflecting the increased elasticity of the network of crosslinks. The complex viscosity, η^*, essentially follows whichever of its two components is larger, as required by its definition in equation (23). This behavior of η^* suggested the possibility that it might be a useful measure of the progress of two important aspects of

the coating process. At the early stages of cure it measures the viscosity which, together with the surface tension, determines the leveling. In the latter stages, η^* is a measure of the modulus, which in turn measures the degree of crosslinking of the resin and, therefore, its mechanical properties.

ISOTHERMAL TIME DEPENDENCE OF COMPLEX VISCOSITY: Measurements were made, as above, in the ERD mode. The temperatures used range from 90°C to 110°C in 5° intervals. For the particular formulation used in this work, this range was most convenient. At lower temperatures the cure rate was too slow to measure. At higher temperatures the cure rate was so rapid that small changes in sample handling procedure and in temperature equilibration made extrapolation to zero time very imprecise, although the slope of the viscosity-time plot, as in *Figure 1*, was still quite reproducible.

Points were read off the force-time traces at 2 min intervals up to 40 min after beginning the run. The data were found to follow a linear relationship in the logarithm of η^* vs. time. The results of least squares fitting to the data are shown graphically in *Figure 4*, with the data points omitted for clarity. The numerical values and the statistical data are given in *Table 3*. All of the correlations were highly

Table 3—Isothermal Variation of Complex Viscosity with Time (Linear Regression Data)

| Temp. (°C)	Intercept (zero time viscosity)		Slope (Cure Rate)		Standard Error of Estimate of ln η_o^*	Correlation Coefficient
	ln η_o^*	η_o^* poise	k (min⁻¹)	S.E. (min⁻¹)		
90	12.95	4.20×10^5	2.41×10^{-2}	9.8×10^{-4}	0.036	0.989
95	11.50	9.86×10^4	4.95×10^{-2}	6.3×10^{-4}	0.0278	0.999
100	10.85	5.16×10^4	6.33×10^{-2}	1.11×10^{-3}	0.041	0.998
100[a]	10.75	4.65×10^4	6.61×10^{-2}	1.03×10^{-3}	0.045	0.998
105	9.93	2.05×10^4	8.49×10^{-2}	1.20×10^{-3}	0.053	0.998
110	9.23	1.02×10^4	1.07×10^{-1}	1.96×10^{-3}	0.086	0.997

(a) Duplicate run
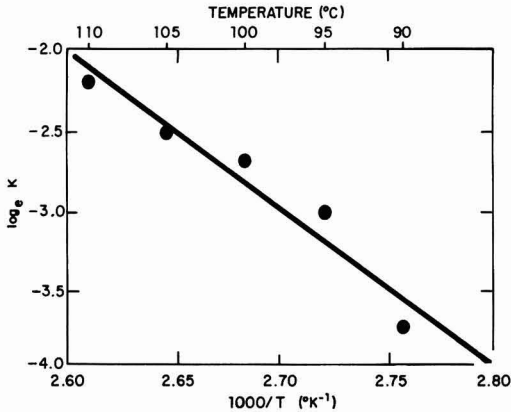
Figure 6—Effect of temperature on rate constant of cure

significant, statistically. The standard errors of estimate of the viscosity were on the order of 5%, which is approximately the precision of the measurements. The dotted line in *Figure 4* shows the results of a duplicate measurement at 100°C. The statistics for this run are also presented in *Table 3*.

The zero-time viscosity and the cure rate constant, k, were then fitted to Arrhenius equations, with results shown graphically in *Figures 5* and *6*. The Arrhenius constants derived from these plots along with the correlation coefficients are presented in *Table 4*. As can be seen the statistical significance of the correlations is very high. The measured and predicted values agree fairly well over the temperature range studied, to about 20% for η_0^* and 15% for the cure rate. The activation energy for the viscosity is somewhat higher and that for cure rate quite comparable to those reported in other studies.[12, 20, 21]

STEP CHANGE NONISOTHERMAL MEASUREMENTS: In order to test the assumptions of a model for the nonisothermal time dependence of viscosity, a number of runs were done. The run was started normally, and after cure had proceeded for some time, the oven temperature was increased 5°C. Three min later 3 points were measured at 2 min intervals, and the temperature was then again increased, and so on. Two runs were begun at 90°C, and one at 100°C.
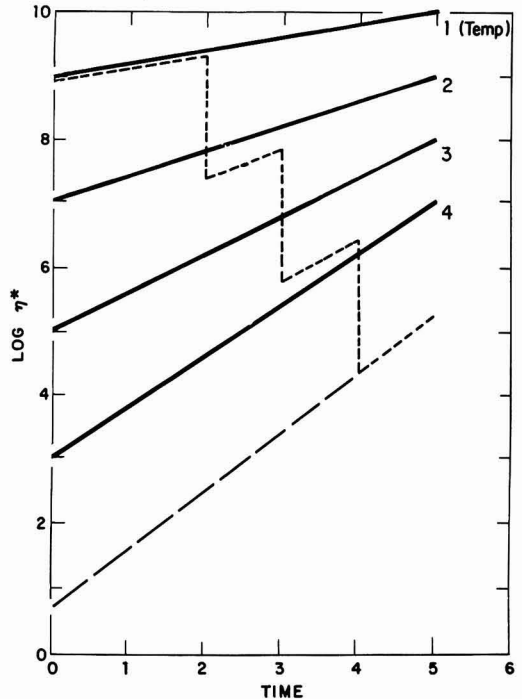

Figure 7—Schematic diagram illustrating step-change test of nonisothermal mode (time and temperature in arbitrary units)

For the points at each temperature an estimate was made, by least squares fitting, of the slope and the intercept.

The cure rate constant and the zero time viscosity were then calculated from these data, assuming that the viscosity changes instantaneously when the temperature is changed with the same activation energy as the initial (zero-time) viscosity, and that the cure rate (slope of log η^* vs. time) depends only on temperature. *Figure 7* schematically illustrates the principle of the computation scheme.

The results of these experiments are shown in *Figures 8* and *9*, where they are compared with the

Table 4—Arrhenius Constants For Initial Viscosity and Cure Rate (Linear Regression Data)

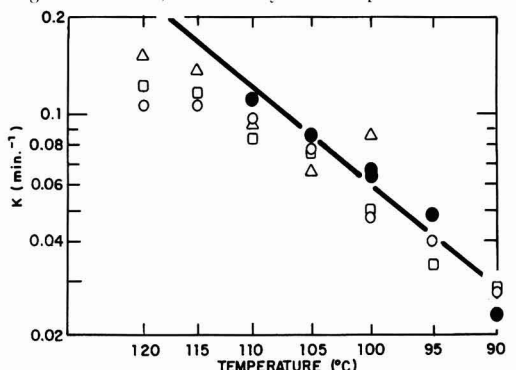|	ln η_0^* (poise)	k (min)
Slope	2.51×10^4	-9.84×10^3
Standard error of slope	0.18×10^4	1.29×10^3
Intercept	-56.46	23.56
Standard error of estimate	0.20	0.15
Correlation coefficient	0.990	0.967
Activation energy (kcal/mole)	-50	20

Figure 8—Cure rates from stepwise temperature increase experiments (solid circles = isothermal; open circles = run 1; triangles = run 2; squares = run 3)

Table 5—Panel Treatments and Results

Oven Temp, °C	Bake Time Min	Film Thickness, mils	Hunter 20° Gloss	MEK Double Rubs	Oven Temp, °C	Bake Time Min	Film Thickness, mils	Hunter 20° Gloss	MEK Double Rubs
120	1	0.9	0	2	190 (cont.)	3	2.2	75	5
	1	2.2	0.2	2		3	3.2	40	14
	1	3.1	0	0.5		4	1.1	52	4
	3	1.1	0.6	2		4	2.2	55	16
	3	2.1	8	4		4	3.2	68	28
	3	3.0	12	4		5	1.2	55	16
	5	1.0	3	2		5	2.2	60	26
	5	2.0	23	4					
	5	2.8	31	4	210	0.5	1.2	3	1
	7	0.9	2	2		0.5	2.2	3	3
	7	2.2	23	4		0.5	3.0	3	4
	7	2.9	42	4		1.0	1.0	38	2
	10	1.0	4	2		1.0	2.1	60	3
	10	2.2	30	6		1.0	2.8	62	4
	10	3.1	44	7		1.5	0.9	64	2
	15	0.9	4	2		1.5	2.0	84	3
	15	2.2	40	6		1.5	3.0	88	5
	15	3.0	49	9		2.0	1.0	72	3
	20	0.9	7	2.5		2.0	2.1	82	4
	20	2.2	42	8		2.0	3.1	90	5
	20	3.1	39	16		3.0	1.2	72	7
168	1	1.1	3	2		3.0	2.2	50	10
	1	2.3	21	4		3.0	3.2	57	15
	1	2.8	12	4		4.0	1.0	59	12
	2	1.1	33	2		4.0	2.2	56	30
	2	2.2	67	4		4.0	3.2	62	42
	2	2.9	63	4.5	230	0.5	1.1	3	2
	3	1.1	48	2		0.5	2.0	10	3
	3	2.1	69	5		0.5	3.0	4	4
	3	3.2	68	6		1.0	1.1	44	2
	4	1.2	68	2		1.0	2.0	81	3
	4	2.2	78	5		1.0	3.1	80	4
	4	3.0	75	9		1.5	1.2	64	2.5
	5	1.1	65	3		1.5	2.2	80	4
	5	2.1	72	6		1.5	2.8	80	5
	5	3.0	76	11		2	1.1	61	7
190	1	1.2	9	2		2	2.0	76	9
	1	2.2	50	4		2	3.1	64	7
	1	2.9	40	7		3	1.2	54	25
	2	1.2	62	2		3	2.2	48	25
	2	2.1	76	4		3	3.2	55	31
	2	3.1	68	8		4	1.2	58	40
	3	1.0	52	2		4	2.2	50	60
						4	3.0	52	80+

isothermal results. In judging the adequacy of the comparison it must be remembered that this is a rather stringent test, for at least two reasons. Only a few points were measured at each temperature, so the precision of the data is generally poorer than that of the isothermal data. As for the extrapolated viscosities, they suffer further in precision because at each temperature other than the first one, its value depends on the accuracy of the results at all previous temperatures.

With these reservations in mind, it was felt that the results were sufficiently encouraging to test the model against the truly nonisothermal conditions encountered in baking a powder coated panel. The cure rates from the step-change and isothermal experiments in *Figure* 8 were in reasonably good agreement although extrapolation may be hazardous. The agreement of the viscosities was less good (*Figure* 9) and there seems to be a clear trend of increasing

deviation with increasing amount of cure at the higher temperatures. This is indicated by the comparatively excellent agreement at 115° and 120° of the viscosities from Run No. 2 with those from the isothermal measurements. This run was started at 100°C rather than 90°C as were the others, so that there had been less total cure at low temperatures when the temperature was raised.

It is interesting to note that the apparent activation energy from these high cure nonisothermal experiments is lower. This behavior would be expected as the contribution of η'' (or G') to η^* becomes larger, for the elastic modulus should be less temperature sensitive than the viscosity. This observation also points up a possible defect of the model proposed below, a defect readily eliminated mathematically, but only at the cost of much more experimental work to determine cure dependent activation energies.
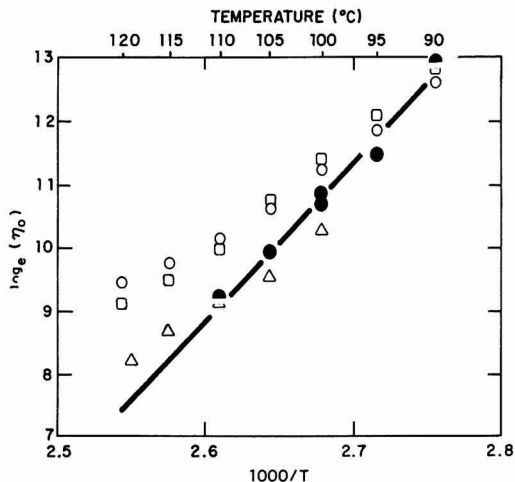
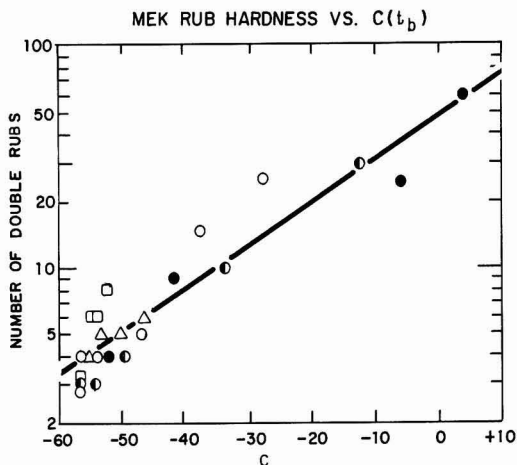**Figure 9—Initial viscosities from stepwise temperature increase experiments (same legend as Figure 8)**

Figure 10—Correlation of MEK rub hardness and predicted extent to cure, C (2 mil film thickness) (solid circles = 230°C; half closed circles = 210°C; open circles = 190°C; triangles = 168°C; squares = 120°C)

CURE: The results of cure evaluations by MEK double-rub on baked panels are given in *Table 5*. The data cover temperatures of 120° to 230°C; bake times of 0.5 to 20 min; and cured film thickness of 1 to 3 mils. The double-rub values are correlated with the calculated cure parameter, C, in *Figure 10*.

LEVELING AND SURFACE TOPOGRAPHY: Appearance evaluation data, measured by Hunter 20° gloss, are presented in *Table 5*. Surface topography data, obtained with the Gould Surfanalyzer, are listed in *Table 6*. Results of measuring surface irregularity wavelength and amplitude are given. *Table 6* also contains values of F, the time-average fluidity, which predicts the amount of flow which occurs during

baking; and h^3F, the product of the cube of the film thickness and the flow.

The topographic measurements, wavelengths, and roughness are correlated with h^3F in *Figures* 11 and 12, respectively. Gloss is shown as a function of h^3F in *Figure 13*.

In general, one sees that gloss and smoothness increase as the predicted flow, F, increases.

The gloss readings and average roughness measurements are plotted against each other in *Figure 14*, and show the expected correlation of increasing gloss with decreasing roughness.

The statistical significance of the proposed correlations for *Figures* 10-13 is very high as shown by the data for the linear regression analyses presented in *Table 7*.

Table 6—Surface Topography and Calculated Flow Values

Bake Temp (°C)	Bake Time (min)	Thickness (mils)	F	h^3F	Avg Roughness (μ in.)	Avg Wave Length (in.)
190	4	3	0.11	3.0	34	0.063
190	4	2	0.11	0.9	44	0.054
190	4	1	0.11	0.1	44	0.043
190	1	2	0.0014	0.011	55	0.031
190	1	1	0.0014	0.0014	96	0.018
168	4	1	0.05	0.05	45	0.043
168	4	2	0.05	0.4	46	0.068
168	4	3	0.05	1.35	50	0.063
168	2	1	0.019	0.019	58	0.026
168	2	2	0.019	0.152	48	—
168	2	3	0.019	0.513	54	0.043
120	15	3	0.002	0.054	46	0.037
120	15	2	0.002	0.016	68	0.034
120	15	1	0.002	0.002	90	0.016
120	5	3	0.0009	0.024	68	0.031
120	5	2	0.0009	0.007	66	0.026
120	5	1	0.0009	0.0009	115	0.015

Table 7—Statistical Significance Of Proposed Correlations (Linear Agression Analysis)

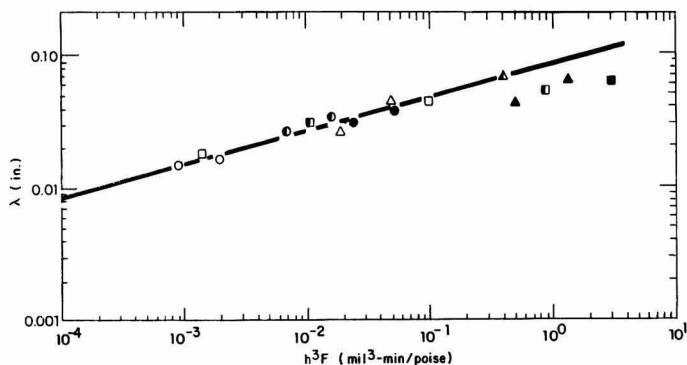| Correlated Variables		Figure Number	Correlation Coefficient	T-Value
Dependent	Independent			
Log (number of double rubs	Cure parameter (C)	10	0.939	12.5
Log (average wavelength)	Log (h^3F)	11	0.949	11.3
Surface Roughness	Log (h^3F)	12	0.847	6.18
Gloss	Log (h^3F)	13	0.891	7.58
Gloss	Average roughness	14	0.886	7.39

Figure 11—Correlation of average wavelength of surface profile and predicted leveling—line drawn with theoretical slope of 0.25 (legend: circles = 120°C; triangles = 168°C; squares = 190°C; open points = 1 mil thickness; half closed points = 2 mil thickness; solid points = 3 mil thickness)

DISCUSSION AND CONCLUSIONS

Leveling and Gloss

To relate the rheological characterization just described, via the Orchard theory, to powder coatings would require complete determination of the surface topography, a task too time-consuming for this study. Two simpler, convenient measures of the progress of leveling were therefore used, namely average wavelengths and roughness from surface profile measurement, and gloss.

Spitz[8] used the change of wavelength with time as a measure of isothermal leveling of thermoplastic powder coatings. He found that on a doubly logarithmic plot against $\frac{h^3 t}{\eta}$, the wavelength increased linearly with a slope of nearly 0.25. The results of this study, plotted in *Figure* 11 in the form of wavelength against $h^3F(t)$ are quite consistent with those of Spitz, but with some evidence in this case for systematic deviation at large values of the independent variable, h^3F. Indeed, the linear least squares fit to the data gave a line with a slope of 0.18 as a best fit to the data. We have drawn the correlation shown in *Figure* 11 with the theoretical slope of 0.25 and emphasized the deviation at large values of h^3F.

For example, consider the situation when the parameter h^3F has the value of 1 mil³ min poise⁻¹, corresponding to the smoothest samples prepared. Assuming a surface tension of 30 dyn/cm, one can calculate the wavelengths where amplitudes have been reduced to some given fraction of their original values with the Orchard equation. In this case if A/A_0 is 0.1, $\lambda = 0.11$ in., and if A/A_0 is as small as 0.001, $\lambda = 0.087$ in. A typical value of A_0 at the start of a baking is $\sim$ 100 microinches or 2.5μm. In other words, irregularities with wavelengths much less than 0.1 in. will have disappeared almost completely, whereas those with much longer wavelengths will not have been affected much at all. The estimate of 0.1 in. corresponds very well with the visible appearance of orange peel, and with the wavelength estimate from the waviness profile measurement.

It is obvious from the surface profiles that the amplitudes of the irregularities do decrease with increased baking time and film thickness. The amplitude, as measured by average roughness, is plotted against the parameter h^3F in *Figure* 12. Again, a reasonable correlation is obtained, with good overlap of points at different film thicknesses and baking temperatures.

Hansen[3] has found that gloss correlates with the center line average roughness. A similar correlation is observed from the data in *Tables* 5 and 6 shown in *Figure* 13. The correlation of gloss, which was measured on all of the panels prepared, with the flow behavior predicted by our model and the Orchard equation, is shown in *Figure* 14. In general the correlation is satisfactory except for some low results at prolonged time at high bake temperature, where loss of gloss is attributed to wrinkling of the film by over-curing. From the results of the wavelength, roughness, and gloss measurements, and the assumed validity of our rheological extrapolations, we conclude that the Orchard equation provides a useful description of the leveling process, not only for thermoplastic coatings, but also for nonisothermal curing of thermosetting coatings. Furthermore, the integrated fluidity of the coating can be satisfactorily calculated from parameters isothermally
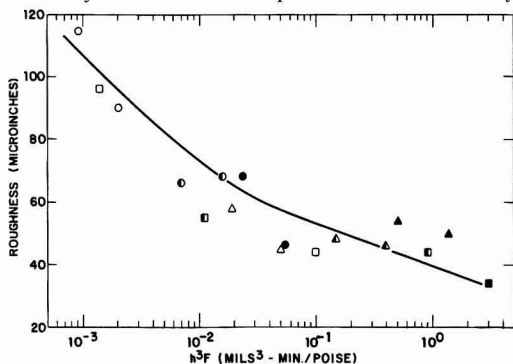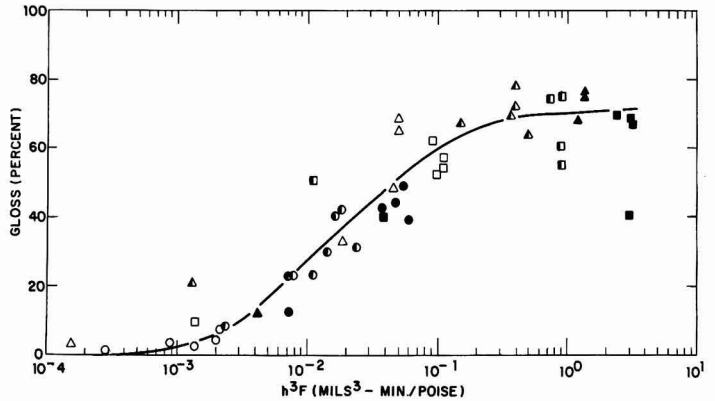

Figure 12—Correlation of average amplitude of surface profile and predicted leveling (legend same as Figure 11)

Figure 13—Correlation of 20° gloss and predicted leveling (legend same as Figure 11)

determined, at temperatures convenient for measurement, and extrapolated to the curing conditions for the coating.

It may be appropriate at this point to emphasize some sobering conclusions from these results. The calculation above showed that a value of h^3F equal to 1 mil³ min poise⁻¹ corresponds to a wavelength of 0.1 in. This means that one cannot expect the leveling process to remove any irregularities of longer wavelengths under any economically reasonable conditions for the paint used in this study. That is, baking for a few minutes, a coating whose thickness is on the order of a few mils will not cause the leveling of disturbances initially present in the deposited coating whose wavelength is greater than 0.1 in. Furthermore, according to Orchard, the maximum shear stress in thin film is given by equation (6):

$$\tau_{max} = \frac{8\pi^3\sigma Ah}{\lambda^3} \qquad (6)$$

For the conditions assumed above, and with a sur-

face tension of approximately 30 dyn/cm, this stress at the measured roughness of 40 μ in. is only 0.1 dyn/cm². Even assuming more severe conditions corresponding to quite noticeable orange peel, say, roughness of 95 μ in. a film thickness of 3 mils and a wavelength of 0.145 cm, this stress is only $\approx$ 4.5 dyn/cm². The existence of any yield stress of this magnitude would prevent any further leveling, if indeed it permitted even this extent of leveling. Detection of such a low yield stress in a viscous thermosetting formulation is not possible with any known rheometers. Indeed, while no results are presented here, it is suspected from other data that the presence of a yield phenomenon can be important in some cases.
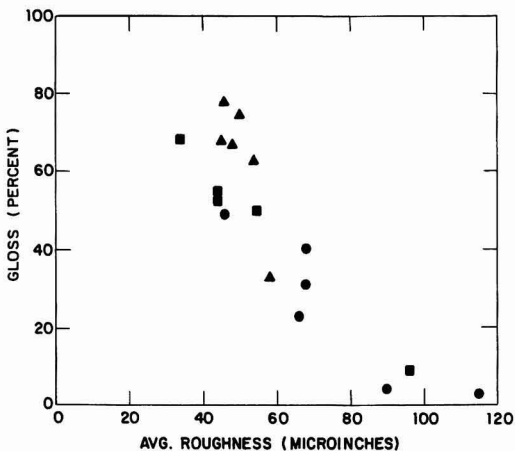
Correlation of Cure

Figure 3 shows that as the crosslinking reactions of cure proceed, the complex viscosity increasingly becomes a measure of the storage modulus, and therefore, approximately a measure of the extent of crosslinking. A test of this idea is shown in *Figure 10* in which the number of rubs a 2 mil film can sustain is plotted against the parameter C calculated from the reaction kinetics parameters by equation (17). Similar correlations were obtained with 1 and 3 mil films. The correlation is far from perfect, but the extent of overlap of data covering a wide range of temperatures and baking times certainly indicates that the model proposed has some merit. As is also true for the leveling correlations, the predictions offered should be most useful in the formulation stage of product development, where even a crude measure of the effects of varying the formulation properties can save much experimental effort. □

Figure 14—Effect of surface roughness on 20° gloss (circles = 120°C; triangles = 168°C; squares = 190°C)

References

(1) Quach, A., *Ind. Eng. Chem. Prod. Res. Develop., 12*, No. 2, 110 (1973).
(2) Dodge, J S., JOURNAL OF PAINT TECHNOLOGY, *44*, No. 564, 72 (1972).

(3) Hansen, C. M., *Ind. Eng. Chem. Prod. Res. Develop., 11,* No. 4, 426 (1972).

(4) Quach, A. and Hansen, C. M., JOURNAL OF PAINT TECHNOLOGY, *46,* No. 592, 40 (1974).

(5) Wolpert, S. M. and Wojtkowiak, J. J., ACS Div. Org. Coatings and Plast. Chem., *Papers, 32,* No. 2, 456 (1972).

(6) Wolpert, S. M., ACS Div. Org. Coatings and Plast. Chem., *Papers, 33,* No. 2, 485 (1973).

(7) Nix, V. G. and Dodge, J. S., JOURNAL OF PAINT TECHNOLOGY, *45,* No. 586, 59 (1973).

(8) Spitz, G. T., ACS Div. Org. Coatings and Plastics Chem. *Papers, 33,* No. 2, 502 (1973).

(9) Smith, N. D. P., Orchard, S. E. and Rhind-Tutt, A. J., *J. Oil Colour Chemists' Assoc., 44,* 618 (1961).

(10) Orchard, S. E., *Appl. Sci. Res., Sect. A, 11,* 451 (1962).

(11) Rhodes, J. R., Ph.D. Thesis "Rheology of Vitreous Coatings," Ohio State University (1968).

(12) Roller, M. B., *Polym. Eng. Sci., 15,* No. 6, 406 (1975).

(13) Patton, T. C., "Paint Flow and Pigment Dispersion," Interscience, New York, New York (1964).

(14) Bennett, H. E. and Porteus, J. O., *J. Opt. Soc. Am. 51,* No. 2, 123 (1961).

(15) Bennett, H. E., *J. Opt. Soc. Am. 53,* No. 12, 1389 (1963).

(16) Flory, P. J., "Principles of Polymer Chemistry," Chap. XI, Cornell University Press, Ithaca, N. Y. (1953).

(17) Macosko, C. and Starita, J. M., *SPE J., 27* No. 11, 38 (1971).

(18) Middleman, S., "The Flow of High Polymers," Chap. 5, Interscience, N. Y. (1968).

(19) Cox, W. P. and Merz, Jr., E. H., *J. Polymer Sci., 28,* 619 (1958); *Am. Soc. Testing Mater.,* 247, 178 (1958).

(20) Hollands, K. M. and Kalnin, I. L. "Advances in Chemistry Series," No. 92, "Epoxy Resins," American Chemical Society, Washington, D. C., 60 (1970).

(21) Mussatti, F. G. and Macosko, C. W., *Polym. Eng. Sci., 13,* 236 (1973).

FEDERATION SERIES ON COATINGS TECHNOLOGY

Series of booklets on coatings technology authored by experts in the field and prepared under the supervision of the Federation's Educational Committee and the Editors of the Series. Units published to date have been:

#1—"Introduction to Coatings Technology": by W. R. Fuller. Oct. 1964. Revised May 1973.

#2—"Formation and Structure of Paint Films": by W. R. Fuller. June 1965.

#3—"Oils for Organic Coatings": by F. L. Fox. Sept. 1965.

#4—"Modern Varnish Technology": by A. E. Rheineck. May 1966.

#5—"Alkyd Resins": by J. R. Blegen. Mar. 1967.

#6—"Solvents": by W. R. Fuller. May 1967.

#7—"White Hiding and Extender Pigments": by W. H. Madson. Oct. 1967.

#8—"Inorganic Color Pigments": by W. R. Fuller and C. H. Love. Mar. 1968.

#9—"Organic Color Pigments": by J. G. Mone. July 1968.

#10—"Black and Metallic Pigments": by W. S. Stoy, E. T. Usowski, L. P. Larson, D. Passigli, W. H. Byler, R. Evdo, and W. von Fischer. Jan. 1969.

#11—"Paint Driers and Additives": by W. J. Stewart. June 1969.

#12—"Principles of Formulation and Paint Calculations": by W. R. Fuller. June 1969.

#13—"Amino Resins in Coatings": by W. L. Hensley and W. E. McGinty. Dec. 1969.

#14—"Silicone Resins for Organic Coatings": by R. W. Clope and M. A. Glaser. Jan. 1970.

#15—"Urethane Coatings": by D. Lasovick. July 1970.

#16—"Dispersion and Grinding": by M. H. Schaffer. Sept. 1970.

#17—"Acrylic Resins": by G. Allyn. Feb. 1971.

#18—"Phenolic Resins": by R. McDonald. Feb. 1971.

#19—"Vinyl Resins": by G. M. Powell. Apr. 1972.

#20—"Epoxy Resins": by R. A. Allen. Apr. 1972.

#21—"Nitrocellulose and Organosoluble Cellulose Ethers in Coatings", by E. C Hamilton and L. W. Early, Jr. Sept. 1972.

#22—"Plasticizers," by Kern Sears. June 1974.

#23—"Interior Finishes", by Murray Abriss and Oliver Volk. April 1976.

$1.50 each

Order From:

Federation of Societies for Coatings Technology

1315 Walnut Street

Suite 830

Philadelphia, Pennsylvania 19107

Analysis and Measurement
Of Foaming Phenomena
In Water-Based Coating Systems

Paul D. Berger and John A. Gast
Witco Chemical Corporation*

Studies were conducted to establish scientific principles for the analysis of foaming phenomena in trade sales and industrial coatings. The fundamental thermodynamics that produce foam were considered. Five factors were found to stabilize foaming phenomena in water-based coatings. They were surface potential, surface transport, surface state, surface viscosity, and bulk viscosity. Theoretical formulas were established and measurement techniques were devised to evaluate these conditions and to develop defoamers that could counteract foaming phenomena. These principles make it possible for defoamer specialists to develop effective control agents without a knowledge of the exact product formulation under study. This information can be extended to coating technologists so they may minimize foaming tendencies in their formulations by choosing surface active ingredients wisely.

KEY WORDS: Foam; Surface state; Viscosity; Defoamer; Bubble size; Wall curvature; Electrostatic repulsion.

INTRODUCTION

Foam has puzzled the physical chemist and, on a more practical basis, the production man for many years in their efforts to determine the causes of foaming and effective means of controlling it. This is particularly true in the production and application of water-based coatings where foaming problems often prove to be troublesome.

Recent development work has put the analysis of foaming phenomena in trade-sales and industrial coatings on a decidedly more scientific basis. Theoretical formulas have been established and measurement techniques have been devised that allow defoamer specialists to measure the surface conditions that promote foaming and to develop defoamer systems that can be effective in counteracting this phenomenon.

FOAM CHARACTERISTICS

An understanding of the fundamental thermo-dynamics that cause foam will be helpful to this discussion. Foams are common to solutions or suspensions of moderate concentration. They are not found in pure liquids. They are two-phase systems consisting of a large gas phase dispersed in a small volume of liquid. There are two principal kinds of foam—dispersion and condensation types. Dispersion foams are formed by the introduction of an external gas phase during pigment grind and application of water-based coatings. Condensation foams are caused by the generation of gas within the liquid through chemical or microbiological action or by a sudden increase in temperature which may render dissolved gas insoluble. Beer foam is a typical example of this type.

Foams are unstable systems which are constantly subject to three disrupting factors. These are: (1) redistribution of bubble size; (2) thinning of bubble walls; and (3) rupture of film walls.

Redistribution of bubble size occurs because of the dependence of the internal pressure on the curvature of its walls. *Figure* 1 shows what occurs when a large and a small bubble stick together. The smaller bubble always penetrates the wall of the larger one. It has been demonstrated that the larger the radius of curvature the higher the pressure within a bubble. Since the smaller bubble has the higher radius of curvature it has a greater internal pressure. The two bubbles would remain as they are if it were not for the fact that the film common to both is permeable to gases. Gas eventually diffuses from the smaller bubble to the larger so that the smaller bubbles become even smaller and the larger ones increase in size. This produces bubbles of large volume which are easily disrupted.

P. D. BERGER and J. A. GAST
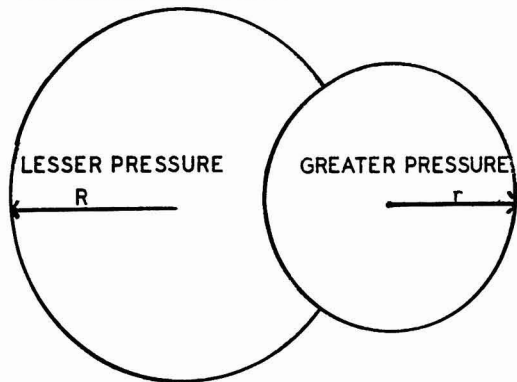
$$\Delta P = 4\gamma (1/r - 1/R)$$

Figure 1—Redistribution

Thinning of bubble walls is a consequence of drainage and evaporation. This phenomenon can be explained in terms of the intersection of three bubbles as shown in *Figure 2*. The points of the intersection, where there is a common wall between any two bubbles, are planar. Hence, the curvature is the same on both sides of the wall and the pressure, therefore, is the same in the liquid filling the walls as in the bubbles. At the air-liquid interface, however, the film is concave toward the air phase. This places the liquid under a negative capillary pressure which drives it from the inside wall to the intersections (known as the plateau borders). This drainage causes the walls to thin until they rupture and form a larger bubble.

Rupture of film walls occurs because of a decrease in surface area which causes a large change in surface free energy. A bubble of 1 cm radius and 10^{-3} cm wall thickness has a surface area of about 25 sq cm². The energy difference is so large that, when this film bursts, the liquid in it may acquire a speed of 20 mph.!
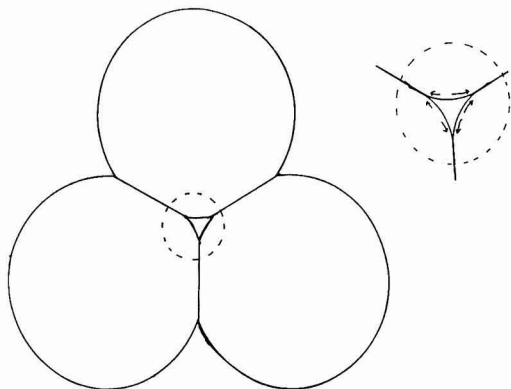
Figure 2—Drainage to plateau borders
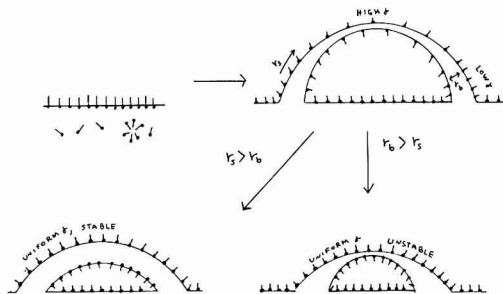
Figure 3—Transport mechanisms

FOAM STABILITY

Why do some foaming systems persist longer than others? Quite often it is the presence of a surface-active agent which may retard drainage by one or more of several mechanisms. It may increase the surface viscosity and, therefore, slow drainage to the plateau borders. Solutions of cellulose derivatives such as methyl cellulose have been found to act in this manner.

The surfactant may also react with oxygen at the air/liquid interface to form a solid skin as do proteins. These surfaces have no tendency to rupture.

When a surface is stretched, a deficiency in surfactant at the surface is momentarily created. Surfactant moves from within the bulk and from regions of higher concentrations on the surface to reestablish equilibrium. If the rate of surface migration, r_s, occurs more rapidly than that of bulk migration, r_b, the solvent carried along with surfactant molecules helps to repair thin spots on bubble walls.[1] (*Figure 3*).

Another mechanism of foam stabilization is electrical in nature and is quite often present in high-speed industrial coating applications. If the surface-active material is charged, the film formed will consist of a layer of long chain molecules on both the outer and inner surfaces of the bubble. The solution within the bubble may contain excess counter ions. The electrostatic repulsion of the two equally charged walls prevents their mutual approach, and the film cannot become thin enough to burst spontaneously.

Table 1 lists the important causes of foam stability and their effects. *Figure 4* shows how these mechanisms operate.

Table 1—Foam Stabilization

Cause	Effect
1—Surface potential	Double layer repulsion
2—Surface transport	Healing
3—Surface state	Diffusion barrier
4—Surface viscosity	Slow drainage
5—Bulk viscosity	Slow migration to surface

FOAM DESTABILIZATION

How can foam be destabilized? The various factors that influence the surface free energy of a film are represented by the terms shown in equation (1)[2,3] where: G=Surface Free Energy; S—Entropy, T=Absolute Temperature, γ=Surface Tension, A—Surface Area, n^i = Moles of Species i, μ^i = Chemical Potential, ψ = Electrical Potential, and e = Electrical Charge at Surface.

$$dG = -SdT + \gamma dA + \Sigma\mu^i \, dn^i + \psi de \quad (1)$$

$$dG = \gamma dA \quad (2)$$

These terms are similar to those used in the thermodynamic treatment of gases or liquids. In most cases, the entropy term can be omitted because the temperature will be constant. The next term is similar to the PdV term of gas thermodynamics. It accounts for practically all the surface free energy in pure liquids. At constant temperatures equation (2) applies. A decrease in surface area causes a decrease in surface free energy which, in turn, causes coalescence to be spontaneous. Foam in pure liquids, which implies an increase in surface area, is thermodynamically unstable.

In solutions, emulsions, and dispersions, however, other terms must be considered. The third term in equation (1) accounts for the chemical potential of the liquid, and the last represents the electrical contribution. If these two terms are sufficient to counteract the γdA term and keep the free energy positive, then the process of coalescence will not be spontaneous and small bubbles will remain for extended periods. If surfactants are present in the system, they will be attracted to the surface as its area is increased by foaming. This process is favored, since by definition surfactants are surface-active.

How then, does one counteract this situation?

Figure 5—Film balance and surface potential apparatus

One approach—since pure solvents do not foam—is to neutralize all materials that detract from the surface properties of a pure solvent. This approach involves the addition of material that neutralizes the effect of the chemical potential and the electrical contribution—the last two terms in equation (1). Products have been developed that can reverse the electrical potential by over one volt by adsorption onto the surface or replacement of a charged monolayer.

Another approach is to add a surface active agent that effectively lowers the surface viscosity. If the surface drainage can be increased enough so that other stabilizing factors cannot keep up, then the film eventually becomes so thin that it no longer has the properties of a bulk solution and subsequently collapses. See Mechanism 4 of *Figure 4*.

Lastly, the rate of surface transport can be decreased to prevent bubble walls from repairing thin spots. This can be accomplished by adding a surfactant which is rapidly adsorbed from the bulk of the liquid ($r_b > r_s$, *Figure 3*).

MEASURING FILM CHARACTERISTICS

The surface viscosity of a film may be measured quite accurately by using a torsional viscometer.
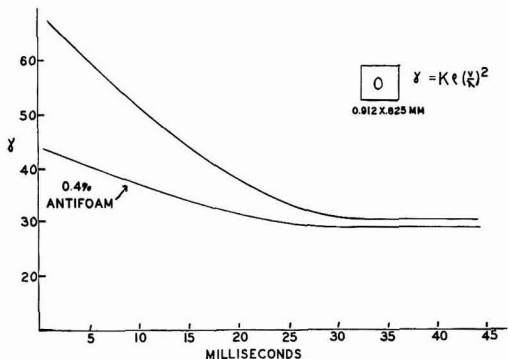

Figure 4—Foam stabilization mechanisms
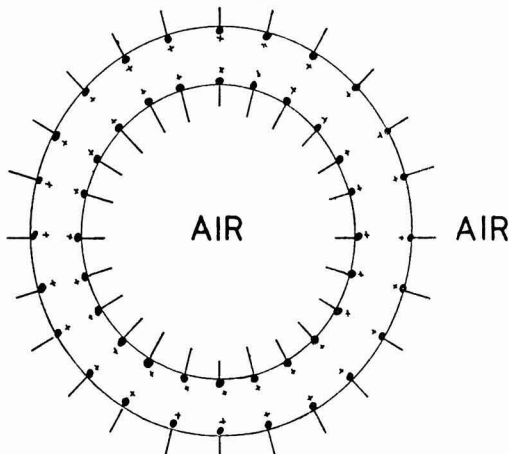
Figure 6—Electrostatic repulsion

Figure 7—Effect of antifoam on dynamic surface tension of a semigloss acrylic

Table 2—Surface Properties of some Water-Based Coatings

	Potent.	Trans.	State	Visc	Bulk Visc
Flexographic ink	−1400MV	Mod.	Solid	High	High
Semi-Gloss acryl. tint base	−130MV	Fast	Liquid	Mod.	High
Acrylic-Epoxy primer	+450MV	Mod.	Solid	High	High
Acrylic-Epoxy Semi-Gloss	+480MV	Fast	Liquid	Mod.	High
Acrylic-Epoxy High gloss	+305MV	Fast	Solid	High	High
Neoprene latex adhesive	−90MV	Slow	Solid	High	Low
Clear epoxy dip coat	+150MV	Fast	Liquid	High	Low
Vinyl-Acrylic Semi-Gloss	−230MV	Mod.	Liquid	High	Mod.

This is simply a sharp-edged cylinder of known mass and diameter which is suspended on a torsion wire. The water-based coating under study is placed in a vessel larger than the torsion cylinder to eliminate wall effects. The cylinder is suspended so that its lower edge just penetrates the surface of the solution and then is given a twist.

A protractor is used to measure the angle torque on the wire, and the number of cycles vs. the torque are recorded. The log of the torque is plotted against the number of cycles and the decrement of the line obtained is inserted in equation (3),[4] where I is the Moment of Inertia of the Cylinder, R is its Radius, $\bar{R}$ is the Radius of the Container, T is the Period of Oscillation, and λ is the Decrement.

$$\eta_s = 2.303 \; \lambda \; I(^1/R^2 - {}^1/\bar{R}^2)/ \; 2 \; \pi T \qquad (3)$$

The surface pressure of a film may be measured by using the apparatus shown in *Figure 5*. The surface pressure is analogous to the pressure of three-dimensional gases. It is determined by placing a solution in a paraffined tray (a), so that the liquid level rises above the edge of the tray. A movable paraffined barrier (b) is used to compress the film against a floating mica barrier. This barrier is maintained in a position by a torsion wire (d). The angular torque on the wire is calibrated in milligrams.

The surface potential is measured by using a calomel electrode immersed in the bulk of the solution and an air electrode suspended above the film. The air electrode contains an alpha particle emitter that ionizes the air between itself and the film and thus produces a complete circuit. The potential is recorded on a Beckman "Century" pH meter and may be monitored automatically by a strip-chart recorder. The apparatus should be shielded to eliminate electrical noise.

Surface pressure-area curves are used to determine the physical state of the molecules at the

liquid/air[5] interface. These molecules may exist in the gaseous, liquid, or solid form. If in the solid form, this material provides an energy barrier to the rising bubble which must be overcome before the bubble surfaces. See Mechanism 3 of *Figure 4*. In other words, the compressibility of a surface gives an indication of its permeability.

Surface potential stabilizes foam by mutual repulsion of like charges on opposite sides of the thinning bubble wall. As these walls are brought closer together through drainage, the electrostatic force of repulsion between them increases and thus retards any further thinning. (See *Figure 6*, and Mechanism 1 of *Figure 4*).

Surface transport is measured using a vibrating jet.[6,7] This is simply an elliptical orifice of known major and minor radii through which is pumped the solution under study. As the stream emerges from the orifice, it is elliptical in cross section. Surface tension forces try to change the cross-sectional shape to circular. These forces overcompensate, and an elliptical stream is formed with its major axis perpendicular to the original. The major axis oscillates back and forth at rates proportional to the change in surface tension. If a known material, such as distilled water, is passed through the apparatus, it may be calibrated by using equation (4) where γ = Surface Tension (dyn/cm), ρ = Density (g/cm³) λ = Wave Length (cm), V = flow rate (cc/sec) and K is a constant found by use of pure water.

$$\gamma = K\rho(v/\lambda)^2 \qquad (4)$$

Utilizing the vibrating jet apparatus, changes in surface tension over millisecond intervals may be measured. *Figure 7* shows the difference in the original surface tension of a semigloss acrylic tint-base before and after addition of 0.4% antifoam agent.

58

RESULT OF SURFACE PROPERTY MEASUREMENT

Table 2 shows the result of surface property studies for several water-based coating systems which demonstrated high foaming tendencies. The results for transport and viscosity are reported qualitatively. Surface viscosities above 600 cps were considered high; below 10 cps, low. Surface tension changes from initial to final of 100% or more were considered fast transport. Changes of 50% or less were considered slow.

The results indicate that the stabilizing mechanisms for foam are independent of each other and of bulk properties except viscosity. This is an important point, since it should be noted that bulk properties do not give any indication concerning surface properties. This holds for viscosity, pH, concentration, and physical state.

The results help to determine what properties are necessary in an antifoam agent to successfully destroy the product's foaming tendencies.

In the case of the flexographic ink, the surface potential, surface state, and viscosity are all contributing factors in foam stability. This is true for the acrylic-epoxy primer and the acrylic-epoxy high gloss. The high gloss sample is also stabilized by surface transport. Surface transport is the predominant stabilizing factor along with high bulk viscosity for the semigloss acrylic tint-base. Surface viscosity is the problem in the neoprene latex adhesive and the vinyl acrylic semigloss. Transport and viscosity are stabilizing factors for the clear epoxy dip-coat. The acrylic-epoxy semigloss is stabilized by high surface charge and fast surface transport. Bulk viscosity appears to contribute to the foam stability of the first five samples from the table.

The examples in *Table 2* were chosen because they represent cases where a successful antifoamer was found which decreased or eliminated the stabilizing effect measured with our equipment.

Several types of defoamer compositions are available commercially. These include: (1) silicone fluids and emulsions; (2) hydrophobic solid dispersions in oil; (3) organic acid salts of calcium, magnesium, etc.; (4) fatty acids and glycerides; (5) organic alcohols and esters; and (6) amide wax dispersions. We have found that metallic soaps and hydrophobic solid dispersions are most effective for surface potential problems. Fatty acids and glycerides are useful where viscosity is a factor. Most of the above examples give expanded type films if formulated properly. To prevent surface healing, hydrophobic solid dispersions are most suitable.

CONCLUSIONS

From this work it has been determined that theoretical considerations and experimental data can be employed to develop effective defoaming formulations that capitalize on both physical and chemical properties. They provide paint chemists with a flexibility in alternatives so that factors such as cost, availability, and compatibility can be considered in selecting products to eliminate or control foam.

In more practical terms related to the coatings industry, the experimental data demonstrate that the foaming phenomena in water-base coatings are stabilized by five factors. The coating formulations tend to form highly viscous surface films that are resistant to drainage. The films are condensed and are therefore less permeable to gas. The films possess a self-healing mechanism through surface transport. The films are charged so that the electrostatic repulsion between the inner and outer surfaces of the film retards the rate of thinning. And finally, high bulk viscosity slows bubble coalescence and migration to the surface.

An understanding of these phenomena as well as a precise means of measuring them make it possible for defoamer specialists to develop control agents without needing to know the exact formulation of the product under study. □

References

(1) Ewers W. E. and Sutherland, K. L., *Australian J. Sci. Res.*, 5, 697 (1952).
(2) Gibbs, W., "Application of Dynamics to Physics and Chemistry," 190 (1888).
(3) Berger, P. D., *Sugar J.*, July, 1974.
(4) Criddle, D. W. and Meader, A. L., *J. Appl. Phys.*, 26, 838 (1955).
(5) Cadenhead, D. A., *Ind. Eng. Chem.*, 61, No. 4, 22 (1969).
(6) Burcik, E. J., *J. Colloid Sci.* 5, 421 (1950).
(7) Ross, S. and Haak, R. J., *J. Phys. Chem.*, 62, 1260 (1958).

Artificial Weathering of Coatings On Organolead-Treated Southern Yellow Pine

H. Michael Barnes
Mississippi State University*

The performance of three coatings on organolead-treated southern pine was investigated. Accelerated weathering tests indicated no discernible difference in coating durability between treated and untreated samples in any coating group. Wood treated with this class of preservatives should offer the advantage of paintability in addition to increased service life in exterior exposure.

KEY WORDS: Accelerated weathering; Vinyl acrylic; Alkyd; Phenolic spar varnish; Organolead compounds; Wood; Southern pine; Weather-Ometer®; Wood preservatives.

INTRODUCTION

The most widely used wood preservatives today are creosote, pentachlorophenol-petroleum solutions, and several inorganic salt solutions. Only wood treated with inorganic salt solutions or pentachlorophenol in LP gas or light petroleum solvents yields a surface which is paintable. This fact, combined with the energy shortage, makes the search for new wood preservatives mandatory if we are to continue producing a durable wood product for use in high hazard conditions. Of the two major wood preservatives, one is petroleum-based and the other is derived from coal.

Organolead compounds may become a future source of wood preservatives. Some such compounds have good fungicidal properties in low concentrations and are not easily leached from wood.[1] For example, standard decay tests conducted on blocks treated with tributyllead acetate and then leached revealed a threshold retention of 0.15 lb/ft.[3] Concentration losses due to the two-week leaching test averaged less than 5%.

This study was undertaken to determine the

* Mississippi Forest Products Utilization Laboratory, P.O. Drawer FP, Mississippi State, Miss. 39762.

paint compatibility and durability on southern pine treated with several organolead compounds.

MATERIALS AND PROCEDURES

Selected southern pine lumber was cut into 6.75 × 2.75 in. (17.1 × 7.0 cm) samples. The lumber was flat-sawn, clear, 6-in. (15.2 cm) kiln-dried boards. The samples, which contained no heartwood and averaged 6-9 rings per in. were randomly assigned to treatment groups. Prior to treatment, the samples were conditioned at 72°F (22°C) and 50% relative humidity. They were then treated with one of four different organolead compound/solvent systems at four concentrations. The compound/solvent systems were trimethyllead acetate (TMLA)/water, triethyllead acetate (TELA)/ethanol tributyllead acetate (TBLA)/toluene, and dibutyllead diacetate (DBLD)/water. Solution concentrations were 0%, 0.1%, 0.5%, and 1% on a weight basis. A treatment regimen of 30 min of vacuum (25 in. Hg (635 mm Hg) or better) and two hr of pressure at 160 psi (11.25 Kg/cm²) was used to impregnate the specimens. After treatment, the specimens were allowed to equilibrate at 72°F (22°C) and 50% relative humidity prior to coating. After conditioning, the samples were edge-sealed with a phenol-resorcinol adhesive.

Two proprietary white pigmented coatings and one proprietary clear coating were included in the investigation. For the treated samples, four replications for each coating × chemical × level combination were used. This yielded a total of 144 coated samples. In addition, 12 untreated (0% level) control samples were coated with each coating system. This yielded 36 coated control samples. Samples coated with the pigmented systems were first primed with one coat of a linseed-soya, alkyd-base primer followed by one coat of either an alkyd-modified vinyl-

**Table 1—Average Coating Durability Parameter Values at Three Exposure Times
For Samples Coated with a Vinyl-Acrylic System[a]**

Treatment/ Solvent	Level	Reps	Checking & Cracking			Flaking & Peeling			Yellowing & Darkening		
						Hours					
			525	1001	1505	525	1001	1505	525	1001	1505
Controls	0%	12	9	8	8	10	10	10	9	8	6
Trimethyllead	0.1%	4	9	9	9	10	10	10	9	8	6
Acetate/water	0.5%	4	9	9	9	10	10	10	9	8	6
	1.0%	4	9	8	7	10	10	10	9	8	5
Triethyllead	0.1%	4	9	8	8	10	10	10	9	8	6
Acetate/ethanol	0.5%	4	9	8	8	10	10	10	8	8	6
	1.0%	4	9	8	8	10	10	10	8	8	6
Tributyllead	0.1%	4	9	9	8	10	10	10	9	8	6
Acetate/toluene	0.5%	4	9	9	8	10	10	10	8	8	6
	1.0%	4	9	8	7	10	10	10	8	7	4
Dibutyllead	0.1%	4	9	8	7	10	10	10	9	8	6
Diacetate/water	0.5%	4	9	8	8	10	10	10	9	8	5
	1.0%	4	9	8	7	10	10	10	9	8	4

(a) A rating of 10 indicates no defect.

acrylic paint or one coat of a linseed-castor-modified alkyd paint. The clear system used was three coats of a phenolic spar varnish containing an ultraviolet absorber. Touch sanding was done between coats. All coatings were brush applied.

Coated samples were placed in a twin carbon-arc Weather-Ometer® and subjected to the ASTM E-42-64 cycle[2] of 18 min of light and water spray and 102 min of light only for approximately 1500 hr, or until failure occurred. Periodic inspection for check-

ing, cracking, flaking, etc., was done, and samples were evaluated using exposure standards.[3] The ASTM cycle was used in lieu of other accelerated aging cycles since the purpose of this study was to evaluate the effect of treatment on coating performance under controllable conditions.

RESULTS AND DISCUSSION

Tabular results from the Weather-Ometer exposure of samples topcoated with the vinyl-acrylic paint are given in *Table* 1 for three exposure times.

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

**Table 2—Average Coating Durability Parameter Values at Three Exposure Times
For Samples Coated with an Alkyd System[a]**

Treatment/ Solvent	Level	Reps	Checking & Cracking			Flaking & Peeling			Yellowing & Darkening		
						Hours					
			497	988	1502	497	988	1502	497	988	1502
Controls	0%	12	9	8	7	10	9	8	8	5	4
Trimethyllead	0.1%	4	8	8	7	10	9	7	8	6	4
Acetate/water	0.5%	4	8	8	7	10	9	7	8	5	4
	1.0%	4	7	6	6	10	9	8	7	5	4
Triethyllead	0.1%	4	8	8	7	10	9	8	8	5	4
Acetate/ethanol	0.5%	4	8	7	6	10	9	8	8	4	4
	1.0%	4	10	8	7	10	9	8	8	5	4
Tributyllead	0.1%	4	9	8	7	10	9	8	8	6	4
Acetate/toluene	0.5%	4	9	7	7	10	9	8	8	5	4
	1.0%	4	9	8	8	10	9	8	8	5	4
Dibutyllead	0.1%	4	8	8	7	10	9	7	7	5	4
Diacetate/water	0.5%	4	5	5	4	10	10	8	7	5	4
	1.0%	4	7	6	5	10	9	8	6	5	4

(a) A rating of 10 indicates no defect.
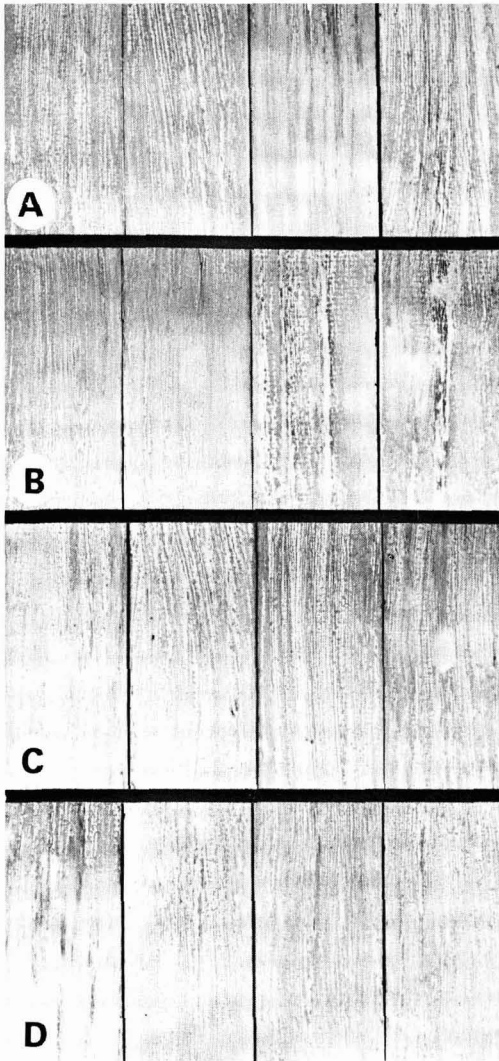
Figure 1—Organolead-treated southern pine samples top coated with a vinyl-acrylic and exposed for 1505 hr (A = TMLA/water; B = TMLA/ethanol; C = TBLA/toluene; and D = DBLD/water; in concentrations (left to right) of 0%, 0.1%, 0.5%, 1.0%)

Figure 2—Alkyd-coated southern pine after 1502 hr exposure (A = TMLA/water; B = TMLA/ethanol; C = TBLA/toluene; and D = DBLD/water; in concentrations (left to right) of 0%, 0.1%, 0.5%, 1.0%)

The performance of this coating on treated wood is characterized as excellent. Only three of the sample groups were rated below the untreated controls after 1505 hr of exposure. Using the Garlock-McMullen nomograph for determining repaint time,[4] the DBLD samples at the 0.5% and 1.0% treatment levels and the TBLA samples at the 1.0% treatment level required repainting after 1505 hr of exposure. All other treatment groups, including controls, did not require repainting.

It is interesting to note the absence of any flaking, peeling, or scaling of the vinyl-acrylic paint, in-

dicative of the superior flexibility and weathering characteristics of this type of coating. The most severe defect with this coating was darkening (staining) of the coated specimens. Both treated and untreated samples exhibited this staining phenomenon, as is evident from *Figure* 1. This leads to the conclusion that this defect was caused by the exposure conditions used, and not from the interaction of treatment chemicals with the coating. Had only the treated samples shown darkening, one might have reason to assume a coating-treatment chemical interaction.
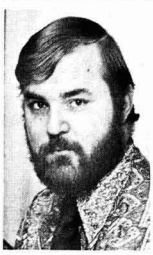
DR. H. M. BARNES received his Ph.D. Degree in Wood Products Engineering from State University of New York College of Environmental Science and Forestry in 1973. Since 1971, he has held the position of Assistant Technologist and Assistant Professor at Mississippi State University. His research interests include exterior finishing systems for wood and wood-based materials.

Specimens coated with the alkyd paint performed less satisfactorily than those coated with the vinyl-acrylic system (*Table* 2). All samples, except the 0.1% TMLA samples, required repainting after 1000 hr of exposure. However, there was no difference in the performance of treated and untreated samples. A series of typical specimens is shown in *Figure* 2. The notable differences in the performance of this system, as compared to the previous coating, are the increased checking, cracking, and flaking. Checking and cracking were characterized as the "line" type. While this system yellowed more than the vinyl-acrylic, it did not exhibit the same degree of staining. The alkyd system exhibit a chalking rating of four after 1502 hr of exposure. This compares to an average rating of six for the vinyl-acrylic samples after the same time period; hence, the self-cleaning properties of the alkyd paint were better. Overall, the alkyd system was rated good.

Performance of the phenolic spar varnish over treated and untreated wood was poor. No improvement in coating durability due to treatment was observed. No consistent pattern of coating performance with respect to treatment chemical or level was conclusively shown. There is an indication from *Table* 3 that DBLD treatment affected the coating durability since it is rated slightly below the control samples. Further experimentation is needed to confirm this trend.

The performance of this coating is typical of clear exterior finishes for wood with failure occurring by checking, cracking, and flaking. Checking and cracking were characterized as of the "alligator" type. The resultant surface did not lend itself to recoating. *Figure* 3 shows a set of representative samples after 892 hr of exposure.

SUMMARY

The Weather-Ometer exposure results presented in this paper indicate that southern pine treated with organolead compounds is compatible with typical coating systems in use today. No discernible differences in the coating behavior of three organic coatings on treated and untreated southern pine were observed. While Weather-Ometer exposure con-
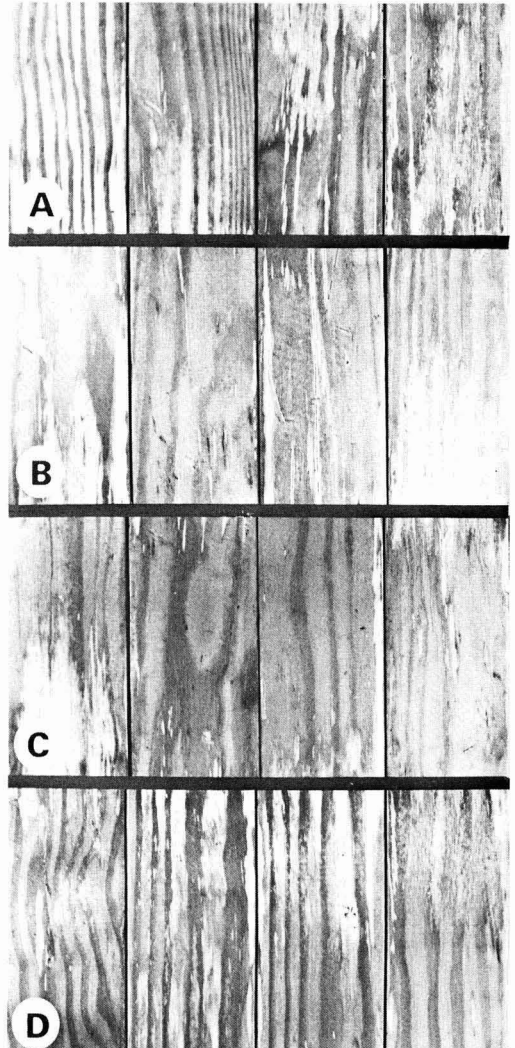
Figure 3—Treated southern pine samples coated with a phenolic spar varnish after 892 hr exposure (A = TMLA/water; B = TMLA/ethanol; C = TBLA/toluene; and D = DBLD/water; in concentrations (left to right) of 0%, 0.1%, 0.5%, 1.0%)

ditions are not directly comparable to exterior exposure, nothing was shown in the present study which would indicate a reduction in exterior durability due to treatment. Performance may, in fact, be better. It was pointed out earlier that these compounds are toxic to fungi (and hence mildew) in low concentrations. Therefore, any migration of these compounds into the coating should provide additional protection to the coating by acting as a mildewcide. Additionally, the wood would be removed as a possible substrate for fungi and mildew. Current studies are being conducted to evaluate similarly treated and coated wood in exterior exposure.

**Table 3—Average Coating Durability Parameter Values at Four Exposure Times
For Samples Coated with a Phenolic Spar Varnish[a]**

Treatment/ Solvent	Level	Reps	Checking & Cracking				Hours	Flaking & Peeling			
			206	459	637	892		206	459	637	892
Controls	0%	12	9	7	6	3		10	8	7	4
Trimethyllead	0.1%	4	8	6	5	4		10	8	8	5
Acetate/water	0.5%	4	8	6	5	4		10	9	6	5
	1.0%	4	8	6	5	3		10	9	7	4
Triethyllead	0.1%	4	9	6	5	4		10	9	8	7
Acetate/ethanol	0.5%	4	9	5	4	4		10	9	6	4
	1.0%	4	9	5	4	2		9	9	7	4
Tributyllead	0.1%	4	9	6	4	2		10	9	8	5
Acetate/toluene	0.5%	4	9	6	5	4		10	9	7	4
	1.0%	4	9	6	5	3		10	9	8	4
Dibutyllead	0.1%	4	8	5	4	2		10	8	5	3
Diacetate/water	0.5%	4	9	6	5	2		10	7	6	2
	1.0%	4	9	7	5	2		9	7	5	2

(a) A rating of 10 indicates no defect.

ACKNOWLEDGEMENTS

References

(1) Toole, E. R. and McGinnis, G. D., Am. Wood Pres. Assn. Proceedings, 70, 314 (1974).
(2) American Society for Testing and Materials, Operating Light- and Water-Exposure Apparatus (Carbon-Arc Type) for Artificial Weathering Test, ASTM Designation E42-64, 1965 Book of ASTM Standards, Part 30, 262 (1965).
(3) Federation of Societies for Paint Technology, "Exposure Standards Manual," FSPT, Philadelphia, 1962.
(4) Garlock, N. B. and McMullen, E. W., Official DIGEST, 18, 88 (1946).

Changing Your Address?

Please advise change of address as soon as possible—six weeks in advance if available—to insure uninterrupted delivery of JCT.

For convenience, simply forward an address label from the envelope in which you receive your monthly issue, and insert your new address. Or send us a note with the following *printed* information:

Name_____

(Old) Address_____

City_____State_____Zip_____

Name_____

(New) Address_____

City_____ State_____ Zip_____

Society Meetings

C-D-I-C
September 13

Robert Van Doren, of N L Industries, Inc., spoke on "FORMULATING AND TESTING NON-LEAD CORROSION INHIBITIVE COATINGS."

The whole area of formulating alkyds and particularly water reducibles for corrosion resistance is very complicated, said Mr. Van Doren. There are a number of variables that effect corrosion inhibition, such as PVC to CPVC relationship, pigment loading, resin type, thickeners, surfactants, pH, etc., he added.

If PVC is beyond the critical (CPVC) amount of pigment, a porous film results. Pigment loadings with lead base inhibitors require one and one-half to two lbs per gallon while the non-lead inhibitors are not as level sensitive and require only one-half to one lb per gallon.

It was also noted that some samples show yellowing, but on close examination surface cracking can be seen which is simply the resin failing. Thickners are important as the water sensitive cellulosics are not as good as the clays. Surfactants effect stability, viscosity, gloss and color development. A low pH tends to accelerate early rust. It is desirable to formulate in the range of the resin itself. In the acrylics pH of 9 to 9.2 is desirable.

LLOYD J. REINDL, *Secretary*

Kansas City
September 9

Joseph Simunac, of Cook Paint and Varnish Co., spoke on "PROCESS OF RATIONAL SELF-COUNSELING."

HUGO R. MANCO, *Secretary*

Los Angeles
September 8

A moment of silence was observed for N. B. Woods, II, of C.P.R. Div. of Upjohn Co., who died recently.

The following slate of officers was elected for the year 1976-77: President—Gerald L. West, of Ameritone Paint Co.; Vice-President— Robert F. Koperek, of Mobil Chemical Co.; Treasurer—Fred Croad, of Engard Coatings Corp.; Secretary—Albert Seneker, of Ameron; and returning as Council Representative—William H. Ellis; of Chevron Research Co.

Members of the Cleveland Society for Coatings Technology Board of Directors for 1976-77. Front row (left to right): Past-President—Thomas H. Keene, of Harshaw Chemical Co.; Secretary—Charles K. Beck, of Addressograph Multigraph Corp.; President—Fred G. Schwab, of Coatings Research Group, Inc.; President-Elect—Helen Skowronska, of Sherwin-Williams Co.; Treasurer—Paul J. Houck, of Morgan Adhesives Co.; and Council Representative—Michael W. Malaga, of Glidden-Durkee Div., SCM Corp. Rear row (left to right): Assistant Treasurer—Jack Malaga, of Body Bros., Inc.; Member-at-Large—Thomas D. Tuckerman, of Devine Paint & Varnish Co., Inc.; By-Laws Committee Chairman—Robert H. Faud, of Osborn Mfg. Co.; Educational Committee Chairman—Carl J. Knauss, of Kent State University; Alternate Council Representative—Donald H. Fordyce, of Body Bros, Inc.; and Member-at-Large—James Broggini, of W. J. Ruscoe Co., Inc.

William Machemer, of Troy Chemical Corp., spoke on "MICROBIOLOGICAL PROBLEMS ASSOCIATED WITH WATER REDUCIBLE INDUSTRIAL COATINGS."

Mr. Machemer outlined the areas of microbiological problems: a bactericide is used to protect wet paint from bacterial growth; a fungicide prevents mildew growth on a dry film; and a serilizer kills fungal growth which is already present on a dry film. Industrial paints are much less subject to bacterial attack than are trade sales paints, said Mr. Machemer.

Q. Have quaternaries been evaluated as sterilizing agents?

A. Past experience indicates that they are good sterilizing agents, but they are not lasting.

ALBERT SENEKER, *Secretary*
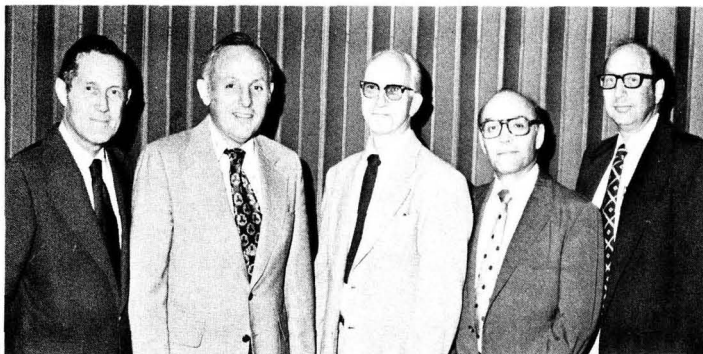
Officers of the St. Louis Society for Coatings Technology for 1976-77. Left to right: President — James J. Koenig, of Alcoa; Vice-President — Bernard M. Brill, of P. D. George Co.; Secretary — Morris D. Gilliam, of Lanson Chemical Co.; Council Representative — Howard Jerome, of Vane-Calvert Paint Co.; and Assistant Treasurer — Herbert Rosenblatt, of Steelcote Mfg. Co. Treasurer — John W. Folkerts, of Plaschem Coatings, not present for photo

Constituent Society Meetings and Secretaries

BALTIMORE (Third Thursday—Eudowood Gardens, Towson). WILLIAM T. COCHRAN, Bruning Paint Co., Inc., 601 S. Haven St., Baltimore, Md. 21224.

BIRMINGHAM (First Thursday—Imperial Hotel). P. A. HARRIS, Midland Specialty Powders, Unit 8, Bilston Industrial Estate, Staffs, England.

CHICAGO (First Monday—meeting sites in various suburban locations) WALTER J. KRASON, JR., Enterprise Paint Mfg. Co., 2841 S. Ashland Ave., Chicago, Ill. 60608.

C-D-I-C (Second Monday—Sept., Jan., Mar. in Columbus; Oct., Dec., Apr. in Cincinnati; Nov., Feb., May in Dayton). LLOYD J. REINDL, Inland Div., GMC, P.O. Box 1224, Dayton, Ohio 45401.

CLEVELAND (Third Friday—meeting sites vary). CHARLES K. BECK, Addressograph Multigraph Corp., 19701 S. Miles Rd., Warrensville Hts., Ohio 44128.

DALLAS (Thursday following second Tuesday—Vic's Gallery Restaurant). SAMUEL F. BIFFLE, Sherwin-Williams Co., 2802 W. Miller Rd., Garland, Texas 75040.

DETROIT (Fourth Tuesday—Rackham Memorial Bldg.). MACKENZIE ENDO, Argo Paint & Chemical Co., 550 S. Edwin, Westland, Mich. 48185.

GOLDEN GATE (Monday before Third Wednesday—Sabella's Restaurant, San Francisco). KEN G. PROBST, San Jose Regional Vocational Center, 760 Hillsdale Ave., San Jose, Calif. 95123.

HOUSTON (Second Tuesday—Sonny Look's Sir-Loin Inn). THOMAS RULAND, Cook Paint & Varnish Co., P.O. Box 3088, Houston, Tex. 77001.

KANSAS CITY (Second Thursday—Fireside Inn). HUGO R. MANCO, Farmland Industries, Inc.. P.O. Box 7305, N. Kansas City, Mo. 64116.

LOS ANGELES (Second Wednesday— Steven's Steak House). ALBERT SENEKER, Ameron, Research & Development, 4813 Firestone Blvd., South Gate, Calif. 90280.

LOUISVILLE (Third Wednesday—Essex House). J. B. LOCOCO, Reynolds Metals Co., P.O. Box 1800, Plant III, Louisville, Ky. 40201.

MONTREAL (First Wednesday—Bill Wong's Restaurant). J. W. A. MELSBACH, Sico, Inc., 2505 de la Metropole Longueuil, Que., Canada.

NEW ENGLAND (Third Thursday—Fantasia Restaurant, Cambridge). GEORGE MULVEY, Dampney Co., 85 Paris St., Everett, Mass. 02149.

NEW YORK (Second Tuesday—varies between New York and New Jersey locations). GEORGE J. DIPPOLD, Whittaker, Clark & Daniels, Inc., 1000 Coolidge St., South Plainfield, N. J. 07080.

NORTHWESTERN (Tuesday after first Monday—Jax Cafe). ROBERT HESKIN, Valspar Corp., 1101 3rd St., S., Minneapolis, Minn. 55415.

PACIFIC NORTHWEST (Portland Section—Tuesday following second Wednesday; Seattle Section—the day after Portland; British Columbia Section—the day after Seattle). MICHAEL GRIFFIN, Reichhold Chemicals Ltd., P.O. Box 130, Port Moody, B.C., Canada.

PHILADELPHIA (Second Thursday—Williamson's Restaurant, Presidential Apartments). LOTHAR S. SANDER, N L Industries, Inc., Industrial Chemicals Div., P.O. Box 700, Hightstown, N.J. 08520.

PIEDMONT (Third Wednesday—Howard Johnson's Coliseum, Greensboro, N. C.). JAMES A. MARTZ, The Lilly Co., P.O. Box 1821, High Point, N. C. 27261

PITTSBURGH (First Monday—Skibo Hall, Carnegie-Mellon University Campus). J. H. DAHL, J. H. Matthews Co., 1315 W. Liberty Ave., Pittsburgh, Pa. 15226.

ROCKY MOUNTAIN (Monday prior to second Wednesday— Gasthaus Ridgeview, Wheatridge, Colo.). JIM PETERSON, Peterson Paint Co., P. O. Box 311, Pueblo, Colo. 81002.

ST LOUIS (Third Tuesday—Salad Bowl Restaurant). MORRIS D. GILLIAM, Lanson Chemical Co., P. O. Box 128, E. St. Louis, Ill. 62202.

SOUTHERN (Gulf Coast Section—Second Tuesday; Central Florida Section—Thursday after third Monday; Atlanta Section—Third Thursday). ALFRED L. HENDRY, A. L. Hendry & Co., P. O. Box 17099, Tampa, Fla. 33612.

TORONTO (Second Monday—Town and Country Restaurant). S. PALLESCHI, Abrex Specialty Coatings Ltd., 280 Wyecroft Rd., Oakville, Ont., Canada.

WESTERN NEW YORK (Second Tuesday—Cavalier Restaurant, Amherst, N. Y.). LEONARD H. GIELINSKI, Spencer-Kellogg Div., Textron, Inc., P. O. Box 210, Buffalo, N. Y. 14225.

Philadelphia
September 9

A moment of silence was observed for Dr. W. G. Vannoy, formerly of E. I. du Pont de Nemours & Co., Inc., who died recently.

The following slate of officers was elected for the year 1976-77: President—Wayne A. Krause, of Lawrence-McFadden Co.; President-Elect—Wayne N. Wood, of Allentown Paint Mfg. Co.; Secretary—Lothar S. Sander, of N L Industries, Inc.; Treasurer—Carl W. Fuller, of Cities Service, Inc.; and returning as Council Representative—J. Richard Kiefer, Jr., of McCloskey Varnish Co.

Alex Siegel, of Silberline Mfg. Co., spoke on "THE USE AND MISUSE OF ALUMINUM PIGMENTS IN SURFACE COATINGS."

Aluminum pigments fall into two classifications: leafing and non-leafing. Although both are made the same way there is a difference in the type of lubricant used in the manufacture of the two.

Mr. Siegel said that preventing moisture contamination is the major problem associated with non-leafing aluminum pigments. However, if dry conditions are observed no problems should be encountered.

LOTHAR S. SANDER, *Secretary*

Piedmont
September 15

J. John Stratta, of Union Carbide Corp., spoke on "SOLVENCY AND SOLVENT RETENTION STUDIES FOR COMPLYING (EXEMPT) VINYL SOLUTION COATINGS."

The following officers were installed for the year 1976-77: President — Johnny C. Lucas, of The Lilly Co.; Vice-President — James A. Martz, of The Lilly Co.; Secretary — Charles B. Wilson, of Reliance Universal, Inc.; and Treasurer — John V. Hjanos, of Rohm and Haas Co.

CHARLES B. WILSON, *Secretary*

Toronto
June 14

The following slate of officers was elected for the year 1976-77: President—Fred A. Pugsley, of Canadian Pittsburgh Industries Ltd.; President-Elect—Andy J. Jones, of Reichhold Chemicals Ltd.; Treasurer—Paul D. F. Cooper, of Chemetron of Canada Ltd.; and Secretary—S. Palleschi, of Abrex Specialty Coatings Ltd.

S. PALLESCHI, *Secretary*

Technical Articles in Other Publications

Compiled by the Technical Information Systems Committee — H. Skowronska, Chairman

COATINGS AND PLASTICS PREPRINTS

Preprints of Papers Presented before ACS Division of Organic Coatings and Plastics Chemistry

San Francisco, Cal   Aug. 30 — Sept. 3, 1976   Vol. 36 No. 2

Characterization of Coatings and Polymers (22 papers + 1 abstract); 1-38, 121-155, 213-232, 353-386, 814-822.
Flammability and Combustion of Non-Metallic Materials (37 papers + 4 abstracts); 39-88, 156-190, 303-352, 387, 448-528, 576-624, 715-742.
Water-Borne Polymers (24 papers + 2 abstracts); 89-120, 191-212, 216, 273-302, 417-447, 552-575.
Chemistry and Properties of Crosslinked Polymers (30 papers + 5 abstracts); 233-272, 387-416, 529-551, 587, 625-653, 689-714, 746-780.
General Papers and New Concepts in Coatings and Plastics Chemistry (11 papers + 2 abstracts); 654-685, 746, 781-813.
Structure-Solubility Relationships in Polymers (21 abstracts); 686-688, 743-745.

Inquiries regarding price and availability of this preprint book should be sent to S.S. Labana, Research Lab, Ford Motor Co., P. O. Box 2053, Dearborn, Mich. 48121.

DEFAZET
DEUTSCHE FARBEN-ZEITSCRIFT
(in German)

Published by Wissenschaftliche Verlagsgesellschaft MBH, 7000 Stuttgart 1, Postfach 40, Germany

Vol. 30 No. 8   August 1976

Landwehr, E.—"Corrosion Resistant Coatings;" 310-311.
von Pokorny, G.—"Protection of Steel against Corrosion with Thick Coatings;" 312-316.
Schwarz, H., Scimar, R., Seils, A., and Toussaint, A. — "Hot-Dip Galvanization Plus Coating. Practical Advice on the Protection of Hot-Dip Galvanized Steel by Coatings;" 317-319.
van Oeteren K. A.—"Protection of Steel Structures against Corrosion. Types of Shop-Primer and Conservation of Rolled Steel;" 320-327.
Penne, R. A. and Rautenberg, H. J.—"Improved Corrosion Resistance in Primers and High Build Coatings with Qualified Fillers;" 328-333.
Zorll, U.—"Studies about the Possibilities of Measuring the Thickness of Coatings on Rough Surfaces of Steel;" 334-339.
Blumentritt, F.—"Coating Material for Nuclear Power Generation Plants —The Facilities of Atucha (Argentina) as an Example;" 339-345.
Linke, L.—"Guarantees for Coating Work;" 345-348.
Daldorf, E.—"The 'Technical Committee for Corrosion Protection' of the Working Group 'Corrosion Resistant Paints' of the German Paint Manufacturers' Association;" 348-350.

DOUBLE LIAISON—CHIMIE DES PEINTURES
(in French)

Published by Les Presses Continentales, Rue du Cherche-Midi, F-75006, Paris, France

Vol. 23 No. 250   June 1976

Pouchol, J. M.—"Influence of Pigment Choice in Vinyl Anti-corrosive Paints;" 19-26.
Eyraud, G.—"Lipari's Pumice Stone;" 29-38.
Caillierez, F.—"Recent Developments in Wet Milling;" 39-41.

FARBE und LACK
(in German)

Published by Curt R. Vincentz Verlag, 3 Hanover, Postfach 6247, Schiffgraben 43, Germany

Vol. 82 No. 8   August 1976

Wünsche, O.—"Mixing and Grinding Machines at the Achema 1976. Attempt at a Trend Analysis;" 683-684.
Epprecht, A. G.—"Break Resistance of Epoxide Resin Adhesives;" 685-689.
Gross, D., Kretzschmar, H.-J., and Wiegel, H.—"Identification of Benzene in Solvents and Preparation;" 690-692.
Bürkholz, A., Widder, J., Müller, W., and Dislich, M.—"Primary Droplet Size Distribution and Breathable Fines in Pressure Spraying;" 693-698.
Engels, K.—"New Machines and Methods of Mixing, Fine Dispersion and Size Reduction Techniques;" 699-702.
Brushwell, W.—"Technology of Polyurethanes (Literature Review);" 703-708.
German Standard Draft DIN 53 243: Paints and Varnishes; Polymers containing Chlorine, Methods of Test — 709-710.
German Standard Draft DIN 55 969: Pigments; Zinc Dust Pigments, Technical Delivery Specifications — 711.

INDUSTRIE-LACKIER-BETRIEB
(in German)

Published by Curt R. Vincentz Verlag, 3 Hannover, Postfach 6247, Schiffgraben 43, Germany

Vol. 44 No. 7   July 1976

Himmler, R.—"Pretreatment Line Installation — Immersion or Spray — Waste Reduction;" 253-256.
Wichmann, U.—"Experience in Application of Electrostatic Powder Coatings to Household Furnishings;" 257-262.
Lambert, M.—"Why the Choice of a New Technique for Household Furnishings Supposes Close Cooperation of Planning Group;" 263-266.
Anon.—"Coating Technology in Yugoslavia;" 267-270 .
Anon.—"Autorefinishing. IX;" 271-274.

JOURNAL of the OIL AND COLOUR CHEMISTS' ASSOCIATION

Published by Oil and Colour Chemists' Association, Priory House, 967 Harrow Road, Wembley, Middlesex, England HAO 2SF

Vol. 59 No. 6   June 1976

Laws, A., Lynn, S., and Hall, R.—"Some Aspects of the Formulation of UV-Curable Polyester Based Systems;" 193-196.
Younger, J. R.—"Use of Polyfunctional Monomers in UV Curing;" 197-201.
Phillips, D.—"Sensitization and Stabilisation in Monomer/Polymer Systems;" 202-207.
Hancox, R. J. and Hill, L. A.—"Determination of the Colorimetric Values of Colours to BS 381 C;" 209-221.

Vol. 59 No. 7   July 1976

McNeill, I. C.—"Photodegradation of Polymers;" 231-236.
Knight, R. E.—"UV-Drying Equipment, Design and Installation;" 237-239.
Gamble, A. A.—"Ultraviolet Curing Inks;" 240-244.
Hulme, B. E.—"Some Aspects of the Pigmentation of UV-Curable Systems;" 245-252.
Ferguson, P. J.—"Painting Metal Bridges — Historical and Current Trends;" 253-258.

Reid, J. C.—"A Fracture Mechanics Approach to Lacquer Cracking;" 278-284.

O'Neill, L. A. and Christensen, G.—"Analysis of Polyamide Resins: a Co-Operative IUPAC Study;" 285-290.

Badran, B. M., El-Mehelmy, F. M., and Ghanem, N. A.—"In-Situ Epoxidation of Linseed Oil in the Presence of Ion-Exchange Resins;" 291-294.

Howe, D. J. T.—"Industrial Carcinogens;" 295-296.

La RIVISTA del COLORE — VERNICIATURA INDUSTRIALE
(in Italian)

Published by La Rivista del Colore S.R.I., Via Imbriana 10, 20158 Milan, Italy

Vol. 9 No. 98   June 1976

Antonioli, V.—"Saving of Energy during Pretreatment Operations;" 195-201.

PIGMENT & RESIN TECHNOLOGY

Published by Sawell Publications, Ltd., 127 Stanstead Road, London SE23 1JE England

Vol. 5 No. 7   July 1976

Rackham, J. M.—"Dispersing of Titanium Dioxide in Non-Aqueous Media;" 11-17.

POLYMER PREPRINTS

Preprints of Papers Presented before ACS Division of Polymer Chemistry

San Francisco, Cal.   Aug. 30 — Sept. 3, 1976   Vol. 17 No. 2

Relaxation Phenomena in Polymers (36 papers + 5 abstracts); 1-212.

Polymer Bound Reagents and Ligands (10 papers + 3 abstracts); 213-267.

Water-Borne Polymers (9 papers + 1 abstract); 268-321.

Structure-Solubility Relationship in Polymers (20 papers + 1 abstract); 322-433.

Charge-Transfer Polymerization (14 papers + 1 abstract); 590-671.

Polymer Spectroscopy (19 papers); 672-778.

General Papers (62 papers); 434-589, 779-953.

Inquiries regarding price and availability of this preprint book should be sent to R. Saxon, P.O. Box 415, Bound Brook, N. J. 08805.

SKANDINAVISK TIDSKRIFT for FARG och LACK

Published by Dansk Bladforlag K/S, Holbergsgade 20, 1057 Copenhagen, Denmark

Vol. 22 No. 6   June 1976

Lindberg, B.—"Painting of Plastics. Part 1: Adhesion;" 182, 195-6. (in Swedish)

Progress Report Available on "Surface Profile" Project

The Steel Structures Painting Council has announced availability of a 163-page progress report on the project, "Surface Profile for Anti-Corrosion Paints," which it is conducting under the co-sponsorship of the Federation of Societies for Coatings Technology and five other organizations: American Institute of Steel Construction; American Iron and Steel Institute; Federal Highway Administration; Pennsylvania Department of Transportation; and Steel Plate Fabricators Association.

New concepts developed to date in this project are expected to have important practical implications for steel painting practice. In addition, the following conclusions are among those detailed in the report.

STATE OF THE ART — At the outset of the project, a state-of-the-art survey revealed that the extensive technology available for defining surface profile has little relevance to blast-cleaned structural steel.

SCANNING ELECTRON MICROSCOPY — This portion of the study made it possible not only to visualize for the first time the true topography of structural steel surfaces cleaned by various methods, but also to reconstruct the probable mechanism of profile formation in blast cleaning. (A 3-D stereo supplement to this report will soon be available).

TRENDS — It was established that profile has less effect on paint performance than previously assumed. Trends also show how this effect is moderated by the degree of surface preparation, type of abrasive used, type of paint, environmental exposure, and paint thickness.

PROFILE MEASUREMENT — A preliminary specification has been drafted for a standard referee method of measuring surface preparation profile using the common microscope to measure peak/valley profile height (either directly or with a replica).

RESEARCH MEASURING METHODS — Results show how four other methods of measuring profile can be used to good effect in research studies: microsections; scanning electron microscopy; computer-related stylus traces; and a triangulation technique using transducers and a computer to analyze SEM stereo pairs.

EFFECTS OF BLAST CLEANING CONDITIONS ON PROFILE — It is shown that profile height tends to increase as the abrasive size increases, as the degree of cleaning is improved, and as the angle of abrasive impingement increases. Profile height was relatively insensitive to steel thickness and to normal differences from one plant to another.

NEW AVENUES — Accelerated tests on paint performance need to be verified by outdoor exposures still in progress. Further scanning electron microscopy (especially stereo) and related techniques can be used to point the way to types of profile required by various paints in shop and field, to a better choice and control of abrasives, to faster, less expensive cleaning, and to prevention of premature rusting.

Copies of the report may be ordered from the Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, Pa. 15213. Price is $20; FSCT members pay $15.

Meetings/Education

Kent State Offering Two Organic Coatings Courses

Two 3-hr credit/audit courses in organic coatings are being offered this fall by the Chemistry Dept., Kent State University as a series of lectures on nine Saturday mornings, September 25 through November 20.

Coatings I features as lecturers Dr. Walter Asbeck, formerly of Union Carbide Corp., and Dr. John Weaver, consultant with Sherwin-Williams Co. This course is designed for junior technicians, new employees, and individuals desiring an introduction to pigments, binders, solvents, additives, coating types, film formation, rheology, etc.

Coatings III features individual lectures at the graduate level given by nine scientists covering fundamentals of adhesion, color, curing and cross-linking, diffusion, electro-deposition, experimental design, molecular architecture, photochemistry, and rheology.

NACE to Host Corrosion/77 In San Francisco, March 14-18

The National Association of Corrosion Engineers (NACE) will hold its annual conference, CORROSION/77, in San Francisco, Calif., March 14-18. Headquarters hotel will be the San Francisco Hilton.

The conference will feature over 200 technical presentations in 33 symposiums sponsored by NACE Technical Committees. Individual meetings of the Technical Committees are also scheduled to provide a forum for discussion on all phases of corrosion control. The Corrosion Research Conference, a series of five sessions comprised of presentations on specific corrosion problems, is another featured segment of the program.

For additional information, write National Association of Corrosion Engineers, 2400 W. Loop South, Houston, Texas 77027.

Book Review

DICTIONARY OF ARCHITECTURE AND CONSTRUCTION

Edited by Cyril M. Harris
McGraw-Hill Book Company
New York, N. Y.
1976 (553 pages)
$35.00

Reviewed by
Stanley Le Sota*
Rohm and Haas Company
Spring House, Pa. 19477

This is a well-organized, comprehensive reference work of building trade terms, reflecting the input of 52 contributing editors. It contains concise, well-written definitions of architectural terms, along with major definitions from many associated fields. There are hundreds of definitions for coatings terms, as well as for building products and related terms dealing with their design, appearance, performance, installation, and testing.

Like the *American Heritage Dictionary*, this handsome volume contains illustrations in the wide margins of each page. There are 1775 illustrations, averaging about three per page, on such terms as acanthus, embrasure, plinth, reredos, sarcophagus, torii, and withe. Many of these appear to be the obscure words used in crossword puzzles. It appears to answer everything anyone wanted to know about architecture but didn't know what to ask.

The definitions are well edited with a uniform style throughout. Each term to be defined is in large size, easy on the eyes, in boldface print. Trade jargon is avoided in the definition; however, in the few cases where it is used, it is in boldface print and defined elsewhere (alphabetically) in the dictionary. Synonyms are also in boldface print and cross-referenced to a more commonly accepted term. Metric equivalents are also given for measurements used in the definitions.

The definitions are easily understood and the line drawings are well chosen to illustrate terms difficult to describe. The quality of the definitions are excellent. With certain terms, one would like to know more about the subject. An obvious and logical successor to this volume would be an *Encyclopedia of Architecture and Construction*.

This reference work would make a worthwhile addition to (or edition for) any coatings library.

*Mr. LeSota is the Definitions Committee chairman of both the Federation and ASTM, D-1.

People

Richard W. Clemens has been appointed Marketing Manager — Resins Dept., for the Industrial Chemicals Div. of American Cyanamid Co., located in Wayne, N.J.

FRP Co., a subsidiary of Monsanto Co., has appointed James E. Feltham Executive Vice-President. He was formerly Manager of Phosphorus Technology at Monsanto's headquarters in St. Louis.

Harry Heimann has been named Technical Director for the Polymer Div. of H. B. Fuller Co. He has recently been involved in new product development of specialty polymers.

Hodag Chemical Corp. has appointed Bjorn G. E. Mattsson Manager—Technical Service, Process Chemicals. He will be responsible for both domestic and international technical service for the company's products.

Kenneth Brown has been appointed Group Leader of the Resins Research Development Dept. of Rust-Oleum Corp.

William K. Dorn has been named Product Manager for Union Flonetics Corp., of Union Corp.

Hodag Chemical Corp., in an expansion move, has appointed Vladimir S. Teokarovic as Director of European Sales. Headquartered in Brussels, Mr. Teokarovic was most recently market research coordinator for Tenneco Chemicals, Europe.

Gulf + Western Industries, Inc., in an administrative restructuring of its natural resources operations, has created a new unit, Gulf + Western Natural Resources Group, which will include four operating divisions: New Jersey Zinc Div., Titanium Div., Metals Div., and Coal Div. Richard W. Hogeland, formerly President of G+W's New Jersey Zinc Co., was elected Chairman and Chief Executive Officer of the Group. A. Reid Eschallier is President; William E. Flaherty and Lawrence S. O'Rourke have been named Vice-Presidents. Both are former officers of NJZ.

Kenneth E. Hyatt has been named President of Georgia Marble Co. He had served as Executive Vice-President since 1974.

R. W. Clemens   J. E. Feltham   H. Heimann   B. G. E. Mattsson

Charles A. Chilver has been named Sales Representative in the Los Angeles area for the Organic Chemicals Div. of American Cyanamid Co.

Thomas G. Brown has joined the Minerals & Chemicals Div. of Engelhard Minerals & Chemicals Corp. as Product Manager, Marketing Dept.

Mooney Chemicals, Inc. has named Timothy D. McLaughlin as Sales Representative for the mid-western territory based in Chicago.

Stephen M. Malaga has been named Product Manager for specialized pigments for Hercules Incorporated and will handle marketing to the coatings industry.

Chemetron Corp. has made three appointments in its Pigments Div. Peter G. Ritz has been named Director of Purchasing; Alan L. Haase was appointed Divisional Environmental Project Engineer; and Dennis R. Reed was named Safety Coordinator for the division's Holland, Mich. manufacturing facility.

Exxon Chemical U.S.A. has named **Glenn A. Sampson** Manager of Operations and Planning for the Solvents Dept. He will be responsible for the development and direction of strategies and plans for the operation of the company's solvent business.

In a series of managerial appointments, C. M. Athey Paint Co. has named **Myron O. Beatty** — Vice-President, Technical; **Wayne L. Morris** — Vice-President, Sales; **George J. Ross** — Vice-President, Purchasing; and **Maurice F. Spedden** — Vice-President, Regional Sales (South).

N L Industries, Inc. has named **Jean-Pierre De Vleeschouwer** as a Vice-President of the company. He is presently head of N L Pigments Europe, Inc. and a Director of Kronos Titan GmbH, West Germany, Kronos Titanium Pigments, England, Kronos S.A./N.V., Belgium, Kronos Titan A.S., Norway, and Societe Industrielle du Titane, S.A., France. N L Industries has also appointed **Thomas W. Zinsser** to the newly created post of Director of International Operations with the Industrial Chemicals Div. He was formerly Business Director for the division.

The Polymer Div. of H. B. Fuller Co. has appointed **Dale Noble** as General Sales Manager in Cincinnati. He was previously Marketing Manager of the company's Packaging Adhesives Div. Also in Cincinnati, **Ronald L. Stafford** has been named Technical Sales Representative for the division.

G. O. Stephenson, retired Editor of the *American Paint Journal,* has been appointed Executive Secretary of the St. Louis Paint and Coatings Association. Earlier this year the organization had presented him with a merit citation for his many years of dedicated service to the coatings industry. Mr. Stephenson, who retired from the APJ five years ago, is an Honorary Member of both the St. Louis PCA and the Society for Coatings Technology.

Obituary

Donald W. Fergusson, 54, Chairman of the Board of Rust-Oleum Corp., died August 18. Directing the manufacturing, research, and technical sales of the company, Mr. Fergusson became the first Chairman of the Board of the company in October 1975.

Wesley G. Vannoy, 76, former research associate with the Pigments Dept. of E. I. duPont de Nemours & Co., Inc., died September 3. Widely acclaimed as an expert on outside housepaints, Mr. Vannoy authored 23 papers on the subject and was a frequent speaker at both national and local Federation meetings in all parts of the U. S. and Canada. An active member of ASTM, he retired from the duPont Co. in 1965 after 38 years of service to the industry.

Literature

Acrylic Resin

Literature has been published which discusses the availability of a 100% solids acrylic resin developed for use as a pigment dispersing agent in industrial coatings for finishing automobiles, appliances, piping, and metal furniture. Acryloid® DM-54 is compatible with a wide range of film formers, and is reported to have excellent pigment wetting and dispersing capabilities and wide solubility. It also serves as a melt and flow modifier for plastics; and it can be employed as a dispersing and binding vehicle for colorants which are utilized in the plastic industry. For additional information write Polymers, Resins and Monomers Marketing, Rohm and Haas Co., Independence Mall West, Philadelphia, Pa. 19105.

Epoxy Curing Agent

A bulletin has been released giving details of a new low-cost epoxy curing agent. The proprietary product is composed of a mixture of aliphatic polyamines and is recommended for epoxy coal tar systems, epoxy pipe coatings, primers, and adhesives. For more information on Dion® Hardener 48, request Bulletin TPD-115 Rev. from the Rubber & Plastics Dept., Diamond Shamrock, Process Chemicals Div., 350 Mt. Kemble Ave., Morristown, N.J. 07960.

Bend Tester Mandrel Set

A bulletin is available which describes the capabilities and components of a new low-cost bend tester mandrel set. The purpose of the set is for studying the relative elasticity or flexibility of applied organic coatings, air dried or baked, or multi-coat systems. For further information write Paul N. Gardner Co., P. O. Box 6633, Ft. Lauderdale, Fla. 33316.

Color Comparator

A brochure has been released introducing a new system of standards for the comparison of color rendition of films, light conditions, cameras and lenses. An array of 24 colored squares, the ColorChecker may be used optically or with a densitometer. For more information write Dr. J. G. Davidson, Macbeth, Little Britain Rd., Drawer 950, Newburgh, N.Y. 12550.

Flatting Agent

A data sheet details a new flatting agent for use with water reducible coatings. It is reported that the dispersion will not affect paint color and is compatible with all aqueous vehicle systems currently in use. For further information write Universal Color Dispersions, 2700 E. 170th St., Lansing, Ill. 60438.

Organic Co-Solvents

A new booklet is now available which lists organic co-solvents for use in water-borne coatings. The four-page booklet details the physical properties of 26 co-solvents. For a free copy of Booklet F-45623 write Union Carbide Corp., Coatings Materials, Dept. JLS, 19th Floor, 270 Park Ave., New York, N.Y. 10017.

Vinyl Acrylic Emulsion

A recently published bulletin details a new vinyl acrylic emulsion for use in both interior and exterior trade sales coatings. Developed specifically to meet the growing demand for improved latex paint systems without increasing raw materials costs, AMSCO-RES® 3077 exhibits excellent scrub resistance, low temperature coalescence, and gloss and enamel holdout. For Bulletin No. 3077 write Market Manager—Paints, AMSCO Div., Union Oil Co. of Calif., 3100 S. Meacham Rd., Palatine, Ill. 60067.

DOT Reg. Compliance

On April 15, 1976, the Department of Transportation published sweeping revisions affecting the marking and shipment of hazardous materials. In the process of consolidating the Regulations for Air, Highway, Rail and Water, approximately 700 commodities have been added, including many Consumer Commodities previously exempted. In addition to new labeling requirements, there are completely new specifications for placarding and shipping papers. Mandatory compliance for much of the above is January 1 and July 1, 1977. A free, 16-page, full color catalog describing many of these changes is available from Labelmaster, 6001 N. Clark St., Chicago, Ill. 60660.

Color Measurement

Newly published literature is available which describe two new color measurement aids. The MC-1010 Colorimeter is a complete color and appearance measurement system which utilizes a self-contained microprocessor with no moving parts. Taking advantage of the latest electronic devices, the MS-2000 Spectrophotometer is a self-contained unit which covers the 380 — 720 nm range. For more information write Marketing Manager, Color Data Products, Macbeth, Little Britain Rd., Drawer 950, Newburgh, N.Y. 12550.

Specialty Gas

Air Products and Chemicals, Inc. has introduced through its Specialty Gas Dept., a multi-facet communications program to inform users of its line of specialty gas products. Featuring segments on components, technical and safety information, conversion data, personnel, and reference material, "The Program" is prepared to meet "nearly all customer needs," according to department manager Willard E. Ent. The program is summarized in a new brochure called "The Story." To obtain a copy write Specialty Gas Dept., Air Products & Chemicals, Inc., Box 538, Allentown, Pa. 18105.

CLASSIFIED ADVERTISING

Coming Events

FEDERATION MEETINGS

(Oct. 26)—Fall Council Meeting. Sheraton Park Hotel, Washington, D. C.

(Oct. 27-29)—54th Annual Meeting and 41st Paint Industries' Show. Sheraton Park Hotel, Washington, D. C. (FSCT, Suite 830, 1315 Walnut St., Philadelphia, Pa. 19107).

SPECIAL SOCIETY MEETINGS

(Feb. 13-16)—Water-Borne and High Solids Symposium. International Hotel, New Orleans, La. (Southern Society and University of Southern Mississippi, Dept. of Polymer Science).

(Mar. 2-4)—Western Coatings Societies' Symposium and Show. Marriott Hotel, Los Angeles, California. (Romer E. Johnson, Dorsett & Jackson, Inc., 3800 Noakes Tr., Los Angeles, Calif. 90023).

(Mar. 11)—Symposium on "Accelerated Weathering: Myth vs. Reality." Technical Education Committee, Cleveland Society. (Carl J. Knauss, Chemistry Dept., Kent State University, Kent, Ohio 44242).

(Mar. 23-26)—Southern Society Annual Meeting. Fairmont Roosevelt Hotel, New Orleans, La. (Thomas E. Marek, Coronado Paint Co., P. O. Box 308, Edgewater, Fla. 32032).

(May 5-7)—Pacific Northwest Society Spring Symposium. Thunderbird Motor Inn, Portland, Ore. (John Hatfield, Reliance Universal, Inc., 1660 Cross St., S. E., Salem, Ore. 97302).

OTHER ORGANIZATIONS

(Nov. 2-4)—ASTM Symposium on Adhesion Measurement of Thin Films, Thick Films, and Bulk Coatings. ASTM headquarters, Philadelphia, Pa. (American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103).

(Nov. 8-10)—Fall Conference on Fundamentals of Adhesion — Theory, Practice and Application. Monk Mountain Resort, New Paltz, N. Y. (Dr. A. V. Patsis, Dept. of Chemistry, State University of New York at New Paltz, New Paltz, N. Y. 12561).

(Nov. 9-10)—Society of Plastics Engineers Seminar on Fundamentals and Problems of Color. (Michael J. Dunn, H. Kohnstamm & Co., Inc., 161 Avenue of the Americas, New York, N. Y. 10013).

(Nov. 19-21)—29th Annual National Decorating Products Show. H. Roe Bartle Center, Kansas City, Mo. (National Decorating Products Association, 9334 Dielman Industrial Drive, St. Louis, Mo. 63132).

1977

(Jan. 9-12)—75th Annual Meeting American Society for Testing and Materials, Committee D-1. Philadelphia, Pa. (ASTM, 1916 Race St., Philadelphia, Pa. 19103).

(Feb. 13-16)—Symposium on Water-Borne and High-Solids Coatings, co-sponsored by Southern Society and University of Southern Mississippi. International Hotel, New Orleans, La. (Dr. B. George Bufkin, Dept. of Polymer Science, University of Southern Mississippi, Hattiesburg, Miss. 39401).

(Mar. 14-18)—National Association of Corrosion Engineers Annual Conference and Materials Performance and Corrosion Show. San Francisco Hilton, San Francisco, Calif. (NACE, 2400 West Loop South, Houston, Texas 77027).

(Mar. 22-25)—OCCA - 29. Oil and Colour Chemists' Association 29th Annual Technical Exhibition. Alexandra Palace, London, England. (The Director & Secretary, Oil and Colour Chemists' Association, Priory House, 967 Harrow Road, Wembley, Middlesex HAO 2SF, England).

Coming Events

(Continued)

(Apr. 25-26)—Washington Paint Technical Group's 17th Annual Symposium. Marriott Twin Bridges Hotel. (Mildred A. Post, c/o U. S. Dept. of Commerce, National Bureau of Standards, Washington, D. C. 20234).

(May 19-20)—1977 International Symposium on Flammability and Fire Retardants. Sheraton-Park Hotel, Washington, D. C. (P. O. Box 1779, Cornwall K6H 5V7, Ontario, Canada).

(June 16-19)—Oil and Colour Chemists' Biennial Conference. Grand Hotel, Eastbourne, Sussex, England. (The Director & Secretary, Oil and Colour Chemists' Association, Priory House, 967 Harrow Road, Wembley, Middlesex HAO 2SF, England).

(June 26-29)—American Society for Testing and Materials Annual Meeting. Denver, Colo. (ASTM, 1916 Race St., Philadelphia, Pa. 19103).

(July 10-15)—Third Congress of the International Colour Association, "Color 77." Rensselaer Polytechnic Institute, Troy, N.Y. (Dr. Fred W. Billmeyer, Jr., Dept. of Chemistry, Rensselaer Polytechnic Institute, Troy, N.Y. 12181).

(July 14-15)—European Conference on Flammability and Fire Retardants. Sheraton Hotel, Brussels, Belgium. (P. O. Box 1779, Cornwall K6H 5V7, Ontario, Canada).

(Sept. 25-28)—First International Convention of Oil & Colour Chemists' Association of Australia. Canberra, Australia. (Oil & Colour Chemists' Association of Australia, P. O. Box 93 Punchbowl, 2196, Australia).

Advertisers In This Issue

Florida:
387,000,000 tons proven ore reserves.

Meet the NL-5...
It's their job to be your link with 1.5 billion tons of TiO$_2$ ore reserves.

Australia:
551,000,000 tons proven ore reserves.
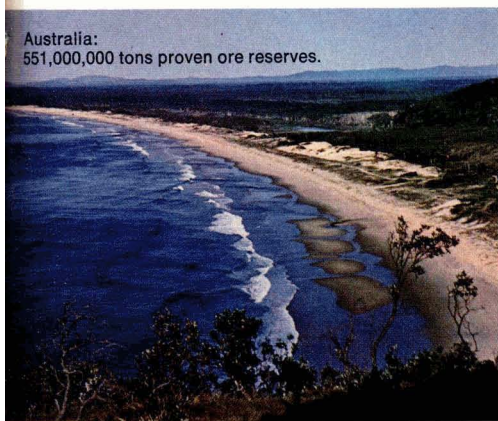
When the NL-5 talk about NL as a dependable source of titanium pigment, there's plenty to back up what they say. Like the world's largest proven reserves of TiO_2-bearing ores. And since NL owns or controls all of its 1,500,000,000 tons of ore reserves, it is uniquely able to provide not only an assured source of supply, but also rigid quality control at every step of the way, from mine to finished product.
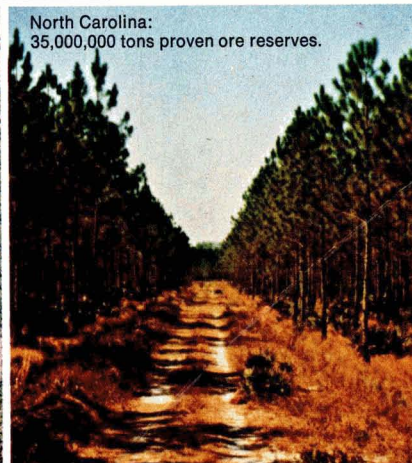
Titanium Pigment Division
NL Industries, Inc.
100 Chevalier Avenue
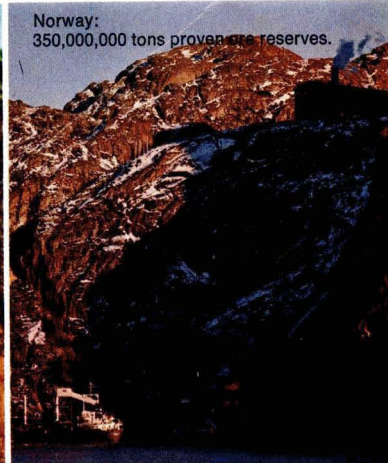South Amboy, N.J. 08879

NL Titanium Pigments

New York:
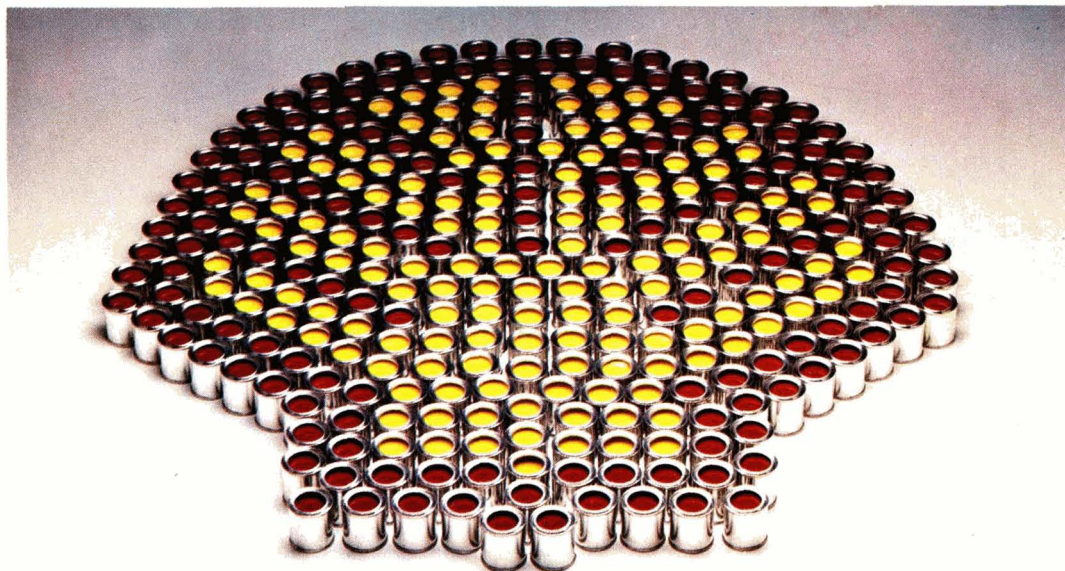142,000,000 tons proven ore reserves.
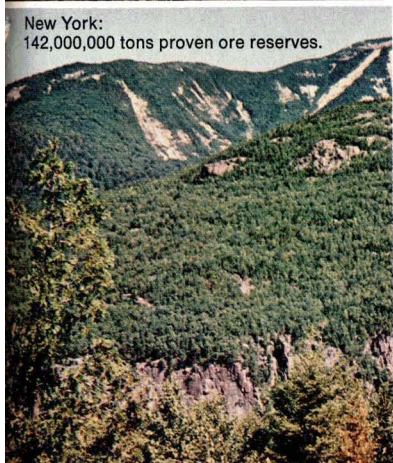
North Carolina:
35,000,000 tons proven ore reserves.

Norway:
350,000,000 tons proven ore reserves.

SHELL RESINS AT THE HEART OF THE PAINT INDUSTRY

Shell's contribution to the paint industry continues to grow. With our new research and development facilities at the Polymers Centre, Amsterdam, we shall be developing new formulae, introducing new products and building on our already extensive product range.

Epikote resins with their exceptional anti-corrosion qualities have become essential raw materials for industrial primers and many other types of coatings. Supplies are assured from plants in nine countries, and major expansions are under way in Europe.

VeoVa monomer gives improved emulsion formulations in domestic paints for both internal and external use, and the characteristics of VeoVa are now being introduced to industrial paints. A new plant in the Netherlands will help meet increasing worldwide demand.

High performance Cardura based resins are being widely used for automotive top coats. Newer developments, particularly in high-solids systems, offer similar outstanding gloss and durability.

For further information please contact your Shell Company.

Shell Chemicals

Better resins make better paints