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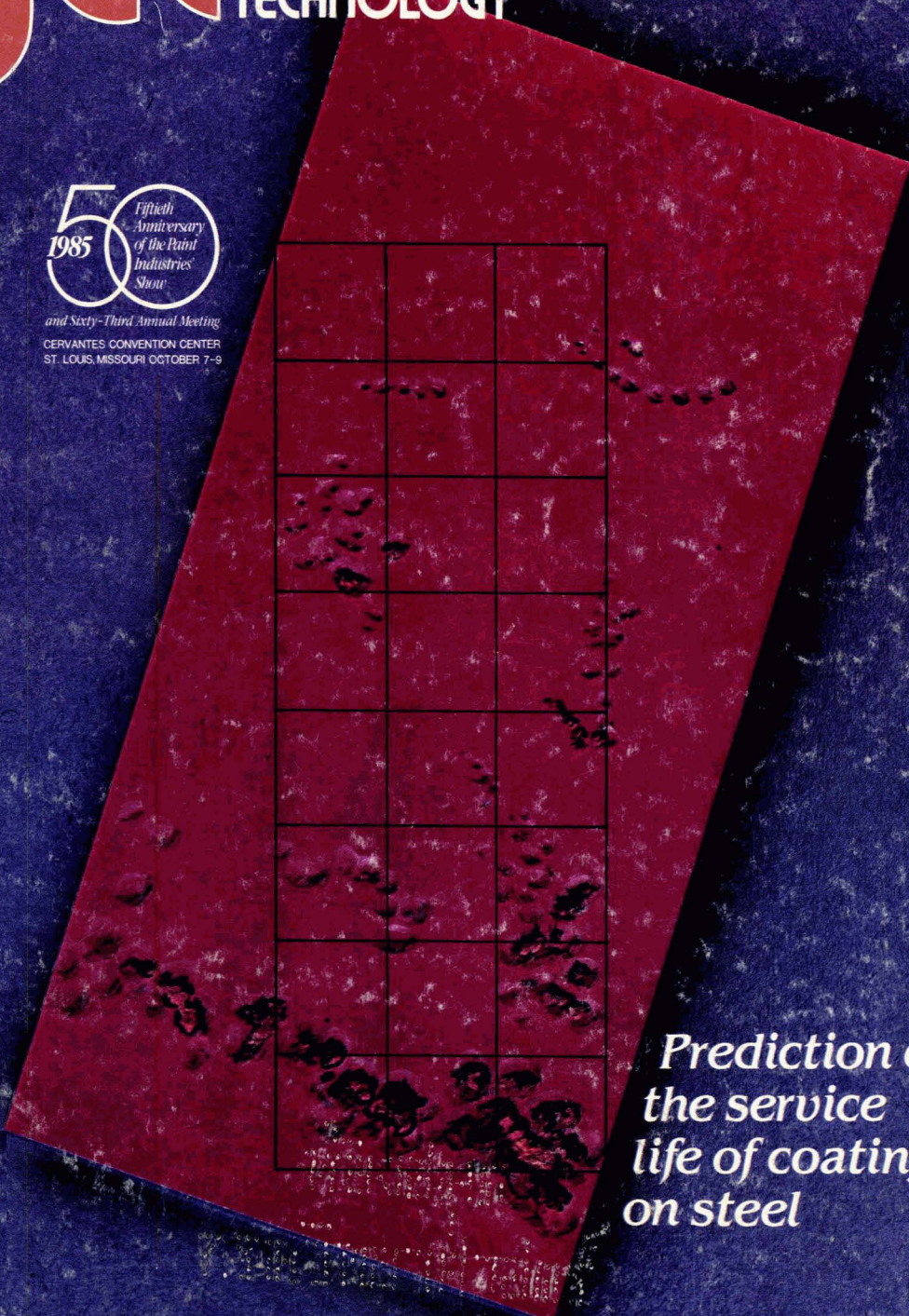
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May 1985

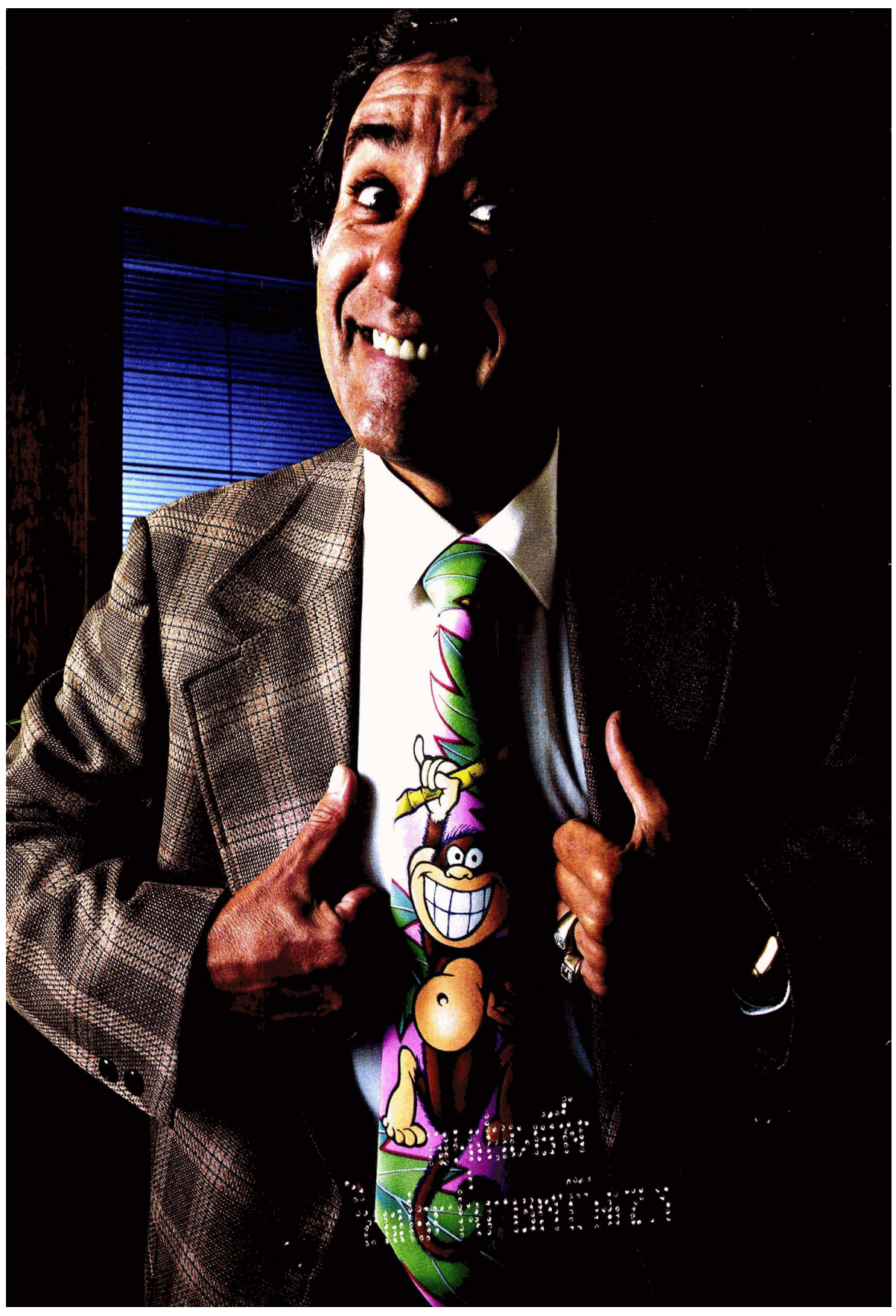
50
1985

Fiftieth
Anniversary
of the Paint
Industries
Show

and Sixty-Third Annual Meeting
CERVANTES CONVENTION CENTER
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*Prediction of
the service
life of coatings
on steel*



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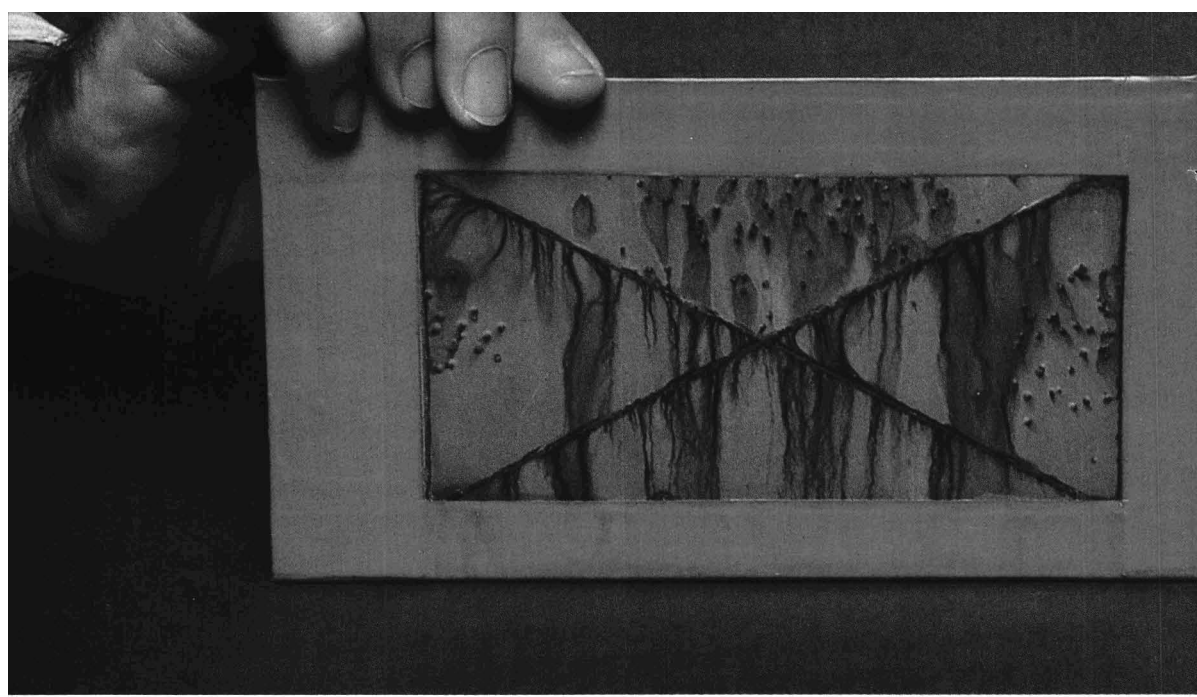


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**With new 100% solids
Hardener XU 283, you can
formulate an EPA-
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improved performance.**

Nobody has to tell you about EPA-mandated restrictions on the volatile organic content (VOC) of industrial coatings. Or about the fact that these restrictions are being adopted state by state.

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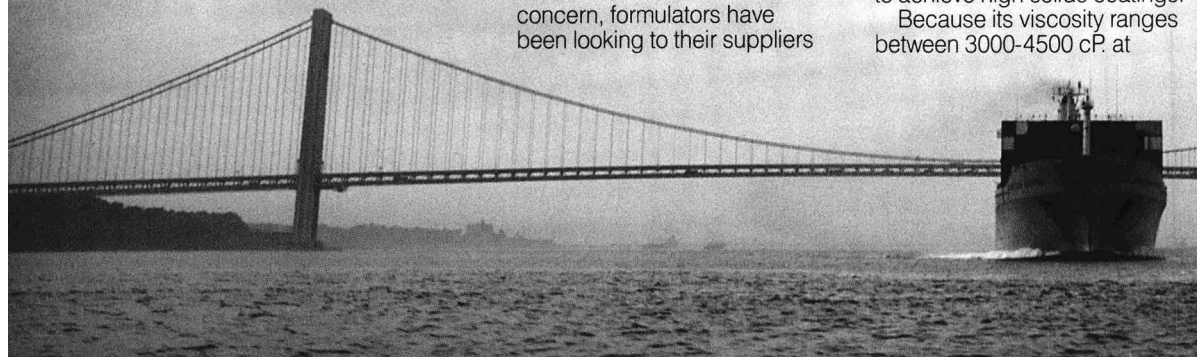
to develop high solids substitutes for existing standard epoxy resin/poly (amidoamine) hardener formulations — substitutes that could provide the high performance characteristics necessary in coatings for bridges, containers and tanks, pipes, ships, and railroad cars.

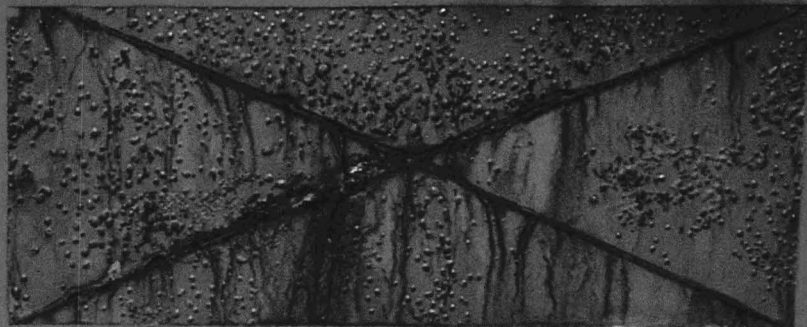
That's why we challenged our chemists to work on a solution. And why that solution is available today as a 100% solids, modified poly (amidoamine) hardener known as XU 283.

More than just a replacement.

A look at its properties should be sufficient to convince you that XU 283 is more than just a replacement for conventional poly (amidoamine) hardeners to achieve high solids coatings.

Because its viscosity ranges between 3000-4500 cP. at





In this side-by-side test, two cold rolled steel panels were coated — one with pigmented Araldite® 6010 epoxy resin and Hardener XU 283, the other with conventional pigmented resin and hardener. Both were then scribed. After 1,000 hours in a salt fog cabinet, the XU 283 formulation had dramatically demonstrated improved corrosion resistance over control.

25°C, XU 283 requires significantly less solvent than standard poly (amidoamine) hardeners to reach a workable stage. Because XU 283 is compatible with solvent-free liquid epoxy resins such as our Araldite® 6010 epoxy resin, no induction period is necessary and, consequently, coatings can be applied immediately after mixing. In addition, XU 283 also resists blushing and exudation.

But what about end results? In the final analysis, how does XU 283 compare to conventional products? The fact is, crosslinked with Araldite 6010 resin, XU 283 actually improves the performance and application of coatings formulations. Compared to formulations using unacceptably high solvent levels, XU 283 produces harder film; exhibits

Chemical resistance

| Immersion tests 12-16 mils; Cured 7-10 days @ R.T. | | |
|---|-----------------|-----|
| Formulation | 1 | 2 |
| | Parts by weight | |
| Araldite® 6010 | 100 | — |
| XU 283 | 70 | — |
| "1" Type Epoxy Resin | — | 100 |
| Conventional Polyamide | — | 54 |
| Weeks to failure (1 Year Test) | | |
| Tap water | >52 | 8 |
| Deionized water | >52 | 8 |
| Sea water | >52 | >52 |
| 50% NaOH | >52 | >52 |
| 10% NH ₄ OH | >52 | 1 |
| 10% H ₂ SO ₄ | >52 | 2 |
| 10% HCL | >52 | 1 |
| Unleaded gas | >52 | >52 |
| Diesel fuel | >52 | >52 |
| Skydrol® 500B* | >52 | 8 |
| Heptane | >52 | >52 |
| Xylene | >52 | 16 |
| MEK | 12 | 1 |
| Isopropanol | >52 | 26 |
| 50% Ethanol/H ₂ O | >52 | 8 |

Note >52=Unaffected after 1 year.

Substrate: Sandblasted hot rolled steel

*Registered trademark of Monsanto Industrial Chemicals Co.

better chemical (see chart), corrosion and abrasion resistance; and can provide excellent mechanical properties, especially adhesion. Add all this to the high solids content of XU 283 and its elimination of sweat-in time, and you can understand why initial response from formulators has been overwhelmingly enthusiastic.

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Education—Key to Preserving a Prime Asset

Promoting educational activities has long been a priority item on the Federation agenda, and some current efforts in this regard are worth noting.

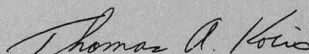
FSCT scholarship funding has been raised to a total of \$22,000 for the 1985-86 academic year. These funds will be shared by six schools (North Dakota State University, Eastern Michigan University, Kent State University, University of Detroit, University of Missouri—Rolla, and University of Southern Mississippi) and used as grants-in-aid for students enrolled in their coatings technology programs, with preference given to qualified scholarship applicants who are children of Federation members.

Additionally, an Ad Hoc Committee is currently investigating the possibility of establishing a Federation Chair at one or more universities, to help upgrade and expand the faculty team serving the coatings program.

And the newly-formed Professional Development Committee is initiating studies to provide for the continuing education of Federation members, as well as to attract needed new talent into the coatings industry.

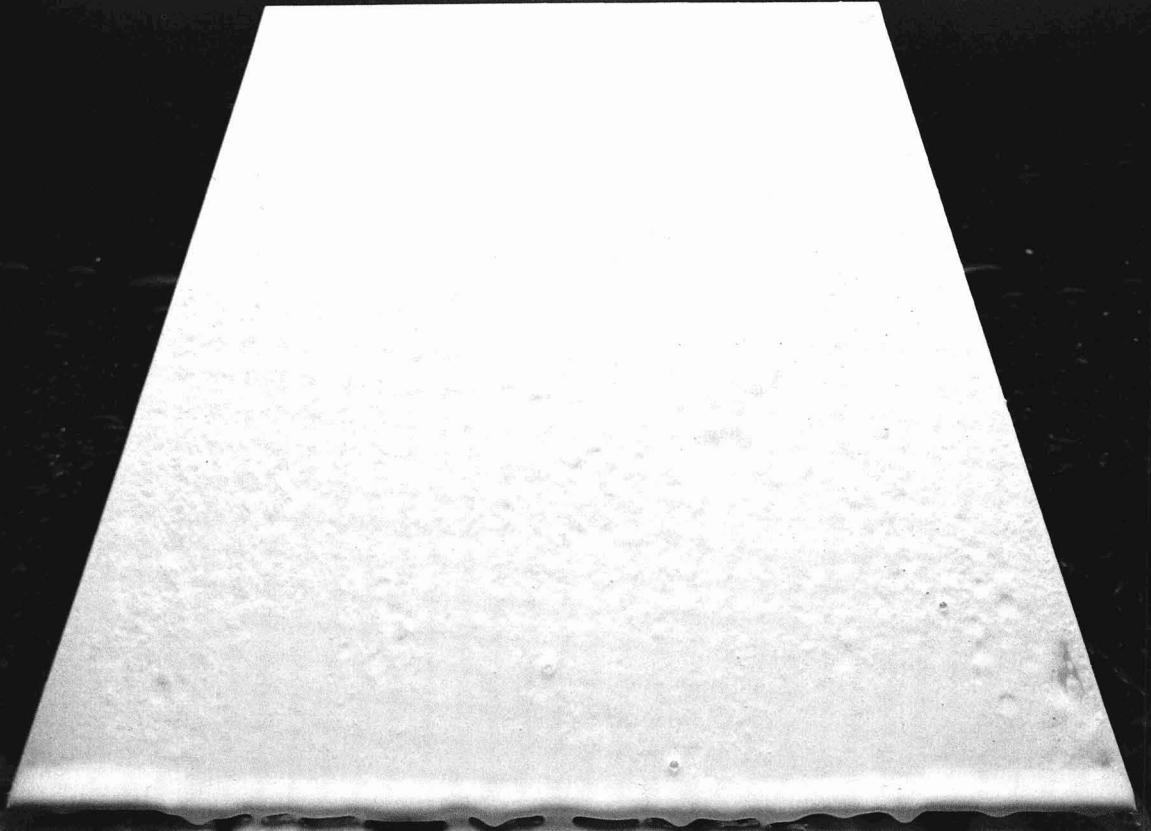
Meanwhile, work continues on development of a totally new Federation Series on Coatings Technology. The original Series, dating back to 1964, has served as a valuable teaching resource, but the many changes which have taken place in the industry underscore the need for the new booklets, the first of which are scheduled for publication early in 1986.

These efforts continue the Federation commitment to serving the educational needs of coatings personnel, for people are our industry's most important asset.



Thomas A. Kocis
Contributing Editor

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challenged traditional roof
mastics to resist moisture.
And they ran.**



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Rhoplex® EC-2218 after 5 minutes dry-time.

Abstracts of Papers in This Issue

PREDICTION OF THE SERVICE LIFE OF COATINGS ON STEEL. PART I: PROCEDURE FOR QUANTITATIVE EVALUATION OF COATING DEFECTS—J.W. Martin and M.E. McKnight

Journal of Coatings Technology, 57, No. 724, 31 (May 1985)

A new evaluation procedure based on spatial statistical techniques is demonstrated for quantitatively evaluating the degradation state of steel panels protected by an organic coating. Representative results from this procedure are presented. These results include changes in the number, size, and location of defects as a function of time. Attributes of the evaluation procedure are discussed in terms of an ideal evaluation procedure. It is concluded that the procedure (1) is simple to apply; (2) is systematic in its approach; (3) generates quantitative measures of the degradation state of a coated steel panel; and (4) outputs the raw data in a publishable format. Although not proven as yet, strong indications exist that the results of the procedure are reproducible and repeatable. At present, the major drawback of the evaluation procedure is the long time needed for evaluating each panel. Alternatives which could significantly reduce this time are discussed.

PREDICTION OF THE SERVICE LIFE OF COATINGS ON STEEL. PART II: QUANTITATIVE PREDICTION OF THE SERVICE LIFE OF A COATING SYSTEM—J.W. Martin and M.E. McKnight

Journal of Coatings Technology, 57, No. 724, 39 (May 1985)

The applicability of a reliability and life testing procedure is demonstrated for quantitatively predicting the service lives of two coating systems. By subjecting an acrylic and an alkyd to three temperatures and 95% relative humidity, it is experimentally demonstrated that the proposed procedure is capable of quantitatively estimating the maximum service life, at 95% RH over a wide range of temperatures, beyond which a specified proportion, $1-\lambda$, of a nominal coating population survives. Although the coating systems are very different, the same equations appear to be applicable to both systems. This indicates that the analysis might be generally applicable for predicting service lives for a wide variety of coating systems.

PREDICTION OF THE SERVICE LIFE OF COATINGS ON STEEL. PART III: CATEGORIZING THE PERFORMANCE OF COATING SYSTEMS ON THE BASIS OF THEIR CORROSION AND BLISTER PATTERNS—J.W. Martin and M.E. McKnight

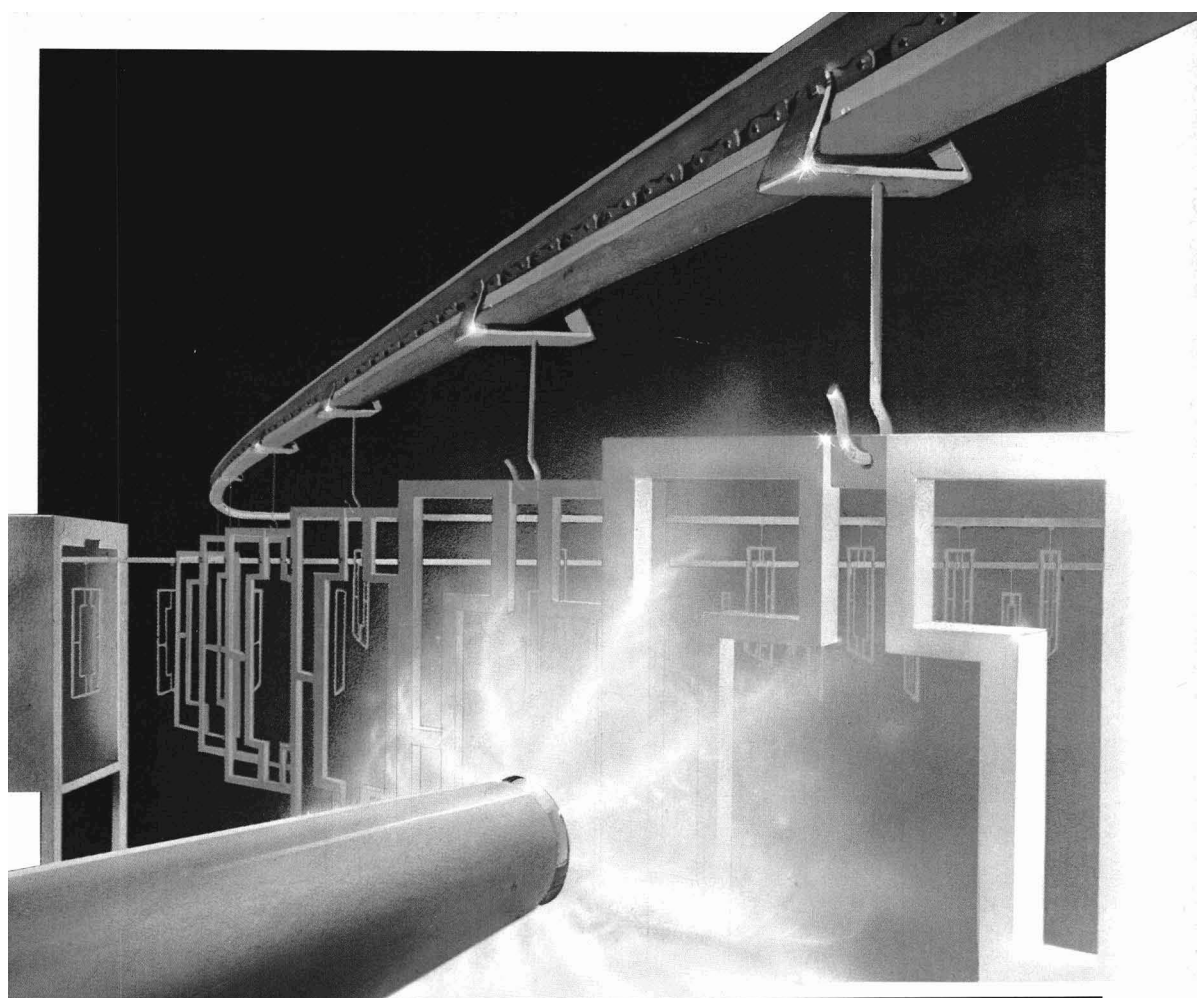
Journal of Coatings Technology, 57, No. 724, 49 (May 1985)

The spatial pattern of defects (corrosion and blister spots) resulting from the aging of coating systems and the scale of clustering of these defects are quantitatively determined for a clear acrylic and a pigmented alkyd coating system. For the acrylic, it is established that defects are randomly distributed over the surface of the steel test panels, whereas for the alkyd, the defects are clustered. For the two coating systems studied, a clear distinction exists between their defect spatial patterns. This suggests that an index based on the defect spatial pattern may be useful for categorizing the in-service degradation of different coating systems.

DISSOLVING POWER OF SOLVENTS AND SOLVENT BLENDS FOR POLYMERS—P.L. Huyskens, et al.

Journal of Coatings Technology, 57, No. 724, 57 (May 1985)

A convenient quantitative definition for the dissolving power, \mathcal{S} , of a solvent for a substance, B, is the difference between the chemical potentials of B in its own phase and in the solution, divided by RT (where R is the gas constant and T is the absolute temperature). When \mathcal{S} is positive, more solute can be dissolved. When \mathcal{S} is negative, phase separation is expected. In the case of polymers, \mathcal{S} can be replaced by \mathcal{S}_m calculated for one repeating unit. According to the prediction method of Hansen using three solubility parameters, \mathcal{S}_m should be proportional to the difference $R_A^2 - 4({}^s\delta_d - {}^p\delta_d)^2 - ({}^s\delta_p - {}^p\delta_p)^2 - ({}^s\delta_h - {}^p\delta_h)^2$ where R_A is the radius of the solute sphere of solubility. In this work a new prediction method based on \mathcal{S}_m is proposed. This method takes into account entropy changes and is based on a more correct treatment of the hydrogen bonds. The new equation giving \mathcal{S}_m contains known characteristics such as the molar volume of the solvent (\bar{V}_s), the molar volume of the repeating unit of the polymer (\bar{V}_m), and the so-called "structuration" factor (b_s), of the solvent, related to the presence or the absence



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Abstracts of Papers in This Issue

(continued)

of H-bond chains. This equation also contains a few parameters that must be measured (1) for the solvent: a modified solubility parameter $^s\delta'$, determined from the solubility of solid alkanes in the given solvent; and (2) for the polymer: its modified solubility parameter $^p\delta'$, a characteristic constant, A , and the stability constants, K , of the hydrogen bonds the polymer can form with the main different groups of solvents.

The predictions of the two methods are compared with the experimental data for three polymers—PVAC, PMMA, and PEMA—in some 25 solvents and their binary blends.

EQUATIONS FOR CALCULATING HOMOLOG SOLUBILITY PARAMETERS. II: SIMPLE EQUATIONS BASED ON CHAIN LENGTH—C.H. Fisher

Journal of Coatings Technology, 57, No. 724, 69 (May 1985)

Linear equations are provided for correlating homolog solubility parameters with numbers of carbons, molecular weights, molar volumes, refractive indices, and boiling points. The linear equations can be used to evaluate some published solubility parameters and to estimate new ones. In some instances, logarithmic and reciprocal equations are superior to the linear equations. The limiting (or infinite-length n -alkane) solubility parameter may be 8.2H or 16.8 (S.I.).

USE OF A FLOCCULATION GRADIENT MONITOR FOR QUANTIFYING TITANIUM DIOXIDE PIGMENT DISPERSION IN DRY AND WET PAINT FILMS—D.J. Rutherford and L.A. Simpson

Journal of Coatings Technology, 57, No. 724, 75 (May 1985)

The degree of pigment flocculation in a dry paint film can be determined by measuring the amount of infrared radiation which is back-scattered as a function of film thickness. This results in the calculation of flocculation gradient. However, the use of this technique has been limited by the necessity for a relatively expensive spectrophotometer. A simple and inexpensive apparatus for

measuring flocculation gradient, which is referred to as a Flocculation Gradient Monitor, has therefore been designed, built, and tested. The advantages and disadvantages of the use of flocculation gradient in practice are discussed.

In addition, pigment flocculation in the wet paint (or millbase) has been quantified using a similar principle to determine back-scatter measurement (R_w^{40}) for only one wet film thickness. For this purpose, a wet cell, 40 μm thick, is used to encapsulate the paint. Since the technique is quick, it is suitable as an online quality control test which can be used at any stage of a paint manufacturing process.

Papers to be Featured In the June Issue

"What the Paint Formulator Should Know About Emulsion Polymerization"—B. Henshaw, McCloskey Varnish Co.

"Kinetics of Crosslinking Using Blocked Reagents and Blocked Catalysts"—W.J. Muizebelt, Akzo Research

"Slime Films on Antifouling Paints: Short-Term Indicators of Long-Term Effectiveness"—M.G. Robinson, B.D. Hall, and D. Voltolina, Royal Roads Military College.

"New Isoindoline Pigments for High Quality Applications"—J. von der Crone, Ciba-Geigy Ltd.

"Viscosity of Oligomer Solutions"—Z.W. Wicks, Jr., et al., North Dakota State University.

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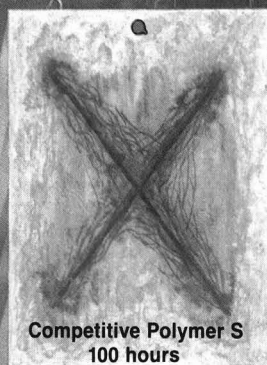
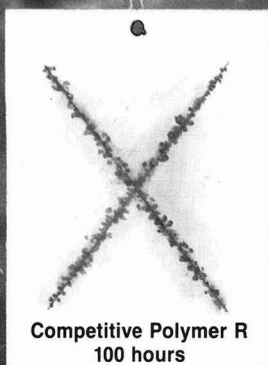
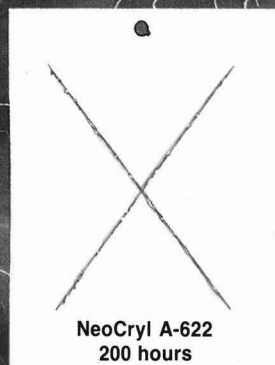
siding refinish.

NeoCryl A-622 is precoalesced so it's ready to go to work. Formulators tell us, "We love it. It's so easy to use in our plant."

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You see what makes us different



Ruth Johnston-Feller, Color Scientist, Will Present 1985 Mattiello Lecture At Federation Annual Meeting in St. Louis

The Federation of Societies for Coatings Technology is pleased to announce that color scientist Ruth Johnston-Feller will present the Joseph J. Mattiello Memorial Lecture at the 63rd Annual Meeting of the Federation to be held at the Cervantes Convention Center, St. Louis, on October 7 to 9, 1985.

Mrs. Johnston-Feller will speak about her work on paint film exposure, "Reflections on the Phenomenon of Fading," at the morning session on Wednesday, October 9.

The lecture commemorates the contributions of Dr. Mattiello, who did much to expand the application of the sciences in the decorative and protective coatings field. Dr. Mattiello, who served as President of the Federation, 1943-44, was Vice-President and Technical Director of Hilo Varnish Corporation, Brooklyn, NY, when he died in 1948.

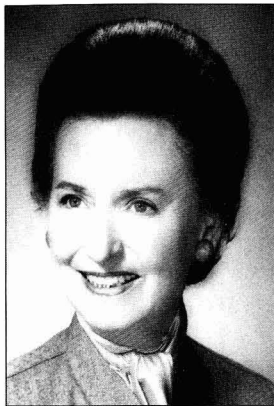
The lecturer is chosen from among those who have made outstanding contributions to science and is selected to present a paper on a phase of chemistry, engineering, human relationships, or other science fundamental to paint, varnish, lacquer, or related protective and decorative coatings.

Early Career

Ruth Johnston-Feller has more than 30 years' experience in industrial color technology. Before joining CIBA-GEIGY in September 1973, she was Director of Application Services of the Color Systems Division of the Kollmorgen Corporation. Prior to joining Kollmorgen in 1967, she was Project Leader for Color Research at the Coatings and Resins Division of PPG Industries, Inc. She was one of the first in America to

introduce instrumental color control in the manufacture of paint.

Author of more than 45 technical articles, Mrs. Johnston-Feller contributed the major chapter on "Color Theory" in the three-volume *Pigment Handbook*, edited by Temple Patton and published by J. Wiley & Sons. She has taught numerous courses on color and the behavior of colorants and has lectured on color science at many universities.



Ruth Johnston-Feller attended Carthage College and is a graduate in Chemistry from the University of Illinois where she worked for the Chemistry Department in the development of spectrophotometric techniques. During World War II, she was associated with the Penicillin Research Project at the U. S. Department of Agriculture's Northern Regional Research Laboratory.

Research Work

Mrs. Johnston-Feller, the former Ruth M. Johnston, is presently consultant in color science to the Research Center on the Materials of the Artist and Conservator at Mellon Institute, Carnegie-Mellon University, Pittsburgh, where she directs the color-science laboratory and the research program on fading of paints and textiles. The Research Center, which receives its basic support from the Andrew W. Mellon Foundation, is directed by her husband, Dr. Robert L. Feller, who, for 35 years, has been engaged in research on new methods and materials for the preservation of artistic and historic works.

Before joining her husband in Pittsburgh in 1975, Miss Johnston was Manager of the Coatings and Col-

orimetry Laboratories of the Pigment Department of CIBA-GEIGY Corp. in Ardsley, NY, where she was responsible for the testing and evaluation of pigments for the coatings industry and for supervision of the Colorimetry Laboratory's work on the application of color technology in the plastics, paint, textile, and paper industries.

In 1970 Ruth Johnston-Feller received the Federation's Armin J. Bruning Award for her outstanding contributions to the science of color. In 1977, and again in 1978, Miss Johnston and her associate at CIBA-GEIGY, Dennis Osmer, were awarded the Dry Color Manufacturer's Award for the year's outstanding publications in the *JOURNAL OF COATINGS TECHNOLOGY* on the subject of color science as applied to the paint and coatings field. Their two award-winning publications concerned the quantitative evaluation of various aspects of appearance changes of paints following exterior exposure. In 1984, Mrs. Johnston-Feller received the Inter-Society Color Council's Macbeth Award in recognition of her outstanding recent contributions to the subject of color.

Affiliation with the work of the Center at Mellon Institute has given Mrs. Johnston-Feller the opportunity to expand her research interests in the evaluation and quantification of colorant fading. In a series of papers with Robert Feller and Catherine Bailie, she has documented the way that both transparent and opaque paints fade in a predictable manner. It is this latter work which she will discuss in her presentation on October 9, summarizing these results and presenting some of her recent and as yet unpublished findings.

Professional Organization Activities

Mrs. Johnston-Feller has given many years of dedicated service to the Federation. A former member of the Board of Directors, she has served as a member of the Publications Committee and of the Editorial Review Board of the *JOURNAL*

(Continued on page 20)

Now ... High Gloss and Corrosion Resistance in a Waterborne Paint for Metal around the House.

MAINCOTETM HG-54

acrylic polymer

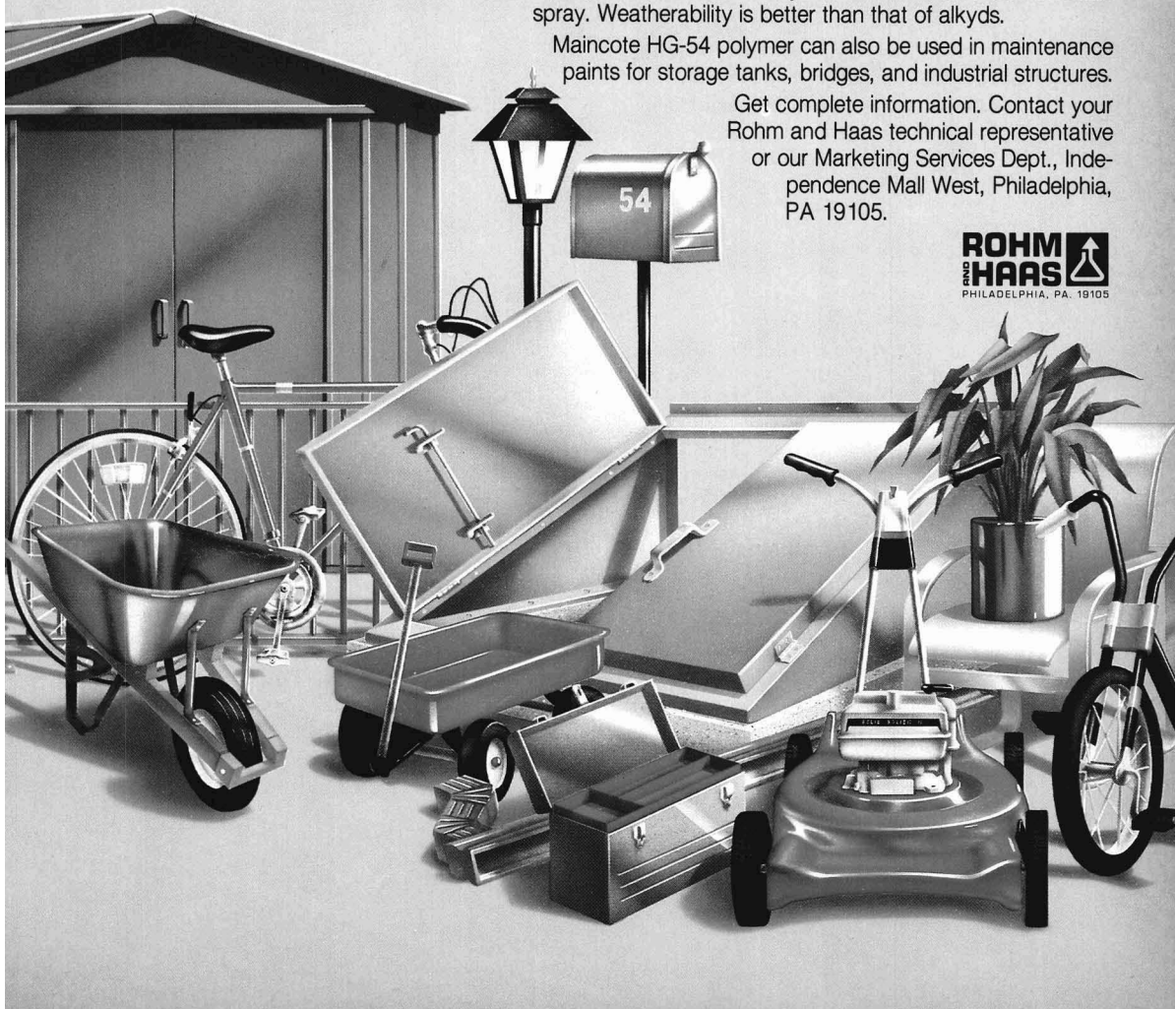
High gloss and corrosion protection.
Have both in your waterborne paint for metal.

Use Maincote HG-54 acrylic polymer. For primers and topcoats that also exhibit outstanding weatherability, gloss and tint retention, and resistance to chemicals and solvents. Direct-to-metal adhesion is excellent, even on galvanized steel surfaces . . . and under damp conditions. Properly formulated 3-coat systems withstand 3,000 hours salt spray. Weatherability is better than that of alkyds.

Maincote HG-54 polymer can also be used in maintenance paints for storage tanks, bridges, and industrial structures.

Get complete information. Contact your Rohm and Haas technical representative or our Marketing Services Dept., Independence Mall West, Philadelphia, PA 19105.

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COLORSHIP is COMMITMENT

In 1852 the American Clipper-ship "Comet" encountered a severe hurricane off the coast of Bermuda. A lesser ship would

not have survived that storm. Through know-how and COMMITMENT, Pfizer has been successfully weathering similar storms in American industry for over a century. Despite the challenges of recession, inflation, regulation and shortages, Pfizer has maintained its COMMITMENT to leadership in Pigment Technology. Through unsettling times, Pfizer has:

- Expanded and modernized its three major manufacturing facilities
- Introduced new innovative products such as Pfferrisperse™ Slurry, RO-2097 Light Shade Kroma® Red Oxide, Easy Dispersing Red and Yellow Pigments, and others
- Added new technical service personnel and laboratories
- Supplemented its direct sales force with a highly responsive LTL distributor network

No one knows what future economic storms may be on the horizon. However, no matter what the climate, Pfizer is committed to meeting the needs of its Pigment customers. *Creative Colorship For Over a Century* represents the continuous pursuit of excellence in Pigment Technology. It takes total COMMITMENT. But at Pfizer, there is no other way.



Pfizer

**MINERALS, PIGMENTS
& METALS DIVISION**

Dept. 3C-1

235 E. 42nd Street, New York, N.Y. 10017

U.S. Sales of Synthetic Latex Polymers Reaches \$2.1 Billion in 1984

Sales of synthetic latex polymers in the U.S. during 1984 reached nearly 2.9 billion dry lb, valued at more than \$2.1 billion. These figures were released in a new survey issued by C. H. Kline & Co., marketing consultants in Fairfield, N.J. These polymers are supplied as water emulsions or colloidal dispersions and are critical raw materials in the manufacture of a wide variety of nondurable products, including coatings, adhesives, paper, and others. The five major latex polymer types—styrene-butadiene, acrylics, vinyl acetate homopolymer, vinyl-acrylics, and vinyl acetate-ethylene—together accounted for almost 89% of the total pounds and over 85% of the dollar value. More than twelve additional minor products made up the balance of volume consumed.

Latex consumption is concentrated in a relatively few major industries. Paint and coatings production leads all areas in latex use, accounting for over 23% of domestic consumption in 1984. The adhesive, paper, carpet, textile, and nonwoven industries follow in declining order, and together represent approximately 60% of all consumption. At least fourteen other consuming industries account for the remaining volume.

Patterns of latex use vary considerably within the different industries. Each consuming industry has its own major and unique requirements. However, with the large number of grades typically available for each major polymer type, interpolymer competition is frequently intense. This complex competitive relationship among latex types is determined by such grade factors as solids content, pH, particle size, chemical/mechanical stability, comonomer flexibility, and chemical derivatization. Furthermore, the situation has become increasingly complicated by the growth of such specialized, high-performance latices as polyvinyl chloride, styrene-acrylics, neoprenes, polyurethanes, and others.

The competitive positions of styrene-butadiene, acrylic, and polyvinyl acetate latices are likely to change as a result of shifts in government regulatory policy, changing feedstock availabilities, and the emergence of acceptable alternative latex polymers.

The direction of future prices for synthetic latex polymers is influenced by many factors. Principal among these are the price of crude oil and natural

gas, from which monomer feedstocks are derived. The comparative prices of latex polymers will depend largely on any upcoming changes in the relationship between crude oil and natural gas prices.

Interpolymer competition will also result from product technology. For years, the major acrylic latex manufacturers have promoted the excellent qualities of acrylic latex systems in paints and other major end uses. However, newer, less costly copolymer and terpolymer products are now gaining greater acceptance as good performance substitutes. Many of these technical advances are being made in vinyl-acrylics.

The outlook for latex polymers will be influenced by many factors, including raw material prices, technological developments, government regulations, and consumer preferences. However, overall growth is projected to average 3% a year through 1988 when demand will reach over 3.2 billion dry pounds. The most rapidly growing major latices will include vinyl acetate-ethylenes, styrene-acrylics, and acrylics. Products projected to grow

at below average rates include styrene-butadiene, polyvinyl acetate, and vinyl-acrylic latices.

Major consuming industries where demand is projected to rise at above average rates include printing inks, adhesives, textiles, and caulks and sealants. Slower growth will be seen in carpet, paint and coatings, paper, and nonwovens. The only industry where latex consumption is expected to decline is leather.

The market for latex polymers in the U.S. was served by about forty suppliers of commercial significance in 1984. The majority of these firms manufactured only a few of the many polymer types available.

The Kline report is based on an in-depth study of the various latex polymers, consuming industries, and suppliers that make up the domestic market. Business level projections through 1988 are supported by a full evaluation of the future outlook and opportunities in latex polymers. The survey is available on subscription from Charles H. Kline & Co., 330 Passaic Avenue, Fairfield, NJ 07006.

USAF Seeks Coatings for Rockets

The D/L Laboratories, New York, NY, under contract with the U.S. Air Force, is actively seeking coatings which will either prevent corrosion of metal and composite motor cases or the migration of moisture and organic liquids within solid propellant air launched rockets.

Corrosion inhibiting coatings should be durable, and designed to inhibit corrosion of metals and composite materials in marine environments.

Migration inhibiting coatings should adhere to elastomers, such as EDPM, hypalon, phenolic SBR, urethanes, or composite material resins. In addition, they should prevent migration of, as well as be resistant to: moisture; plasticizers, such as DOA,

DOS, IDP; and nitroglycerine; curing agents such as IPDI, HMDI, and BITA; and catalysts such as catacene and ferrocene.

All coatings should be stable and effective at temperatures from -65° to $+145^{\circ}$ F, in a vacuum, under vibration during flight, and in humid environments.

The Air Force prefers that these coatings be made of non-hazardous, readily available raw materials, easily processed in standard equipment, capable of application by spray or flow coat, and be reasonable in cost. Color is immaterial.

Samples, with any available data, should be sent to: Saul Spindel, D/L Laboratories, 116 East 16th St., New York, NY 10003.



**Hats off to consistent quality.
Our new lead chromate pigments plant
will cover your needs for years to come.**



We've put \$20 million into expanding and improving our Glens Falls, NY, facility so you can be sure of consistent-quality lead chromate pigments whenever you need them.

We installed the most modern process technology and equipment for the production of these pigments. And we built a plant for making our own litharge. As a result, you can expect the consistency, the quality and the quantity you need, well into the future.

In addition to giving us more capacity, these facilities are an industry model of employee and environmental protection, in full compliance with current and anticipated regulations.

Our commitment to consistently high quality lead chromate pigments doesn't end there. A network of strategically located warehouses insures that you get what you need promptly. And a team of technical sales and service people, who deal only with pigments, provides the expert support you need.

For additional information—and a free booklet on our pigments—call 800 431-1900 (in New York, 914 347-4700). Or write Pigments Department, CIBA-GEIGY Corporation, Three Skyline Drive, Hawthorne, NY 10532. To place an order, call 800 431-2777 (in New York, 914 347-4724).

CIBA-GEIGY

Johnston-Feller to Present Mattiello Lecture

(Continued from page 14)

OF COATINGS TECHNOLOGY, and continues to work on the Definitions Committee. She served for several years as a member of the Board of Trustees of the Paint Research Institute. Currently, she is a member of the Federation's Professional Development Committee.

Much of her service to the Federation was associated with color science. For many years she was Chairman of the Federation's Inter-Society Color Council Committee and Chairman of the FSCT delegation to the Inter-Society Color Council, as well as Chairman of the Bruning Award Committee. She assisted the FSCT Annual Meeting Program Committees, arranging many sessions of particular interest to the ladies as well as to the men of the Federation. She coordinated the work of the ISCC Committee of the Federation in contributing definitions of more than 400 color terms in the *Paint/Coatings Dictionary*, 1978,

Cabot Corp. Names New Distributors

The Cab-O-Sil® Division of Cabot Corporation, Tuscola, IL, has appointed Pacific Coast Chemicals Co. as their distributor of its specialty chemical products for the entire West Coast region. Pacific Coast Chemicals is headquartered in Berkeley, CA.

a section that was published separately in 1979 as the *Glossary of Color Terms*. She is past Chairman of the Problems Committee of the Inter-Society Color Council.

In addition to the Federation and the Inter-Society Color Council, Mrs. Johnston-Feller is a member of numerous other professional Societies: American Chemical Society, American Society of Testing and Materials, American Association of Museums, Optical Society of America, the American Institute for Conservation of Historic and Artistic Works, and the International Institute for Conservation of Historic and Artistic Works. She is listed in *American Men and Women of Science*.

Engelhard Completes Purchase of Freeport Kaolin

Engelhard Corporation, Edison, NJ, has completed the purchase of Freeport Kaolin Co., Gordon, GA, from Freeport-McMoRan Inc. Freeport Kaolin Co. is a producer of performance minerals primarily for the paper, paint, and plastics industry.

According to L. Donald LaTorre, Senior Vice-President for the Performance Minerals Group, Specialty Chemicals Div. of Engelhard, the added manufacturing, minerals reserves, products, and

Special Discount Fares Available from TWA To Annual Meeting

Special arrangements have been made with TWA to offer discounted fares within the U.S. to/from St. Louis, MO, for the October 7-9 Annual Meeting and Paint Show at the Cervantes Convention Center. These special fares are available only when you call the unlisted toll-free number (800-325-4933); in Missouri only, call (800-392-1673). Be sure to ask for lowest fare available! You must give the FSCT Convention number which is:

#9911077

technologies will allow Engelhard to expand its product offering and strengthen its presence in key domestic and international markets, notably in Brazil and Australia.

Premier Mill Begins Construction Of New Manufacturing Plant

Premier Mill Corp., New York, NY, has announced the construction of a new manufacturing plant to be located in Reading, PA. The facility will be used to manufacture and assemble the company's full line of high speed mixing, dispersing, and grinding equipment.

The engineering staff, purchasing department, and technical service group will also operate from offices in the building. Premier's testing and customer demonstration laboratory will be incorporated and expanded in this location.

PPG Acquires Ladywood Business

PPG Industries, Pittsburgh, PA, has purchased the Ladywood Business Group of International Paint PLC, a subsidiary of Courtaulds PLC of the United Kingdom.

Producers of automotive and industrial coatings, Ladywood has one plant in Birmingham, England. The business of the new acquisition will be conducted through a wholly-owned subsidiary, PPG Industries (UK), Ltd.

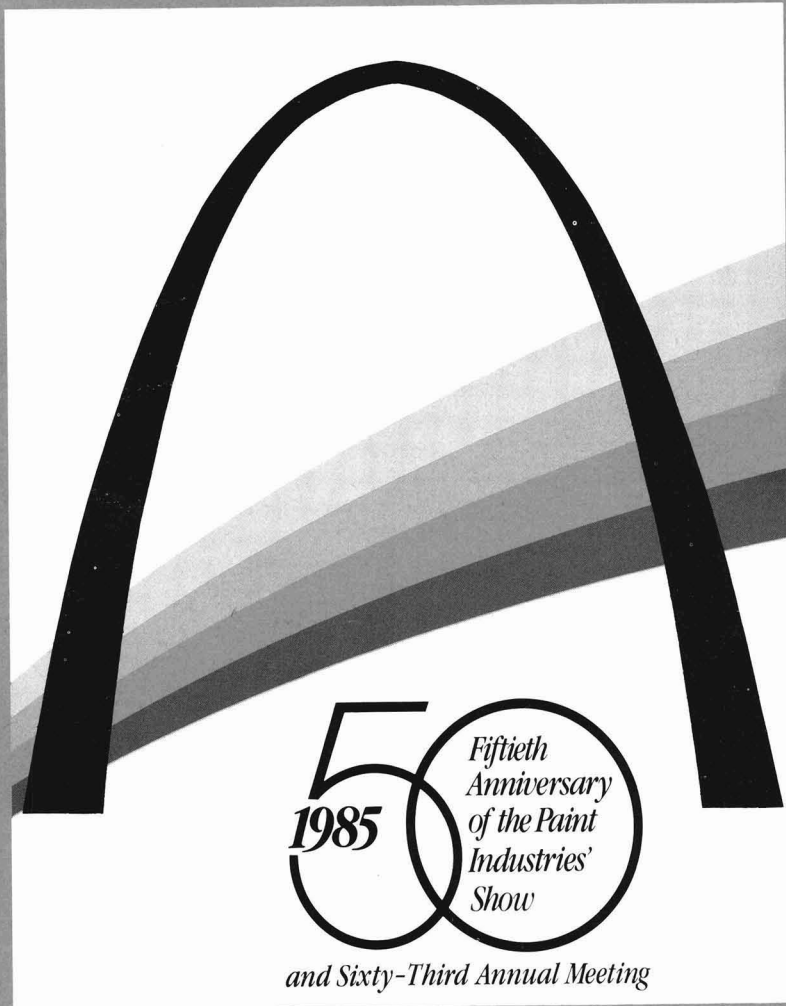
THE BIG



CERVANTES CONVENTION CENTER
ST. LOUIS, MISSOURI OCTOBER 7-9

FEDERATION OF SOCIETIES FOR COATINGS TECHNOLOGY

Housing and Advance Registration Forms



**CERVANTES CONVENTION CENTER
ST. LOUIS, MISSOURI OCTOBER 7-9**



**1985 Annual Meeting
Paint Industries' Show
October 7, 8, 9
Cervantes Convention Center
St. Louis, Missouri**

TO OUR MEMBERS AND FRIENDS:

With much pleasure, I invite all those associated with the coatings manufacturing industry to attend the Federation's 63rd Annual Meeting and 50th Paint Industries' Show in St. Louis, October 7-9.

In 1972, the Federation marked the 50th Anniversary of its founding. In 1985, we reach another milestone with the Golden Jubilee of the Paint Show, the largest and finest exhibit of materials, equipment, and services for paint and coatings manufacturers.

The "Big 50" Paint Show will indeed be that—and another record-breaker.

Matching the Show in quality of content will be the Program Sessions under the chairmanship of Joseph A. Vasta. And how significant and timely



is the theme: "Coatings R&D: Today's Investment in Tomorrow."

I am pleased that our 1985 convention will get underway on a high note with the Monday morning Keynote Address by John P. McAndrews, Group Vice-President, F&F Products Dept., DuPont Co.

Come join us in St. Louis for the Big Show, the Big Program, and a Learning Experience well worth your time.

Joseph A. Bauer
President, FSCT

**FEDERATION OF SOCIETIES FOR COATINGS TECHNOLOGY
1985 ANNUAL MEETING AND PAINT INDUSTRIES' SHOW
CERVANTES CONVENTION CENTER, ST. LOUIS, MISSOURI
MONDAY THROUGH WEDNESDAY, OCTOBER 7, 8, 9**

The Combined Annual Meeting and Paint Industries' Show is a Major Educational Activity of the Federation. This Significant Coatings Industry Event Consists of Three Days of Technical Program Sessions and Exhibits, Running Concurrently.

**"COATINGS RESEARCH AND DEVELOPMENT:
TODAY'S INVESTMENT IN TOMORROW"**

The outstanding program presentations being arranged for the Annual Meeting Program will be centered about the theme—"Coatings R&D: Today's Investment in Tomorrow." The theme emphasizes the need to shape, guide, and protect the future through innovative coatings science and technology. Investments in coatings R&D will ensure continued ability to provide quality products to meet today's requirements and anticipate tomorrow's challenges.

**"BIG 50" PAINT SHOW WILL FEATURE
PRODUCTS/SERVICES OF 220 EXHIBITORS**

The Paint Industries' Show—best known and largest exhibit of products and services used in the formulation, testing, and manufacture of paints and related coatings—will be another record-breaker in both size and number of exhibitors.

Exhibiting in the Show will be more than 220 companies which manufacture and supply a wide variety of raw materials, production equipment, laboratory apparatus & testing devices, containers, and a variety of services for the coatings manufacturing industry. The list of current exhibitors is included in this brochure.

Key personnel from coatings manufacturers in the U.S., Canada, and several other countries attend each year. The Paint Show gives them the opportunity to learn of the latest developments in the industry and to discuss them with the top technical/sales staffs of the exhibitors.

Show hours will be: Monday—12:00-5:30; Tuesday—9:30-5:30; Wednesday—9:30-3:00.

**FEDERATION BOARD
TO MEET ON SUNDAY**

The Federation's Board of Directors meeting will be held on Sunday, October 6, in the Marriott Hotel.

HOTELS AND RESERVATIONS

Thirteen hotels have reserved blocks of rooms for the Federation. A map showing the location of the hotels and a schedule of rates are included in this brochure.

All reservations will be processed by the St. Louis Convention and Visitors Bureau. The Bureau will send you an acknowledgment, noting the hotel to which you have been assigned. (Bureau telephone # 314-421-1166). The confirmation of your reservation will come directly from the hotel, to whom you must direct all inquiries.

Phone numbers of the hotels (Area Code 314) are:

| | | | |
|------------------------|----------|------------------------|----------|
| Marriott Pavilion | 421-1776 | Holiday Inn Riverfront | 621-8200 |
| Sheraton St. Louis | 231-5100 | Mayfair | 231-1500 |
| Bel Air Hilton | 621-7900 | Omni-Union Station | 241-6664 |
| Best Western | 421-4727 | Radisson St. Louis | 421-4000 |
| Clarion | 241-9500 | Rodeway Inn | 534-4700 |
| Embassy Suites | 241-4200 | University Plaza | 534-8300 |
| Holiday Inn Market St. | 231-3232 | | |

Requests for accommodations at the Marriott Pavilion or the Sheraton St. Louis will be limited to five rooms per company. A parlor counts as one room.

**FEDERATION
OF SOCIETIES
FOR COATINGS
TECHNOLOGY**

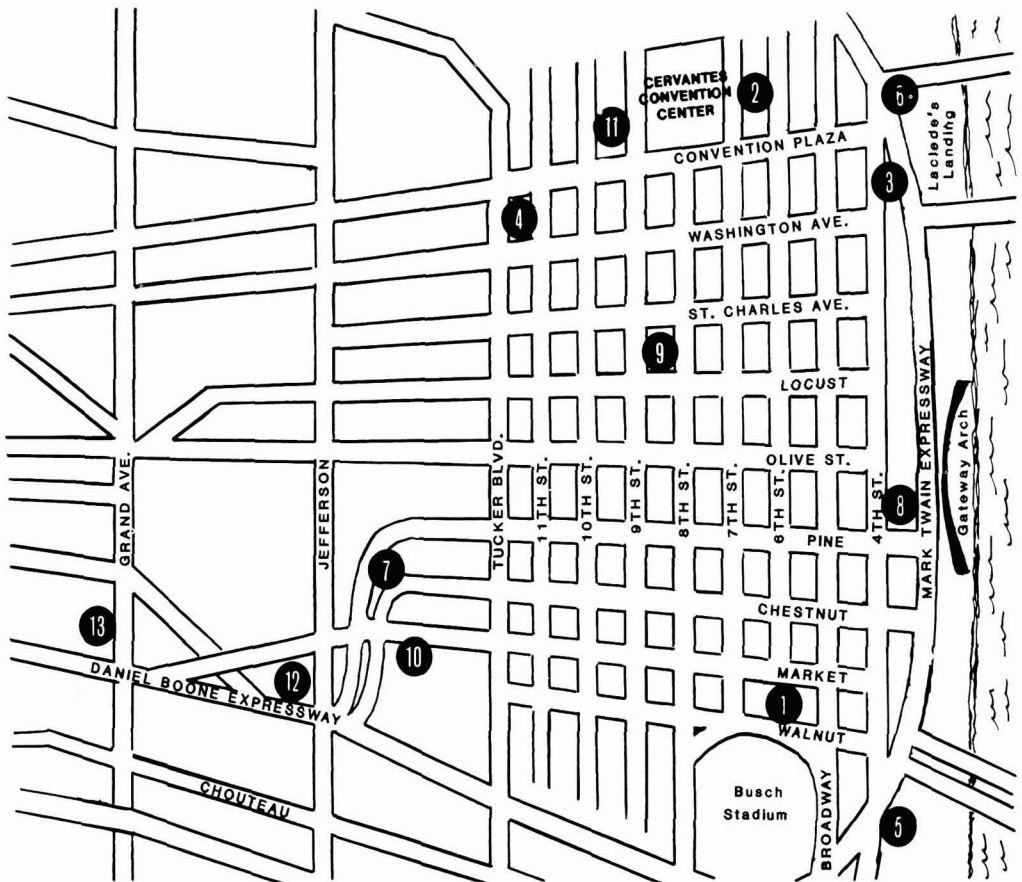


**ANNUAL MEETING AND
PAINT INDUSTRIES' SHOW**

| No. on Map | Hotel | Singles | Doubles/ Twins | Parlor & 1 Bedroom | Parlor & 2 Bedrooms |
|------------|---------------------------|---------|-------------------|-----------------------|------------------------|
| (1) | †Marriott Pavilion | \$74 | \$86 | \$185-\$295 | \$225-\$375 |
| (2) | †Sheraton St. Louis | 74 | 86 | 275 | |
| (3) | Bel Air Hilton | 72 | 84 | 175 | 350 |
| (4) | Best Western St. Louisian | 46 | 54 | | |
| (5) | Clarion | 72 | 84 | 195-315 | 325-405 |
| (6) | Embassy Suites | 80 | 90 | | |
| (7) | Holiday Inn Market St. | 54 | 61 | | |
| (8) | Holiday Inn Riverfront | 70 | 80 | | |
| (9) | Mayfair | 59 | 69 | | |
| (10) | Omni—Union Station | 83 | 96 | 250 & up | 375 & up |
| (11) | Radisson St. Louis | 65 | 81 | 110 | 380-450 |
| (12) | Rodeway Inn | 48 | 54 | | |
| (13) | University Plaza | 49 | 55 | | |

* All room rates are subject to a City and State Tax of 9.75%.

† Requests for accommodations at the Marriott Pavilion or the Sheraton St. Louis will be limited to five rooms per company. A parlor counts as one room. Additional reservations will be assigned to other cooperating hotels.



**FSCT 1985 ANNUAL MEETING AND PAINT INDUSTRIES' SHOW
CERVANTES CONVENTION CENTER, ST. LOUIS, MISSOURI
OCTOBER 7, 8, 9 (Monday, Tuesday, Wednesday)**

APPLICATION FOR HOTEL ACCOMMODATIONS



**MAIL TO: Fed. Socs. Coatings Tech.
1315 Walnut St.—Dept. H
Philadelphia, PA 19107**

Please indicate below the type of accommodations requested and choice of hotels. All reservations will be processed by the Housing Bureau of the St. Louis Convention & Visitors Bureau. Hotel assignments will be made in accordance with prevailing availability. The Housing Bureau will send you an acknowledgment, noting the hotel to which you have been assigned. (Bureau telephone # 314-421-1166). The confirmation of your reservation will come to you directly from the hotel, to whom you must direct all inquiries (phone numbers in this brochure).

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

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

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

NAMES OF ROOM OCCUPANTS AND DATES OF ARRIVAL DEPARTURE

| Type of Room | Name | Dates | |
|--------------|------|--------|--------|
| | | Arrive | Depart |
| | | | |
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Please Type Additional Reservations on a Separate Sheet and Attach to This Form

SEND CONFIRMATION FOR ALL RESERVATIONS TO:

Name _____

Company _____

Address _____

City _____ State or Province _____

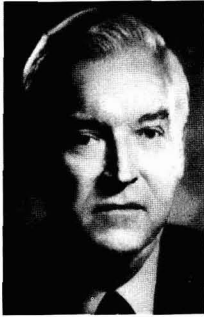
Country _____ Mailing Code _____

Telephone _____

Note: Requests for accommodations at the Marriott or Sheraton will be limited to five rooms per company. A parlor counts as one room.

**JOHN P. McANDREWS, OF DUPONT,
WILL GIVE KEYNOTE ADDRESS**

The Federation is pleased and honored to announce that *John P. McAndrews*, Group Vice-President—Finishes & Fabricated Products, DuPont Co., will present the Keynote Address at the Monday morning opening session. Mr. McAndrews joined the DuPont Co. in 1947 as a chemical engineer at the Marshall Lab. in Philadelphia. In succeeding years he advanced through several posts within the F & FP Dept. He was transferred to Remington Arms in 1966 and elected President in 1979. He was named Vice-President of the F & FP Dept. in 1982 and assumed his present position in 1983.



**ANNUAL FEDERATION LUNCHEON
TO BE HELD ON WEDNESDAY**

The Annual Federation Luncheon will be held on Wednesday in the Sheraton. It will feature a guest speaker and the presentation of the Paint Show, Heckel, Roon, and other awards.

**SPOUSES ACTIVITIES TO BEGIN
WITH MONDAY AFTERNOON SOCIAL**

A get acquainted wine and cheese social in the Convention Center will open the Spouses Program on Monday afternoon. There will be continental breakfasts on Tuesday and Wednesday morning and a special tour with lunch on Tuesday.

**TWA NAMED OFFICIAL AIRLINE
FOR ANNUAL MEETING AND PAINT SHOW**

The Federation has appointed TWA as the official airline for the convention in St. Louis. For flights within the United States, phone the toll-free number: 800-325-4933 (in Missouri 800-392-1673). You must give the Federation's account number: 9911077. Be sure to ask for the lowest fare available. Applicable dates of travel for the special fare are October 4–12, 1985.

HOST COMMITTEE

The Federation's two Societies in Missouri (St. Louis and Kansas City) will serve as the official hosts for the Annual Meeting and Paint Show. The General Chairman is Howard Jerome, of Spatz Paint Industries, Inc. Subcommittee Chairmen are: Spouses—Mrs. Howard (Gene) Jerome; Program Operations—John Folkerts, of Future Coatings; Registration Area—Joseph W. Wrobel, Jr., of Ciba-Geigy Corp.; Information Services—William Reckel, of Amteco, Inc.; and Liaison—Nick Dispensa, of Davis Paint Co.

PROGRAM COMMITTEE

Joseph A. Vasta, of the DuPont Co., F&FP Dept., Wilmington, DE, is the Chairman of the Federation's Program Committee. The Vice-Chairman is Percy E. Pierce, of PPG Industries, Inc., Allison Park, PA. Other members of the committee are: Taki Anagnostou, of AKZO (Wyandotte) Paint Products, Inc., Troy, MI; William H. Ellis, of Chevron Research Co., El Segundo, CA; Richard Eley, of Glidden Coatings & Resins Div., Strongsville, OH; Stanley LeSota, of Rohm and Haas Co., Spring House, PA; John S. Ostrowski, of Valspar Corp., Minneapolis, MN; David Richie, of Midland Div., Dexter Corp., Waukegan, IL; and James Lee, of Lanchem Corp., E. St. Louis, IL.



Shown above is the famous Gateway Arch. In the background is Busch Stadium.

1985 Paint Industries' Show

Current List of Exhibitors

- Aceto Chemical Co., Inc.
Advanced Coating Technologies, Inc.
Air Products and Chemicals, Inc.
Akzo Chemie America/Interstab Chemicals, Inc.
Alcan Powders & Chemicals
Allied Industrial Tank
C.M. Ambrose Co.
American Chemical Society
AMF Cuno, Gen. Filter Prod. Div.
Angus Chemical Co.
Anker Labelers Corp.
Applied Color Systems, Inc.
Arco Chemical Co.
Aries Software Corp.
Ashland Chemical Co., IC&S Div.
Atlas Electric Devices Co.
- B.A.G. Corp.
BASF Wyandotte Corp.
Battelle Memorial Institute
Bausch & Lomb, Inc.
Beltron Corp.
Berol Chemicals, Inc.
Blackmer Pump Div., Dover Corp.
Bonar Industries, Inc.
Bowers Process Equipment, Inc.
Brookway Standard, Inc.
Brookfield Engineering Laboratories, Inc.
Buckman Laboratories, Inc.
Buhler-Miag, Inc.
Bulk Lift International, Inc.
Burgess Pigment Co.
Byk-Chemie USA
- Cabot - Cab-O-Sil Div.
Caigon Corp., Div. of Merck & Co., Inc.
Cargill, Inc.
CasChem, Inc.
Celanese Chemical Co.
Celanese Specialty Resins
CEM Corp.
Certified Equipment & Mfg. Co.
Chemische Werke Huls AG
Chemtech, Inc.
Chevron-American Gilsonite
Chicago Boiler Co.
Clawson Tank Co.
Color Corp. of America
Columbian Chemicals Co.
Commercial Filters
Consolidated Packaging Machinery/Pfandler
Continental Fibre Drum Co.
Cook Paint & Varnish Co.
Cordova Chemical Co.
Cosan Chemical Corp.
Cray Valley Products, Inc.
Cyprus Industrial Minerals Co.
- Daniel Products Co.
DataLogix Formula Systems, Inc.
DeFelsko Corp.
Degussa Corp.
University of Detroit
Diamond Shamrock Chemical
Disti, Incorporated
D/L Laboratories
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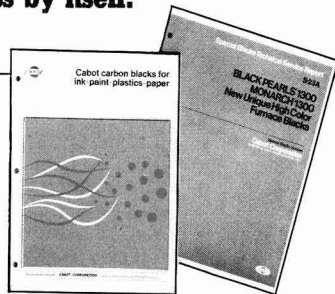
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Prediction of the Service Life Of Coatings on Steel

Part I: Procedure for Quantitative Evaluation Of Coating Defects

Jonathan W. Martin and Mary E. McKnight
National Bureau of Standards*

A new evaluation procedure based on spatial statistical techniques is demonstrated for quantitatively evaluating the degradation state of steel panels protected by an organic coating. Representative results from this procedure are presented. These results include changes in the number, size, and location of defects as a function of time. Attributes of the evaluation procedure are discussed in terms of an ideal evaluation procedure. It is concluded that the procedure (1) is simple to apply; (2) is systematic in its approach; (3) generates quantitative measures of the degradation state of a coated steel panel; and (4) outputs the raw data in a publishable format. Although not proven as yet, strong indications exist that the results of the procedure are reproducible and repeatable. At present, the major drawback of the evaluation procedure is the long time needed for evaluating each panel. Alternatives which could significantly reduce this time are discussed.

INTRODUCTION

In 1980, it was estimated that the cost for protecting highway structural steel bridges from corrosion was approximately \$130 to \$160 million per year.¹ Since bridges comprise only a small fraction of all public structures, society could realize considerable economic

savings if the time interval between maintenance coatings could be increased. One way this can be accomplished is by improving the decision-making tools for selecting more durable coating systems.

Purposeful selection or manufacture of more durable coatings implies that specific knowledge is available on the performance of candidate coating systems. Specifically, it implies that a decision-maker can predict the service life of a coating system subjected to its expected in-service operating and environmental conditions, choose between or among coating systems on the basis of their service life and cost-effectiveness, and identify the causes of coating degradation by associating material properties of a coating system to its corresponding service life. This performance information should be required of any material or system prior to its large scale field application. One way of obtaining this information is through outdoor exposure tests. To conduct outdoor exposure tests in all representative exposure sites in the United States, however, would be prohibitively expensive and time consuming. A far better procedure is to acquire the necessary data via accelerated aging tests.

Accelerated aging tests have two distinct advantages over outdoor exposures. First, the experimenter has complete control over the factors comprising his environment; that is, he can control what degradation factors are present, set their intensity, and, if desired, vary their intensity over time. The second advantage of accelerated aging tests, and the major reason for preferring them over outdoor exposures, is that the degradation process can be speeded up. This is accomplished by setting one or more

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of the degradation factors to intensity levels greater than that found in-service. The obvious benefit of this is that the service life data is available in a shorter period. The difficulty lies in selecting degradation factors and a stress regime from which the empirical results can be extrapolated to an in-service environment. To make these extrapolations, the functional relationship between the imposed degradation factors and the performance of the coating system must be known. In the past, the lack of this knowledge has limited the usefulness of accelerated aging tests.^{2,4,5} The objective of this series of papers is to demonstrate several methodologies which are capable of elucidating these relationships.

The accelerated aging test procedure can be divided into three parts (1) experiment, (2) evaluation, and (3) analysis. Each of these elements is vital. In the accelerated aging tests currently used for coatings, however, the emphasis has been on the experimental procedure with comparatively little emphasis being placed on either the evaluation or the mathematical analysis. The philosophy behind the currently used accelerated aging tests has been to develop a laboratory-based experimental program that correlates with the results from all or a large portion of outdoor exposures. It is generally agreed that this approach has not been successful.⁷

In the accelerated aging test procedures which are proposed in this series of papers, the emphasis is on mathematical analysis.³ This emphasis should be expected, inasmuch as the objective of the accelerated aging tests is to quantitatively predict the service life of a coating system. As is pointed out by the authors,³ the mathematical analysis procedure selected was reliability theory.⁶ Before reliability techniques could be used, however, a more quantitative evaluation procedure had to be identified for evaluating the degradation state of coated panels. The evaluation procedure developed has a basis in spatial statistics and was used in place of the current

visual evaluation procedures like ASTM D610.⁷ A description of this procedure and examples of the kinds of information that are obtained are included in this paper.

REVIEW OF SPATIAL SAMPLING PROCEDURES

Defects begin to appear after a coating is exposed to an adverse environment for a long period of time. These defects often form a complex spatial pattern over the surface of a coating. Each defect can be characterized by its size, type (corrosion or blister), and location. The total area of the defects can be determined by summing the areas of each of the individual defects. With increasing time, the number and the size of defects (hence, the area of the defects) increase. The total area of the defects is often used as the criterion for determining when a coating fails. The time at which failure occurs is called the service life of the coating. As is shown in "Part III" of this series,⁸ the pattern of defects may also provide useful information, with respect to the causes of coating failures.

The spatial analysis problem is not unique to coatings. It appears in many other disciplines. In ecology, one is often interested in the spatial distribution of plants, trees, or animals.⁹⁻¹¹ In geography and economics, the problem is couched in terms of the distribution of retail stores¹² or the distribution of males employed in agriculture in a specified geographical region.¹³ Other examples include geology (e.g., the distribution of uranium deposits in a region,¹⁴ microbiology (e.g., the distribution of bacteria in a culture medium,¹⁵ and microscopy.¹⁶ The problem arises so often, in fact, that an entire theory has been developed. This theory is called spatial statistics.^{9,17,19} Spatial statistics provides a systematic, quantitative theory for analyzing spatial phenomena. It also provides experimental sampling procedures.

In general, two sampling procedures are available: points and quadrats. (The term quadrat is borrowed from ecology¹²). Points contain theoretically no area (see Figure 1). A quadrat, on the other hand, has area and shape, usually square, rectangular, or circular. Points are binary in nature; that is, either a point intersects a defect or it does not. For quadrats, defects are contained within its area. Within each quadrat, the number, size, and type of defects are recorded.

Points can be distributed randomly or systematically (see Figure 2). Practically, points can be located by the intersection of a pin with the surface¹⁸ or by an optical device with cross hairs. The major advantages of points are that the data collection is fast and the apparatus for locating points is simple. The accuracy of this procedure increases with an increasing number of points. Random points have a theoretical advantage¹⁷ over non-random arrangements; however, this advantage is far outweighed by its disadvantages.¹⁹ These disadvantages include: (1) the manual location of points, without the use of random number tables, introduces an indeterminable bias into the analysis; (2) locating random points in the x,y-plane is very time consuming; and (3) information on the location of individual points is lost, thus precluding many spatial

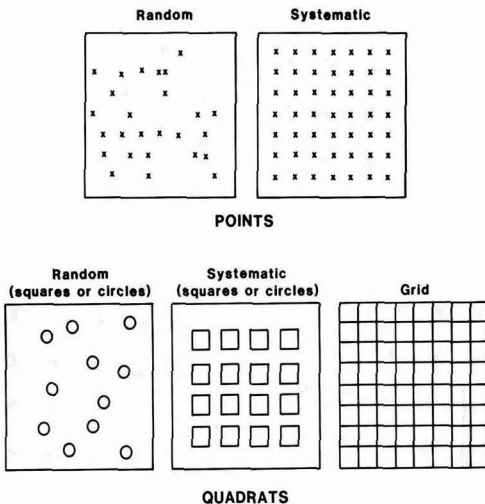


Figure 1—Alternative sampling plans for quantifying the amount of coating degradation

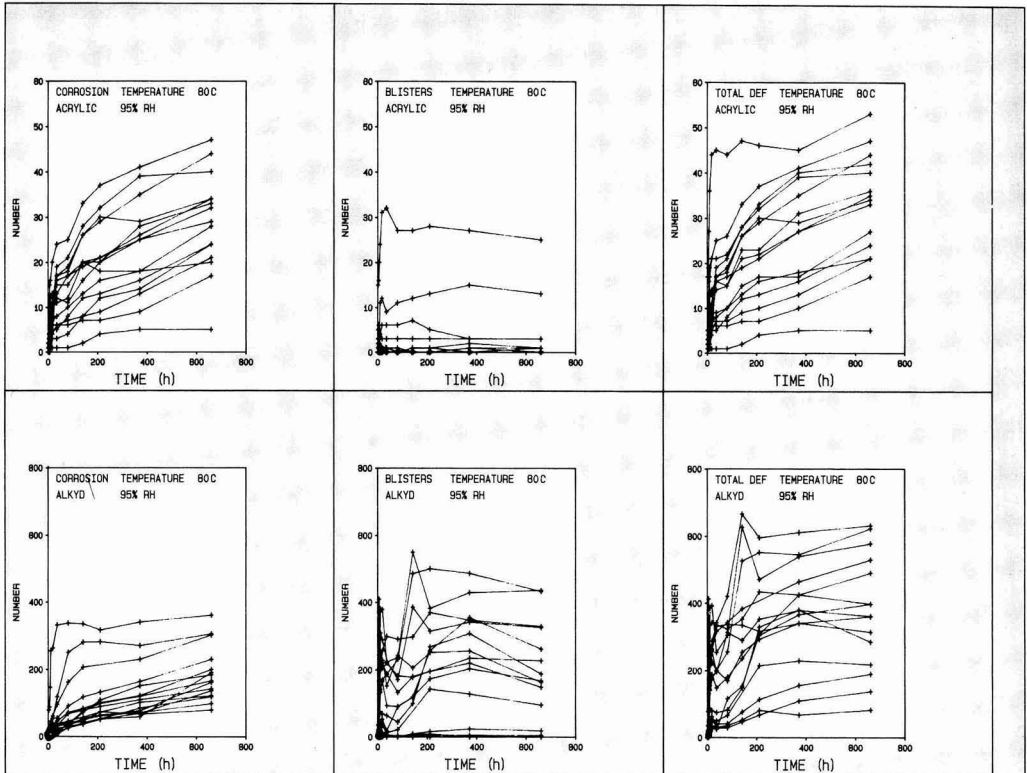


Figure 2—Cumulative number of defects as a function of time

analysis techniques. The recommendation, therefore, is to use a systematic arrangement of points.

As with points, quadrats can be located randomly or systematically. Unlike points, a grid of quadrats can be used to cover the entire sampling area. If a grid pattern is used, the accuracy of the sampling procedure is known. If a grid is not used, then the accuracy of the procedure again increases with an increasing number of quadrats. There are many advantages in using quadrats, particularly with systematic or grid patterns. The first advantage is that the analysis can be computerized.²⁰⁻²¹ A video camera or an infrared camera can be set up to take a picture of a study area (the picture area is equivalent to one quadrat). This picture can then be digitized and the digitized signal processed by the computer giving the number, size, type, and location of each defect in the picture. This information can then be transmitted to a computer mass storage unit for future reference. This whole process would take a matter of seconds. After the data is transmitted, the camera can be repositioned and the process repeated. Another advantage of quadrats is that they permit the use of a variety of spatial analysis methodologies which are not accessible with point sampling.¹⁹ There are some disadvantages with quadrat analysis, however. Since quadrats have a boundary, some defects will intersect this boundary; thus a decision rule will have to be developed as to when to include or exclude a defect. This disadvantage is somewhat mitigated when a grid pattern

is used, since a defect not included in one grid block falls into the adjoining block. Another disadvantage of quadrats is that the results are somewhat dependent on the size of the quadrat.¹⁰

In this research, a grid type sampling pattern was selected.

EXPERIMENTAL

The test panels were sandblasted, hot-rolled steel plates having dimensions 200 mm \times 100 mm \times 2.5 mm (8" \times 4" \times .125"). The panels were sandblasted according to SSPC-SP5 and had a surface profile ranging between 0.05 mm and 0.13 mm (2-5 mils). Prior to the application of a coating, all panels were washed several times with acetone to remove any residual grease.

Two coatings were selected—a clear acrylic and a titanium dioxide pigmented alkyd. Neither coating was commercial grade because both lacked inhibitors and some other additives. Otherwise, the formulations were close to those of typical commercial coatings.

The test coatings were applied using a flat blade film applicator. Warped panels were flattened by placing them on a table with a very high magnetic flux after which the coating was applied. To prevent corrosion in non-test areas, the back and edges of each panel were coated with a very durable commercial epoxy coating. All coatings were allowed to cure at room temperature and 45%

relative humidity for approximately four weeks. The dry thickness of each panel was measured using a magnetic thickness gauge and an optical microscope. For the acrylic coating, the statistical mode of the dry thickness measurements was 45 μm (1.8 mils) and ranged between 25 and 60 μm (1.1 and 2.4 mils). For the alkyd coating, the statistical mode of the dry thickness measurements was 55 μm (2.1 mils) and again ranged between 25 and 60 μm (1.1 and 2.4 mils).

The experiments were conducted at three temperatures (60°C, 70°C, and 80°C) and at one relative humidity (95%). For each coating and at each temperature, 15 panels were exposed. (15 panels \times 2 coatings types \times 3 temperature levels = 90 panels.) The panels were exposed in one of two relative humidity cabinets. The cabinets differed with respect to their recovery to the 95% relative humidity level after the cabinet door was opened. The fast recovery cabinet (recovery time of approximately five minutes) was used for the 70°C and 80°C exposures. The slow recovery cabinet (recovery time to 95% relative humidity was approximately three hours) was used for the 60°C exposure. The cabinets were calibrated using sensors independent of the cabinet controls. Each cabinet was outfitted with 12 thermocouples and 12 calibrated electrical resistance humidity sensors (factory calibrated to an accuracy of $\pm 1/2$ percent). These sensors were placed in a two tier grid pattern covering the interior

volume of the cabinet. The cabinets were then operated for about one week at 60°C, the maximum operating temperature of the humidity sensors. The temperature range during this period was within 1°C for all the thermocouples. The relative humidity sensor readings ranged between 93.5% and 96% relative humidity. These readings agreed with those of the cabinet; hence, the cabinet sensors were used during the experiment.

At each temperature level, 15 panels were randomly assigned from each coating to one of four specimen racks. The racks oriented the panels in a vertical direction. Prior to insertion of the loaded racks, they were heated to a temperature approximately 5°C above the cabinet temperature. This prevented any condensation on the panels. Panels which were not on test were stored in a nitrogen atmosphere to minimize the effects of oxidation.

The panels were evaluated by placing a transparent grid over each test panel. The grid was sectioned into a 3 \times 8 matrix of square blocks, each block having dimensions of 20 mm \times 20 mm. A 20 mm border surrounded the grid. Defects falling in this edge area were not counted. The grid was located using a hole in the border of the panel as a reference point. This hole ensured that all of the 24 blocks covered the same area from one evaluation to the next. During each evaluation, the number, size, and type of defects in each block were tabulated for every panel. The location of the defects was known from the block

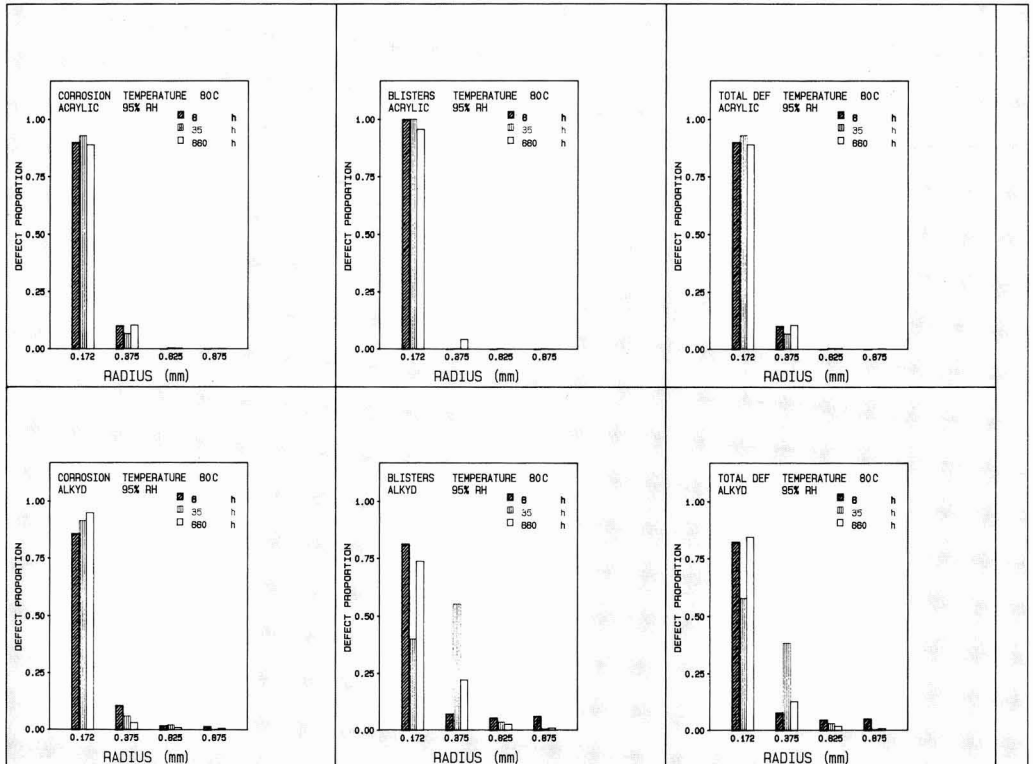


Figure 3—Size of defects histograms

number. Five diameter size categories were designated for the defects: they were (1) $0.2 \text{ mm} < S < .5 \text{ mm}$; (2) $0.5 \text{ mm} < S < 1.0 \text{ mm}$; (3) $1.0 \text{ mm} < S < 1.5 \text{ mm}$; (4) $1.5 \text{ mm} < S < 2.0 \text{ mm}$; and (5) $S > 2.0 \text{ mm}$, where S is the size of the defect. Defect diameters greater than 2.0 mm were only observed for the alkyd coating at 80°C and at long exposure times. The total number of evaluations at 60°C, 70°C, and 80°C was 10, 11, and 11, respectively. The maximum exposure time at 60°C, 70°C, and 80°C was 3065 hr, 1505 hr, and 660 hr, respectively. Panels were exposed for longer periods of time at the lower temperatures, because the rate of degradation decreases with decreasing temperature. At each temperature, the exposure test was terminated when enough panels passed through a predetermined area percentage.

RESULTS

From the raw data, the following information on the deterioration of the coating system as a function of time is available: (1) the total number of defects, (2) the size density of the defects, (3) the percent area of defects, and (4) the location of the defects. Representative output is presented for each.

In Figure 2, the total number of defects at 80°C is plotted versus time for both the acrylic and the alkyd coating. Each line in Figure 2 represents the cumulative

number of defects over time for one of the 15 panels. The cumulative number of corrosion spots tends to monotonically increase with exposure time, while the cumulative number of blisters increases rapidly at first and then decreases. This decrease occurs because blisters either become corrosion spots or collapse upon removal of the panel from the 95% relative humidity environment leaving no visible sign of either corrosion or blisters. When the two defects are summed, the combined corrosion and blister curve trends are controlled by the more numerous of the two defects. At 80°C, the number of corrosion spots controls the combined defect curves for the acrylic coating while the blisters dominate the early portion of the combined defect curves for the alkyd system. Regardless of the temperature, the number of defects for the alkyd system was always greater than that for acrylic system indicating that the degradation of the alkyd system is more temperature sensitive at 95% relative humidity.

In Figure 3, the size defect histograms at 80°C are shown for both coatings. In these histograms, the proportion of the total number of defects is plotted versus the median radius for the first four defect size categories. For both corrosion and blisters, the trend of the size distribution was the same. The proportion of defects exponentially decreases with increasing defect size. For the acrylic coating, the histograms at 80°C do not appear

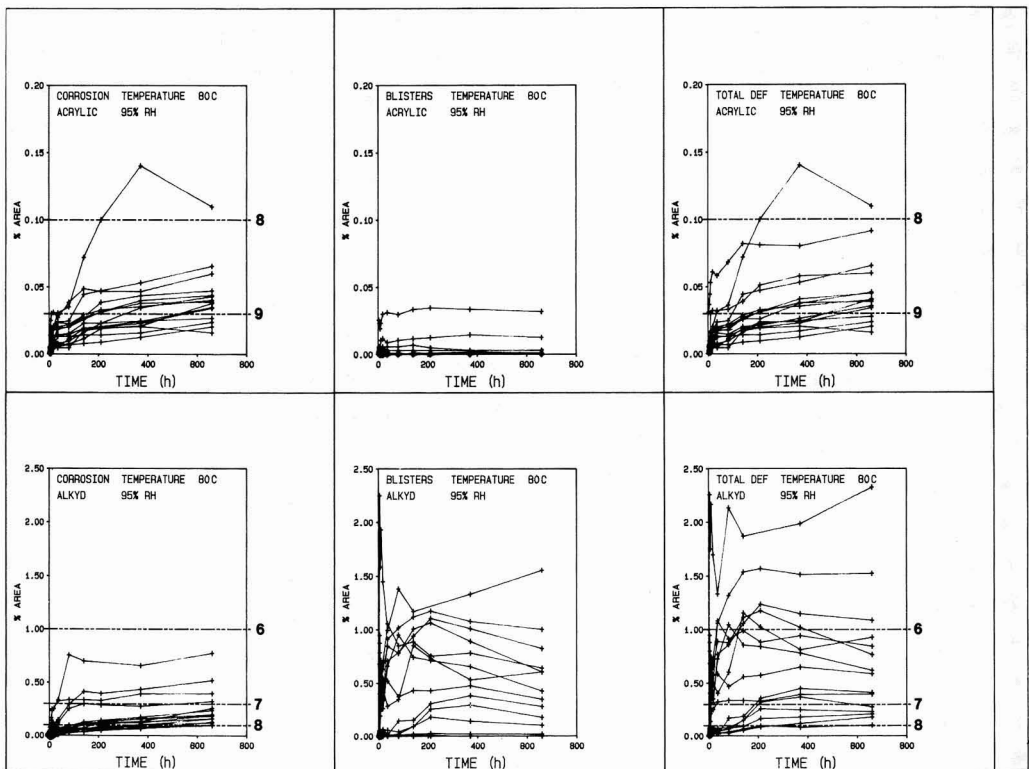


Figure 4—Cumulative area of defects as a function of time

to change significantly over time for either corrosion or blisters. For the alkyd system, the corrosion size distribution appears to shift slightly to smaller diameter defects. Size distribution changes for blisters are more erratic. After 35 hr, the defects appear to become proportionally larger in size than they were after six hours' exposure; after 660 hr, however, the size distribution shifts to smaller defects.

In *Figure 4*, the percent area of defects are plotted as a function of time for both the acrylic and the alkyd coatings. As with the number of defects, each line in *Figure 4* represents the cumulative percent area of a defect for an individual panel. These panels were exposed at 80°C and 95% relative humidity. For comparison purposes, the percent area of corrosion for the top four visual grades of ASTM D610 is superimposed in *Figure 4*. Area percentage of 0.03, 0.1, 0.3 and 1.0% correspond to visual standards 9, 8, 7, and 6, respectively. Hence, the proposed procedure is fully compatible with the accepted ASTM visual standards. Given that some percent area is defined as a failure, then the time to failure is defined as the time at which the percent area defect for a panel first passes through this predesignated percentage. For example, if a visual standard of seven (equivalent to 0.3% area degraded) is defined as the failure area for corrosion, then the first two panels of the alkyd coating in *Figure 4* fail at 28 hr and the third one occurs at 80 hr. Using this same failure criteria for the acrylics, no failures were observed during the test period. Also of interest in *Figure 4* is the large variation in the rates of degradation for individual panels. Although the panels were exposed to the same service environment, one or more panels almost

always have a rate of degradation much greater than that of the others. From the aspect of service life prediction, this disparity is very important for it directs the research to isolate the causes of failure for those panels having the highest rate of degradation. If this cause can be identified and corrected, then the service life of the coating will shift to longer times. This shift is equal to an improvement in the service life of the coating system.

The last output from the raw data is the location of defects on a panel. In *Figure 5*, a time sequence is shown for the spatial location of corrosion spots for an alkyd panel exposed at 70°C and 95% relative humidity. The 3 × 8 grid simulates the grid pattern used in evaluating a panel. The number in each block indicates the number of corrosion spots of all defect sizes located in that block. As before, the number of defects generally increases with increasing exposure time. Of interest is how the defects grow in time and space relative to each other. That is, can one detect any contagion in the spread of defects? If this occurs, the properties of this location should be investigated to determine how the properties of this area differ from other areas in the panel where corrosion spots do not occur.

DISCUSSION

In this section, the attributes of the proposed procedure and ASTM D610¹ are compared against attributes which the authors' consider to be ideal. These attributes are tabulated in *Table 1* along with the authors' assessments as to whether the proposed procedure and ASTM D160 satisfy each attribute. Both procedures were considered to be non-destructive.

The proposed procedure meets the requirements of being systematic and simple. In a short time both the professional and technical staffs became proficient with the procedure. As a testimony to this, the task of evaluating the panels was given to the technical staff after the first few evaluations. Before this could be done, however, a small problem had to be resolved as to defining the minimum defect size which should be counted. The problem arose because different observers examined the blocks for different lengths of time. In general, the longer the examination period, the greater the number of small defects observed. This problem was resolved by specifying a minimum defect diameter of 0.2 mm, below which defects were not counted. With respect to being systematic and simple, ASTM D610 was considered to fall somewhere between satisfying and not satisfying this attribute. ASTM D610 is simple, but it is not really systematic. That is, the procedure does not break down into a logical sequence of steps, each of which is testable for its accuracy. Instead, the process results in a judgement of the degradation state of the coating. The mental steps taken to arrive at this judgement are untestable and are probably unique to each individual.

As is shown in *Figures 2-4*, the proposed procedure is definitely quantitative. Quantitative estimates are available both spatially (*Figure 5*) and temporally (*Figures 2 and 4*). ASTM D610, on the other hand, is not a quantitative procedure; it is a comparative one. Although each grade number in ASTM D610 has a corresponding

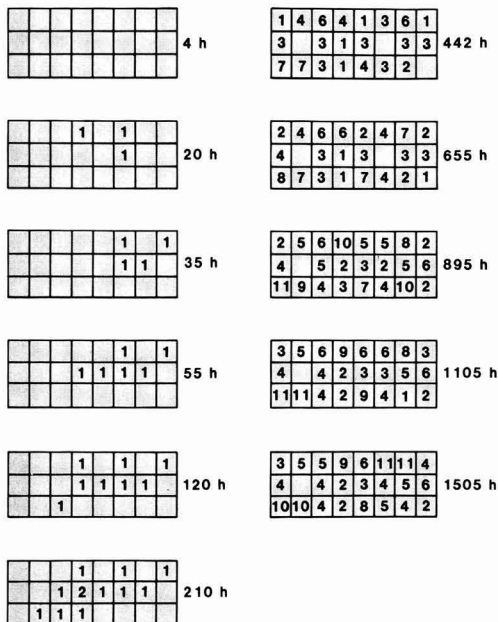


Figure 5—Location of corrosion spots with increasing exposure time for an individual alkyd panel exposed at 80°C and 95% relative humidity

percent area degraded, these percent areas have little meaning except to give the researcher a crude estimate of the corrosion area. The crudeness of these measures increases with increasing degradation, since the percent areas approximately follow a geometric series. This is pictorially demonstrated in *Figure 4* in that the actual quantitative degradation often falls somewhere in-between two grades.

The proposed procedure has yet to be tested in a round robin experiment; hence, the final assessment as to whether the procedure is reproducible and repeatable has not been made. Our experience is that the degradation assessments are at least repeatable. For visual procedures like ASTM D610, reproducibility and repeatability have always been major problems, because of the human error factor.²² In practice, evaluations for different observers can often range between plus or minus two visual grades. One way of mitigating this effect is to have several evaluators rate the same panels at the same time.²²

For any science or technology to evolve, the raw data must be publishable; that is, researchers must be able to compare their results and build on each other's results. This data base must be unquestionably accurate and must be in a format useful to both engineers and scientists interested in improving the service life of coating systems. Data obtained using visual standard, e.g., ASTM D610, partially satisfy this criterion. This is certainly the case with published results from researchers having a long history in coatings service life research.²² Problems arise, however, when service life evaluations are compared between laboratories, since the evaluations are seldom reproducible. The information from the proposed evaluation procedure is quantitatively more precise than the traditional visual procedures, as is shown in subsequent papers. This information can be used in predicting the service life of a coating system.

The last attribute is the speed of making the degradation assessments. Short assessment times are very desirable since the faster the assessment the lower the cost of running a durability program. This decrease in cost, however, must be tempered against the quality and the quantity of the data obtained. For currently available visual standards, the speed of making assessments is probably their greatest attribute. It usually takes less than two minutes to evaluate a panel. In comparison, the proposed procedure is slow; the average evaluation time was approximately 15 minutes per panel. After reviewing the temporal and spatial analysis results presented in forthcoming papers, a 15 minute evaluation time might not be considered excessive. This almost certainly will not be true in all cases, however. In these instances, changes in the proposed evaluation procedure must be made. Two possible changes include the use of systematic point or quadrat sampling procedures, and computerized image processing of the defect area. The systematic point or quadrat sampling procedures will reduce the evaluation time, because the defect area is only partially sampled. The computerized image processing has been mentioned previously. It will reduce the experimental time in two ways. First, the evaluations should be faster than doing them manually; and second, the raw data is entered

Table 1—List of Ideal Panel Evaluation Attributes

| Attribute | ASTM D610 | Proposed Procedure |
|-----------------------------|------------------|--------------------|
| Systematic and simple | Y/N ^a | Y |
| Non-destructive | Y | Y |
| Reproducible and repeatable | N | Y |
| Quantitative | N | Y |
| Publishable data | Y/N | Y |
| Rapid | Y | N |

(a) Y = yes, N = no, Y/N = yes and no — it meets some of characteristics of the attribute, but not all.

directly into the computer, thus foregoing manual entry of data. Work on computerized image processing of degraded panels is currently proceeding.²⁰⁻²¹

CONCLUSION

In this paper, a new evaluation procedure was proposed and demonstrated. Representative output from this procedure is presented. This output included changes in the number, size, area, and location of defects as a function of time. The attributes of the proposed procedure were then discussed in terms of those of an ideal evaluation procedure. It was concluded that the proposed procedure (1) is simple to apply; (2) is systematic in its approach; (3) generates quantitative measures of the degradation state of a coated panel; and (4) outputs this raw data into a publishable format usable by both engineers and scientists. Although not proven as yet, strong evidence exists that the results from the proposed procedure should also be both reproducible and repeatable. The major drawback of the proposed procedure is the long evaluation time for each panel. Alternatives to the sampling procedure used in this study which should significantly reduce this evaluation time were discussed.

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Prediction of the Service Life Of Coatings on Steel Part II: Quantitative Prediction Of the Service Life of a Coating System

Jonathan W. Martin and Mary E. McKnight
National Bureau of Standards*

The applicability of a reliability and life testing procedure is demonstrated for quantitatively predicting the service lives of two coating systems. By subjecting an acrylic and an alkyd to three temperatures and 95% relative humidity, it is experimentally demonstrated that the proposed procedure is capable of quantitatively estimating the maximum service life, at 95% RH over a wide range of temperatures, beyond which a specified proportion, $1-\lambda$, of a nominal coating population survives. Although the coating systems are very different, the same equations appear to be applicable to both systems. This indicates that the analysis might be generally applicable for predicting service lives for a wide variety of coating systems.

INTRODUCTION

It is generally recognized that making quantitative service life predictions for a coating system exposed to its intended operating environment is a difficult task. To make these predictions, the interrelationships between the performance of the coating system, the expected environmental factors to which it will be exposed in service, and the material properties of the coating system must be known. Due to the large number of material and environmental variables which should be considered,

these interrelationships have not, as yet, been identified for any environment. Some doubts exist, at least in the authors' minds, as to whether the currently available coating service life prediction techniques are sufficiently powerful to unravel these complex relationships. A search was made, therefore, to identify successful service life prediction techniques used for other materials and to apply these techniques to coatings.

Accurate service life predictions using reliability theory and life testing analysis techniques have been made for many years for the materials, components, and systems used in the electronics, aerospace, and medical industries.¹ Using reliability theory and life testing analysis is a systematic, probabilistic procedure designed for the purpose of making quantitative service life predictions.²⁻⁴ The output of the analysis is a statement of the probability that a material, component, or system will perform its intended purpose for a specified period of time when subjected to its expected operating conditions. These predictions can be made from field test data for a specific in-service environment or by extrapolating accelerated aging results to in-service environments.

In this paper, reliability theory and life testing techniques are applied to the prediction of the service lives of two coating systems. These systems were subjected to a 95% relative humidity environment at each of three different temperatures—60°, 70°, and 80°C. Since only one degradation factor (temperature) is varied in this experiment, extrapolation to in-service environments cannot be expected. Instead, it is intended that the results of this research demonstrate the power of the techniques and provide a foundation for future experiments. To aid

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in the design of these experiments, the generalized accelerated aging problem is presented in the following section.

MATHEMATICAL PRESENTATION OF THE ACCELERATED AGING PROBLEM

Let Σ denote a vector of degradation factors and their intensities to which a coating system is expected to be stressed in service. Let the i -th stress level (S_i) be a combination of degradation factors having known intensities such that:

$$S_0 < S_1 < \dots < S_i < S_{i+1} < \dots < S_m \tag{1}$$

where S_0 is the stress level at normal operating conditions; S_m is the stress level at the most severe laboratory conditions; and $S_i < S_{i+1}$ indicates that the i -th stress level is less severe than the $(i+1)$ -th stress level. Implicit in equation (1) is that an ordering in the severity of the stress levels can be made. Typically, this can be accomplished by either *a priori* knowledge of the failure mechanisms or by the results of a systematic experimental design.

The experimental procedure for determining performance at S_0 from stress levels greater than S_0 is as follows: (1) randomly select n_i panels ($i = 1, 2, \dots, m$) from a nominal coating system population for each of m different stress levels; (2) at each stress level, subject the n_i panels to their predetermined level of stress and observe the times to failure (experimentally, failure is defined in terms of a maximum allowable percent area degradation); and (3) terminate the experiment at the i -th stress level when the r_i -th failure ($r_i \leq n_i$) is observed. Since the n_i panels are simultaneously exposed to the i -th stress level, the observed times to failure are ordered; that is,

$$t_{i1} \leq t_{i2} \leq \dots \leq t_{ij} \leq \dots \leq t_{in_i} \tag{2}$$

where t_{ij} is the j -th time to failure for panels exposed to stress level S_i ; and $r_i \leq n_i$. For coating systems, the range in times to failure tends to be quite large. Panels not failing prior to terminating the life test (panels $r_{i+1}, r_{i+2}, \dots, n_i$) are called censored times to failure.^{2,4} The analysis, which follows, can be performed with or without censored times to failure.

From these ordered times to failure, an empirical cumulative distribution function at stress S_i can be formed. To this empirical cumulative distribution, a

“theoretical” cumulative distribution function $F(t; \theta(S_i))$ is fitted where θ is the vector of parameters for this distribution function at stress S_i (see Figure 1). (Henceforth, this “theoretical” cumulative distribution is called a life distribution.) In Figure 1, the solid dots are data points; the tails after the dots are used in evaluating the visual fit of the “theoretical” life distribution to the sample life distribution. If the “theoretical” life distribution intersects most of the tails following the sample quantiles, then the “theoretical” life distribution is considered to fit the sample distribution well. To simplify the notation, let the parameter vector for the i -th stress, $\theta = \theta(S_i)$, be denoted by θ_i . Further, let the life distribution at the i -th stress level, $F(t; \theta(S_i))$ be denoted by $F_i(t)$.

At the i -th level of stress, the probability that a given coated panel will fail prior to an exposure time, t , is

$$F_i(t) = P(\tau \leq t) \tag{3}$$

where τ is a random variable; $P(\)$ is the probability of the event in parenthesis taking place at stress S_i , and t is a time. Complementary to this probability of failure is the reliability, denoted by $R_i(t)$. [As before, $R(t; \theta(S_i))$ is shortened to $R_i(t)$]. The reliability at time t is the probability that a coated panel will not fail prior to time t , symbolically $P(\tau > t)$. At the i -th stress level, the reliability is related to the life distribution by

$$R_i(t) = 1 - F_i(t) \tag{4}$$

The reliability function is of interest because it is used in estimating the maximum service life for a coating system. In reliability analysis, the maximum service life for a material is defined as the time beyond which some specified proportion, $1 - \lambda$, of the population survives, where λ is the proportion that fail prior to this time and $0 \leq \lambda \leq 1$. The maximum service life, t_{sl} , is found by solving the reliability function for the $100(1 - \lambda)$ distribution percentile (see Figure 1); that is

$$t_{sl} = R^{-1}(1 - \lambda) \tag{5}$$

For most applications, the value assigned to λ is small; e.g., 0.01, 0.05, or 0.10. The selection of the λ value depends on such factors as the accessibility of the structure to maintenance and the importance of the component being protected. For example, a small value of λ might be selected for coatings applied to the towers of a suspension bridge while a high value of λ might be applied to a coating protecting a small building.

As the level of stress increases, the coated panels tend to fail in a shorter period of time. An acceleration of the degradation process is said to have occurred if

$$F_i(t) < F_{i+1}(t) \tag{6}$$

for $t > 0$ and for $i = 1, 2, \dots, m - 1$. That is, for a given exposure time, the probability of failure at the higher stress level is greater than that at the lower stress level. If equation (6) is followed, then a function $\rho(t)$ exists, where $\rho(t) = \rho(t; \theta_i)$, relating the life distribution parameters at any elevated stress level, S_i , to the life distribution parameters at normal conditions, S_0 , as follows:

$$F_i(t) = F_0(\rho(t)) \tag{7}$$

where $\rho(t)$ is a time transformation function. Commonly,

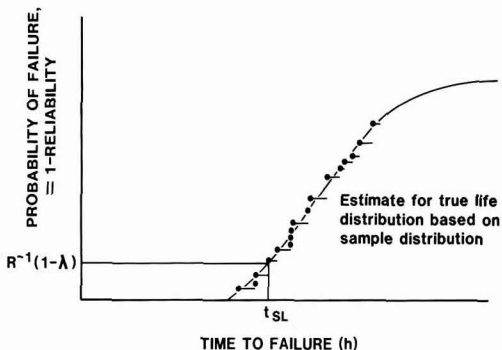


Figure 1—Schematic representation of proposed reliability plan

the time transformation function, $\rho(t)$, is defined as the product of an acceleration factor $\psi(S, \theta)$ and time⁶: that is,

$$\rho(t) = \psi(S, \theta)t. \quad (8)$$

Often, as is the case here, an acceleration factor does not exist and equation (7) must be used. Regardless of the equation used, it is important that the equation relating the parameters of the life distribution to the applied stress have a basis in the time-dependent chemical/physical mechanisms of the coating system degradation.

Before concluding this section, the effects of estimating the life distribution parameters with censored data should be discussed. With censoring, some loss in confidence in the distributional parametric estimates, θ , may occur. The confidence interval for a parameter (hence, our confidence in the estimate) is a function of both the number of panels tested, n_i , and the number of observed times to failure, r_i . Hence, the same confidence for an estimate can be obtained by having either a large number of panels on test with few observed times to failure or a small number of panels on test with many observed times to failure. The advantage of terminating the life test prior

to observing the failure of all of the panels failing is that significant reductions in the maximum exposure time can be obtained.⁵

EXPERIMENTAL

The experimental procedure, described in detail by Martin and McKnight,⁷ is summarized here. In this experiment, each of two coatings were subjected to three different constant temperature/RH environments for exposure times up to 3000 hr. The two coatings were an acrylic and an alkyd. Both coatings were similar to commercial formulations. The coatings were applied to a thickness of 50 μm (2 mils) over sandblasted, hot-rolled, steel plate substrates having a surface profile between 51 to 127 μm (2 and 5 mils). After curing for at least four weeks at 22° C and 45% RH, the panels were subjected to one of three temperatures (60°, 70°, and 80° C) and 95% RH. It was assumed *a priori* that the severity of the test increases with increasing temperature [see equation (1)].

For each temperature/RH level and for each coating type, a set of 15 panels was randomly selected (2 coating

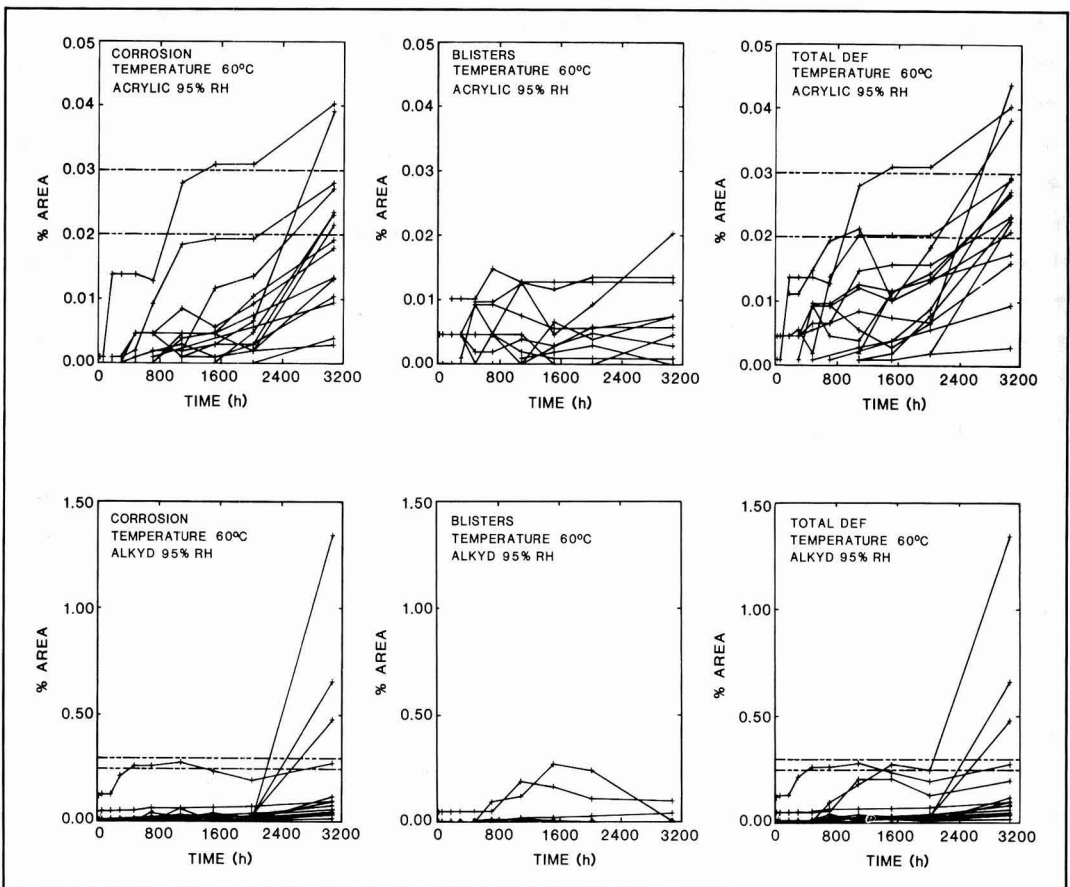


Figure 2—Change in percent area corrosion, blister, and corrosion plus blister as a function of time for the acrylic and alkyd panels subjected to 60° C and 95% RH

types \times 3 temperature levels \times 15 panels = 90 panels). Each set of panels was exposed at a constant temperature in a relative humidity cabinet for a predetermined period of time. At the end of this interval, the panels were removed, evaluated, and then put back into the relative humidity cabinet. This procedure was repeated 10 or 11 times at each temperature/relative humidity level. During each evaluation, the number, size, and location of each defect (corrosion or blister) was ascertained using the evaluation procedure described in Martin and McKnight.⁷

RESULTS

The cumulative percent area degradation for corrosion, blisters, and corrosion plus blisters was determined for each panel after each exposure interval. Degradation tracks for all the test panels are depicted in Figures 2, 3, and 4 for the 60°C-95% RH, 70°C-95% RH, and 80°C-95% RH environments, respectively. From Figures 2 through 4, it is seen that percent area of corrosion tended to increase monotonically with increasing time.

(Individual acrylic corrosion tracks sometimes showed a temporary decrease in percent area. This is probably due to the evaluators categorizing borderline defects into a higher size category during an early evaluation and then a lower size category in successive evaluations.) The tracks of the percent area of blisters are more variable. Typically, the number of blisters increased rapidly at first and then decreased. This decrease can be attributed to either the blister changing into a corrosion spot or collapsing, leaving no external sign of its previous existence. The percent area of corrosion plus blisters is obtained by adding the areas of the two types of defects together. The trends for these tracks are largely governed by the more dominant of the two defects. As a general observation, the variation in the rates of panel degradation tend to be large; correspondingly, the range in times to failure is large.

The service life or time to failure of an individual panel is defined as the time at which the percent area degradation reaches a predesignated maximum allowable amount. This definition of failure is in accordance with visual standards such as ASTM D610⁸ or ASTM D714.⁹

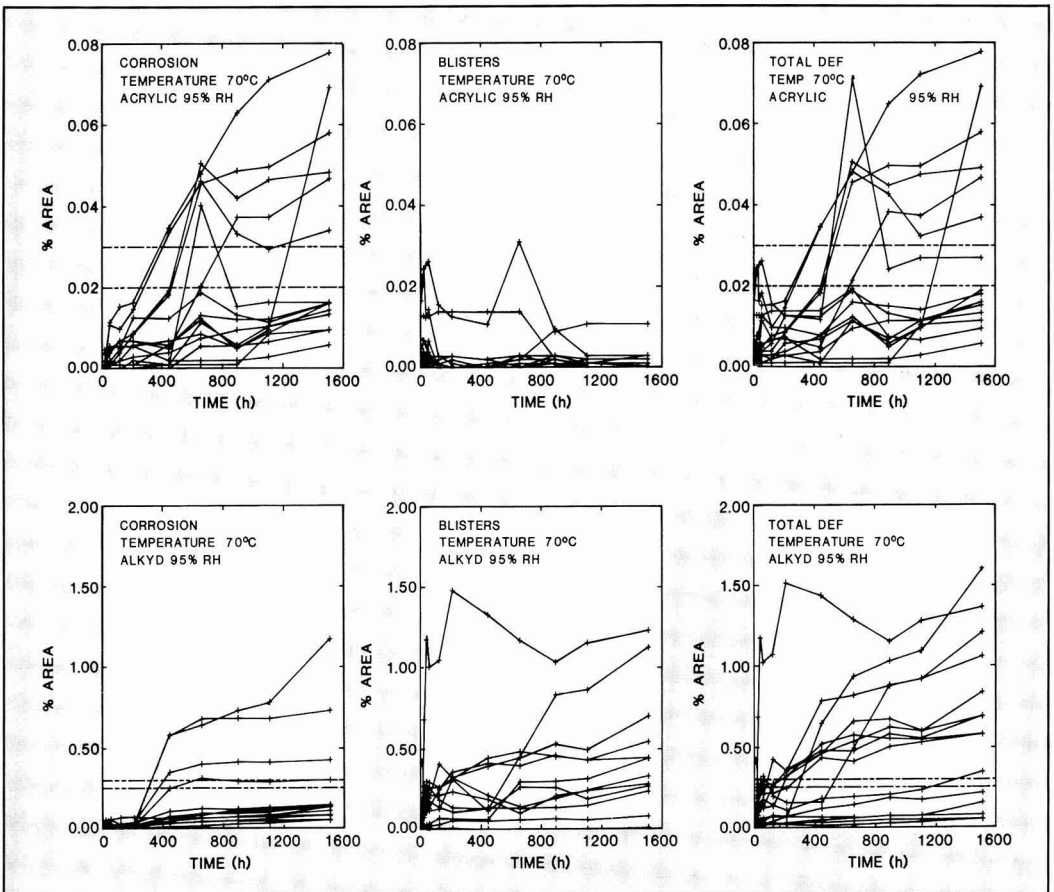


Figure 3—Change in percent area corrosion, blister, and corrosion plus blister as a function of time for the acrylic and alkyd panels subjected to 70°C and 95% RH

Panels having defect percents less than the maximum allowable amount at the termination of the test are said to be censored. For each coating type, two different coating failure criteria were applied. This was necessary because the acrylic degraded little, even at the highest temperature. For the acrylic, failure was defined as 0.02% and 0.03% degradation and for the alkyd, failure was defined as 0.25% and 0.30%. Lines corresponding to these percent areas of failure are superimposed on *Figures 2* through 4. The extent of blistering was not analyzed as a single evaluation criterion because it was felt that the analysis of the combined defects (corrosion plus blisters) would be of greater interest.

ANALYSIS OF EXPERIMENTAL RESULTS

The reliability analysis proceeds by first determining the ordered times to failure [see equation (2)] at each stress level from *Figures 2* through 4. As examples, the ordered failure times for corrosion plus blisters are listed in *Table 1* for the acrylic system at 70°C and 95% RH and for the alkyd system at 80°C and 95% RH. These failure

times were taken from *Figures 3* and 4, respectively. From *Table 1*, it is noted that the number of observed failures tends to decrease and the times to failure tend to increase as the percent area of the defect criterion increases, e.g., from 0.25% to 0.30%. Also, at 80°C, the alkyd coating tended to degrade in one of two ways. Half of the panels failed very quickly (less than 30 hr) while only two of the remaining specimens failed prior to the termination of the test at 660 hr.

For each temperature/relative humidity level, and for each failure criterion, a sample life distribution was constructed from the ordered times to failure. In *Figures 5a* and *5b*, sample life distributions are depicted for the acrylic (0.02% corrosion plus blisters, 70°C, and 95% RH), and for the alkyd (0.3% corrosion plus blisters, 80°C, and 95% RH). To each sample life distribution a "theoretical" life distribution was fitted [see equation (3)]. The Weibull distribution (see Appendix A) was selected, because it tended to visually fit the sample life distribution rather well. The Weibull cumulative distribution function is

$$F(t) = 1 - \exp\left(-\left(\frac{t}{\beta\tau}\right)^{\alpha\tau}\right) \quad (9)$$

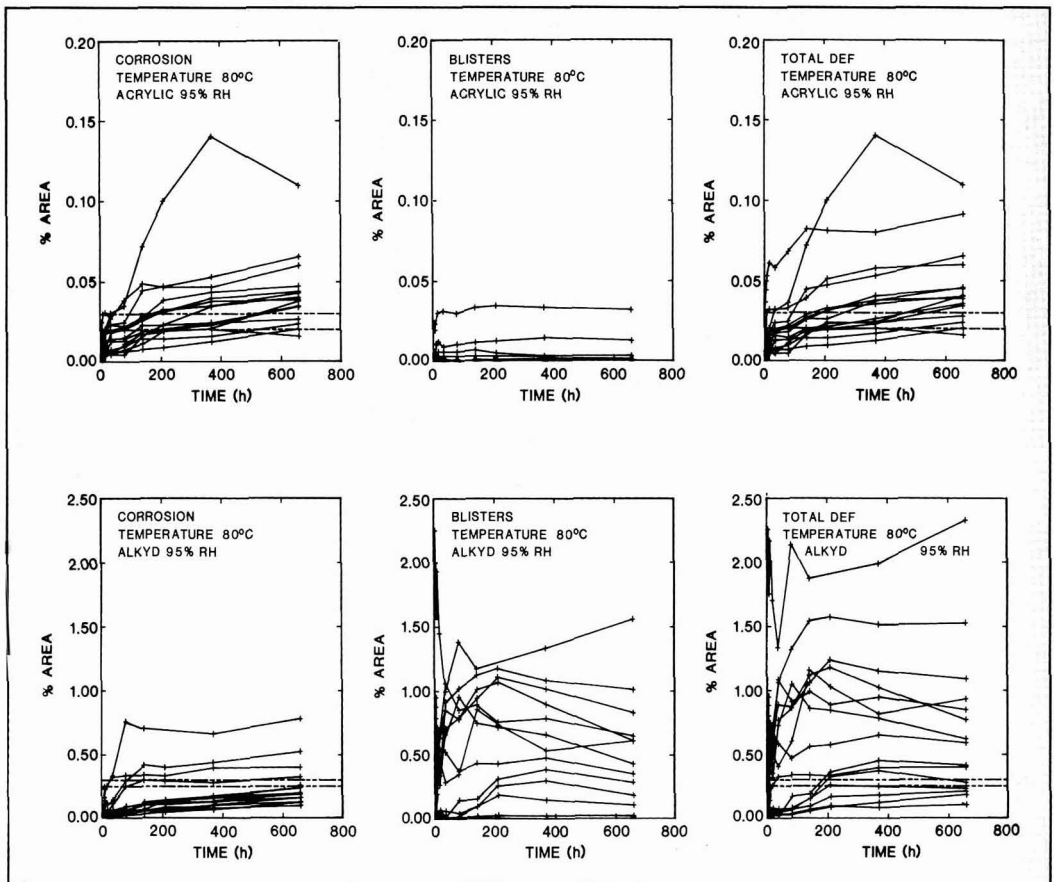


Figure 4—Change in percent area corrosion, blister, and corrosion plus blister as a function of time for the acrylic and alkyd panels subjected to 80°C and 95% RH

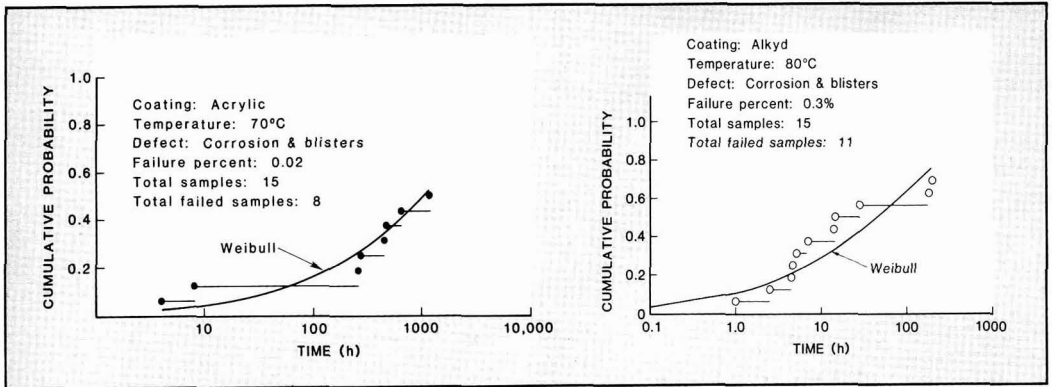


Figure 5—Life distributions for (a) the acrylic coating system subjected to 70° C and 95% RH; failure criterion was 0.02% area corrosion plus blisters; and (b) the alkyd coating system subjected to 80° C and 95% RH; failure criterion was 0.30% area corrosion plus blisters

where α_T and $\beta_T > 0$ and α_T is the shape parameter at temperature T and 95% RH and β_T is the scale parameter for the same conditions. The Weibull life distribution curve is superimposed on two different sample life distributions in Figure 5. Values for the Weibull shape parameter, α_T , and scale parameter, β_T , are tabulated in Table 2 for corrosion plus blisters for both coating systems. In all cases, the fit of the Weibull distribution function was as good as that in Figure 5, indicating that a Weibull distribution adequately describes the times to failure for both coating systems.

The maximum service life, t_{s1} , for the two coating systems can be computed from the life distributions. After designating the fraction of panels which are allowed to fail, λ , one can compute the maximum service life by solving equation (9) for t; that is,

$$t_{s1} = \beta_T [-\ln(1-\lambda)]^{1/\alpha_T} \tag{10}$$

For example, the maximum service life for the acrylic at 60°, 70°, and 80°C is 1958 hr, 251 hr, and 8 hr, respectively, using 0.03% corrosion plus blisters as the failure criterion and letting λ equal 0.05. These service

Table 1—Times to Failure for Acrylic Panels Subjected to 70° C and 95% Relative Humidity and Alkyd Panels Subjected to 80° C and 95% Relative Humidity (All Times to Failure Are for Corrosion Plus Blisters)

| Ordered Time to Failure Index | Acrylic | | Alkyd | |
|-------------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| | Defect Percent = 0.02% (hr) | Defect Percent = 0.03% (hr) | Defect Percent = 0.25% (hr) | Defect Percent = 0.30% (hr) |
| 1 | 4.0 | 386.0 | 1.0 | 1.0 |
| 2 | 8.0 | 390.3 | 2.2 | 2.5 |
| 3 | 263.0 | 508.5 | 3.8 | 4.5 |
| 4 | 271.0 | 517.0 | 4.1 | 4.7 |
| 5 | 449.0 | 538.3 | 4.5 | 5.2 |
| 6 | 462.0 | 779.8 | 5.7 | 7.0 |
| 7 | 644.0 | 1153.3 | 6.3 | 14.0 |
| 8 | 1178.0 | — | 11.6 | 14.5 |
| 9 | — ^a | — | 11.6 | 28.6 |
| 10 | — | — | 156.0 | 184.0 |
| 11 | — | — | 169.0 | 200.0 |
| 12 | — | — | 181.0 | — |
| 13 | — | — | — | — |
| 14 | — | — | — | — |
| 15 | — | — | — | — |
| No. specimens tested | 15 | 15 | 15 | 15 |
| No. specimens failed | 8 | 7 | 12 | 11 |
| Max. exposure time | 1505 | 1505 | 660 | 660 |

(a) — Indicates panel did not fail during life test.

Table 2—Weibull Parametric Estimates for Acrylic and Alkyd Coating Systems for Corrosion Plus Blisters

| | Acrylic | | | | | | Alkyd | | | | | |
|-------------------------------|------------------------|--------|--------|------------------------|--------|--------|------------------------|--------|--------|------------------------|--------|--------|
| | Defect Percent = 0.02% | | | Defect Percent = 0.03% | | | Defect Percent = 0.25% | | | Defect Percent = 0.30% | | |
| | 60°C | 70°C | 80°C | 60°C | 70°C | 80°C | 60°C | 70°C | 80°C | 60°C | 70°C | 80°C |
| No. panels tested | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| No. panels failed | 11 | 8 | 14 | 3 | 7 | 11 | 4 | 10 | 12 | 3 | 10 | 11 |
| Weibull shape α_T | 2.97 | 0.58 | 0.71 | 4.58 | 1.67 | 0.74 | 1.75 | 0.46 | 0.49 | 10.00 | 0.53 | 0.47 |
| Weight assigned to α_T | (1.70) | (1.26) | (2.26) | (0.23) | (1.16) | (1.70) | (.51) | (1.55) | (1.86) | (0.23) | (1.55) | (1.70) |
| Weibull scale β_T | 2810. | 1969. | 169. | 3745. | 1486. | 431. | 5034. | 871. | 69. | 3056. | 1056. | 98. |
| Weight assigned to β_T | (3.36) | (3.36) | (3.02) | (2.05) | (3.27) | (3.36) | (2.54) | (3.51) | (2.83) | (2.05) | (3.51) | (3.36) |

lives are computed using equation (10) and the tabulated α_T and β_T values in Table 2.

For corrosion and corrosion plus blisters, the logarithm of the Weibull scale parameter, β_T , is a linear function of the reciprocal of the absolute temperature; that is,

$$\log_{10} \beta_T = a + b(1/T) \tag{11}$$

where a and b are the coefficients of the Arrhenius model. Several examples are plotted in Figure 6. In Figure 6, two numbers in parentheses are located by each sample parametric estimate. The first number indicates the number of panels on test, while the second number indicates the number of observed failures. When the same number of panels is put on test at all temperature levels, the confidence in the parametric estimate decreases with decreasing number of observed times to failure, as can be seen in Table 3. Weighted least squares regression coefficients, a and b, and the correlation coefficients are tabulated in Table 4. In Table 4, the relationships between the scale parameter and reciprocal absolute temperature are nearly linear for both coating systems. This is important, for it implies that the equations relating the applied stress to coating system performance may have

the same mathematical form for different coating systems, differing only in the values of their coefficients.

For corrosion and corrosion plus blisters (at least in the range of the experimental temperatures), a power law adequately describes the relationship between the Weibull shape parameter, α_T , and temperature; that is

$$\alpha_T = cT^d \tag{12}$$

where c and d are the coefficients of the power law. Several examples are plotted in Figure 7 and the weighted least squares regression and correlation coefficients are tabulated in Table 3. Note, from Figure 7 and Appendix A, that the probability density function at the highest temperature has a mode equal to zero for both the acrylic and the alkyd, since the shape parameter has a value less than one. As the temperature decreases, however, the shape parameter becomes greater than one; thus, the mode of the distribution is greater than zero. This increase in the value of the mode with decreasing temperature is expected since the most probable failure time is generally greater than zero at low temperatures. However, the exponential growth of the shape parameter with decreasing temperature, as predicted by the power law is not

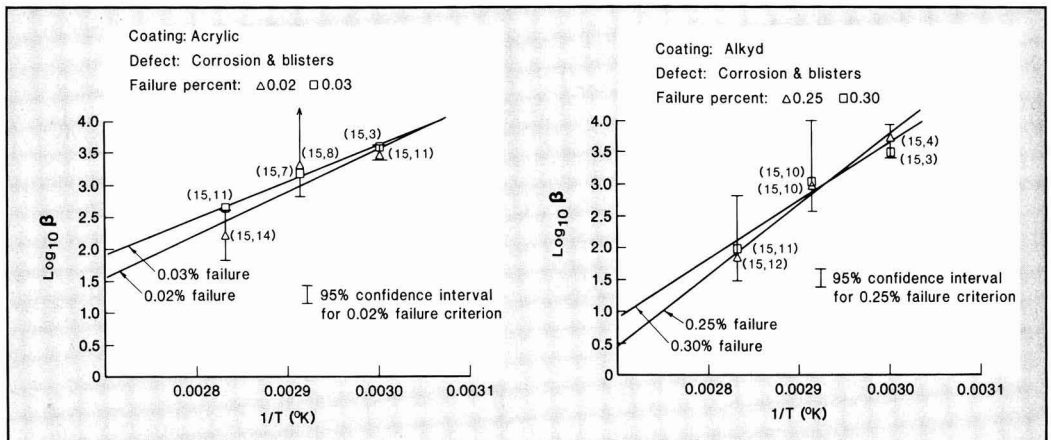


Figure 6—Regression line of common logarithm of the Weibull scale parameter vs reciprocal absolute temperature: (a) acrylic coating with failure criteria 0.02% and 0.03% corrosion plus blisters, and (b) alkyd coating with failure criteria 0.25% and 0.30% corrosion plus blisters

Table 3—Lower and Upper 95% Confidence Bounds Assuming Both the Shape and Scale Parameter Of the Weibull Distribution Are Unknown

| Coating and Failure Criterion (Corrosion plus blisters) | Scale Parameter (β) | | | Shape Parameter (α) | | |
|--|-----------------------------|-------------|-------------|------------------------------|-------------|-------------|
| | Scale Estimate | Lower Bound | Upper Bound | Shape Estimate | Lower Bound | Upper Bound |
| (1) Acrylic, 0.02% defect | | | | | | |
| 60°C | 2810. | 2328. | 3846. | 2.97 | 1.48 | 4.20 |
| 70°C | 1969. | 680. | 28,086. | .58 | .22 | .94 |
| 80°C | 169. | 66. | 424. | .71 | .41 | 1.01 |
| (2) Acrylic, 0.03% defect | | | | | | |
| 60°C | 3745. | 3065. | 26,420. | 4.58 | .59 | 8.87 |
| 70°C | 1486. | 1005. | 4992. | 1.67 | .63 | 2.67 |
| 80°C | 431. | 203. | 1520. | .74 | .37 | 1.05 |
| (3) Alkyd, 0.25% defect | | | | | | |
| 60°C | 5034. | 2793. | 319,680. | 1.75 | .24 | 3.07 |
| 70°C | 871. | 229. | 12,098. | .46 | .21 | .71 |
| 80°C | 69. | 20. | 386. | .49 | .25 | .70 |
| (4) Alkyd, 0.30% defect | | | | | | |
| 60°C | 3056. | 2788. | 7478. | 10.00 | 1.29 | 19.36 |
| 70°C | 1056. | 331. | 10,366. | .53 | .24 | .82 |
| 80°C | 98. | 30. | 714. | .47 | .23 | .67 |

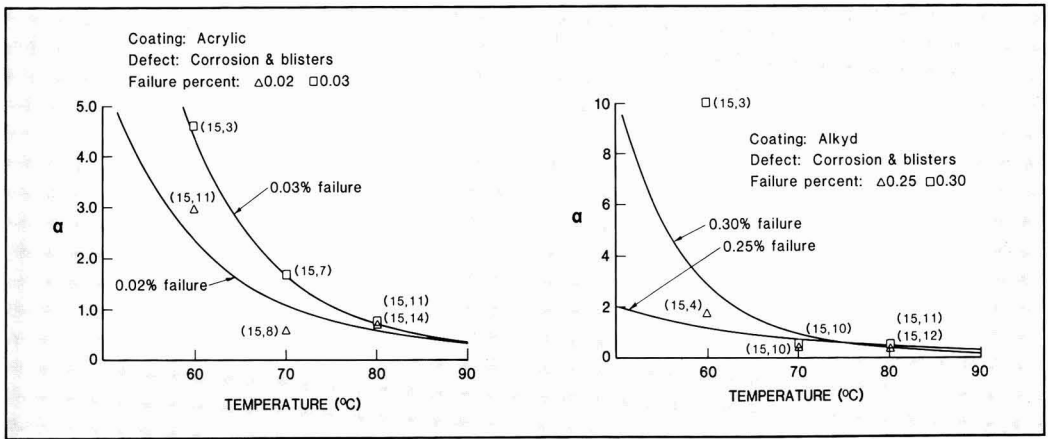


Figure 7—Power law regression fit of Weibull shape parameter vs temperature: (a) acrylic coating with failure criteria of 0.02% and 0.03% corrosion plus blisters, and (b) alkyd coating with failure criteria of 0.25% and 0.30% corrosion plus blisters

Table 4—Weighted Linear Regression Coefficient for Regression Line of Weibull Shape And Scale Parameter vs Temperature for Acrylic and Alkyd Coatings

| Coating and Failure Criterion | Weibull Scale $\log_{10}\beta = a + b(1/T)$ | | | Weibull Shape $\alpha = cT^d$ | | |
|--|---|--------|---------------------------|-------------------------------|-------|---------------------------|
| | Coefficients | | Correlation Coefficient r | Coefficients | | Correlation Coefficient r |
| | a | b | | c | d | |
| (1) Acrylic, 0.02% corrosion plus blisters | -16.4 | 6644. | 0.89 | 1.25×10^9 | -4.91 | 0.84 |
| (2) Acrylic, 0.03% corrosion plus blisters | -13.2 | 5611. | 0.99 | 5.94×10^{11} | -6.26 | 0.99 |
| (3) Acrylic, 0.03% corrosion plus blisters | -15.4 | 6365. | 0.99 | 2.96×10^5 | -2.84 | 0.98 |
| (4) Alkyd, 0.25% corrosion plus blisters | -29.3 | 11019. | 0.99 | 1.11×10^6 | -3.37 | 0.75 |
| (5) Alkyd, 0.30% corrosion plus blisters | -23.6 | 9073. | 0.97 | 2.06×10^{13} | -7.23 | 0.76 |

expected because as the shape parameter increases, the Weibull probability density function becomes more attenuated (see Appendix A). If the power law fit is used the shape parameter value at low temperatures would be so high that it would attenuate the Weibull probability density function to the point where the maximum service lives at different failure proportions would converge. (This is shown in the probability of failure-temperature-time to failure diagram in Figure 8). For this reason, the accuracy of the power law fit at low temperature is suspect. One way to resolve this problem is to conduct life tests at low temperatures and to determine the Weibull parameter values.

By substituting equations (11) and (12) into equation (10), the maximum service life can be computed as a function of temperature and λ . When these computations are plotted as a function of temperature and exposure time, the result is a probability of failure-temperature-time to failure diagram (see Figure 8). The probability of failure-temperature-time to failure diagram gives the maximum service life at each temperature and at each survival probability, $1-\lambda$. As an example, the maximum service life at 99% survival and 50° C for the alkyd (failure criterion, 0.30% corrosion plus blisters) is computed to be 20000 hr or just over 2-1/4 years. The importance of this diagram is its value in both predicting the maximum service life for a coating system and making selections between coating systems. This diagram can be generalized to include other stress conditions (e.g., Martin¹⁰). For this reason, the generalized diagram should be referred to as a probability of failure-stress-time to failure diagram.

SUMMARY AND CONCLUSIONS

The capabilities of reliability theory and life testing analysis are investigated for predicting the service lives of two coating systems subjected to 95% RH over a range of temperatures. To this end, an experiment was designed, executed, and the data analyzed in conformance with reliability analysis techniques. From this analysis, it is concluded that the proposed procedure is capable of quantitatively predicting the maximum service life at 95% RH over a wide range of temperatures such that a specified percent, $1-\lambda$, of a nominal coating system population will survive. The success of this analysis is important in demonstrating that the procedure is capable of:

- handling the large variations in times to failure inherent in coating systems,
- drawing from relevant aspects of statistical theory,
- addressing the service life prediction problem in a format germane to engineers and scientists, and
- placing the parameters of the life prediction model in terms of the chemical kinetics of coating system degradation.

Specific results of this research which should be highlighted include:

- the Weibull distribution adequately describes the times to failure of the two coatings at 95% RH for the three temperature levels studied.

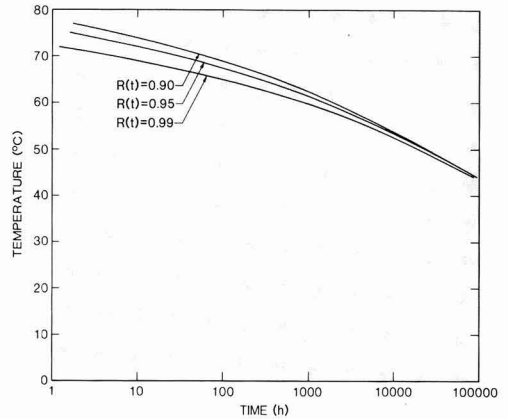


Figure 8—Probability of failure-temperature-time to failure diagram for alkyd coating. Failure criteria was 0.30% corrosion plus blisters

- the Weibull scale parameter is related to reciprocal absolute temperature via an Arrhenius model.
- for both the scale and the shape parameter, the form of the dependence on temperature is the same for both coating systems. Only the values of the parameters differ.

Since these results are applicable to two coating systems which are very different chemically they may be generally applicable to all organic coating systems.

ACKNOWLEDGMENTS

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APPENDIX A: Weibull Distribution

The Weibull distribution was originally proposed by Fisher and Tippett¹¹ in 1928 as the third asymptotic distribution of minimum values. The name Weibull was affixed to the distribution because Waloddi Weibull recognized the importance of the distribution and widely applied it to many engineering problems. At present, the Weibull distribution has "emerged as the most popular parametric family of failure distributions."³

The Weibull cumulative distribution function is given by

$$F(t) = 1 - \exp(-(t/\beta)^\alpha) \quad (A1)$$

for $t > 0$ and the probability density function is given by

$$f(t) = (\alpha/\beta)(t/\beta)^{\alpha-1} \exp(-(t/\beta)^\alpha) \quad (A2)$$

where α , β and $t > 0$. In equations A1 and A2, α is the shape parameter and β is the scale parameter. Plots of the Weibull probability density function, $f(t)$, are given in Figure A1. Note that changes in the scale parameter, β , tend to move the distribution horizontally along the time axis (the abscissa). The greater the value of β , the further out the density function is pushed. Changes in the shape parameter, α , tend to attenuate the distribution. For shape parameter values greater than one, the mode of the distribution is greater than zero. For values less than or equal to one, the mode of the distribution is zero. For a shape parameter equal to one, the Weibull distribution is identical to the exponential distribution.

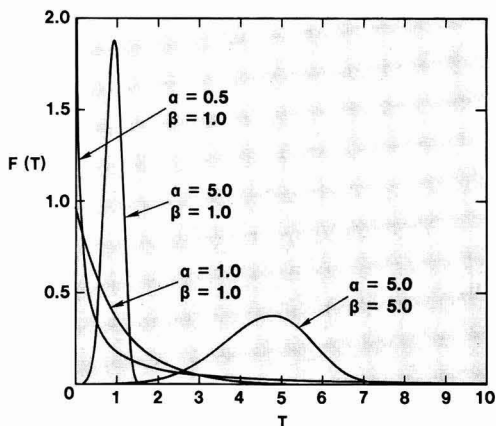


Figure A1—Weibull probability density function plots for different shape and scale parameter values

A wide variety of parametric estimators are available for the Weibull shape and scale parameters. Parametric estimates can be made for samples with or without censoring (a sample is said to be censored if not all of the experimental units fail during the experimentation period). In this paper, the parameters were estimated using maximum likelihood estimates.^{2,3}

ABBREVIATIONS AND LIST OF SYMBOLS

- $\exp = e^x$, where e is the base of the natural system of logarithms
- $F(t; \theta)$ = cumulative distribution function with parameter space θ
- $F_i(t)$ = shortened notation for cumulative distribution function $F(t; \theta)$ at the i -th stress level (life distribution at stress level i)
- \ln = natural logarithm
- $P(\cdot)$ = probability of the event described within the parenthesis
- $R_i(t)$ = reliability function at the i -th stress level
- RH = relative humidity
- α_T = Weibull shape parameter at absolute temperature of interest
- β_T = Weibull scale parameter at temperature of interest
- θ = life distribution parameter space
- λ = failure proportion

- $\rho(t; \theta)$ = time transformation function
- τ = random variable
- $\psi(S, \theta)$ = generalized acceleration factor
- a, b, c, d = empirical constants
- i = stress level index
- j = panel index
- m = number of stress level
- n_i = number of panels tested at the i -th stress level
- S_i = i -th stress level
- t = time
- t_{ij} = j -th ordered time to failure at the i -th stress level
- t_{s1} = maximum service life
- T = temperature
- T_o = reference temperature

Prediction of the Service Life Of Coatings on Steel Part III: Categorizing the Performance Of Coating Systems on the Basis Of Their Corrosion and Blister Patterns

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National Bureau of Standards*

The spatial pattern of defects (corrosion and blister spots) resulting from the aging of coating systems and the scale of clustering of these defects are quantitatively determined for a clear acrylic and a pigmented alkyd coating system. For the acrylic, it is established that defects are randomly distributed over the surface of the steel test panels, whereas for the alkyd, the defects are clustered. For the two coating systems studied, a clear distinction exists between their defect spatial patterns. This suggests that an index based on the defect spatial pattern may be useful for categorizing the in-service degradation of different coating systems.

INTRODUCTION

When coated steel panels are exposed to an adverse environment, they degrade. This degradation is marked by the formation of corrosion and blister spots (defects) over the surface of the panels. For panels coated with the same coating and exposed to the same adverse environment, the spatial arrangement of defects is usually similar. For panels coated with different coatings, however, the spatial arrangements of defects are often dissimilar. This implies that the pattern of defects may be controlled by

intrinsic chemical and physical properties of a coating system (a coating system, as defined here, is the collective characteristics of the coating, substrate, and interface). Hence, it may be possible to index spatial arrangements of defects for categorizing the performance of coating systems and for determining the causes and mechanisms of coating failures. This general approach has proved to be successful in other disciplines.^{1,2} It has not been applied to coating degradation, however.

SPATIAL ANALYSIS THEORY

Defect arrangements (*Figure 1*) can be categorized into one of three basic patterns as follows: (1) regular, (2) random, and (3) clustered.

In nature, few examples have been reported where objects have a regular spatial arrangement.¹ Based on the few cases where a regular pattern has been observed,¹ one would expect regular arrangements of defects to occur on a coating system if there is a systematic distribution of nucleation sites over the surface of a test panel, or competition for a small amount of remaining space on a panel resulting from the large number of defects already present on the panel.

In a random spatial arrangement, the position of a defect is independent of the position of all other defects on the surface of the panel; that is, knowledge of the location of a particular defect yields no information on the location of any other defects. Because of this independence property, a random spatial arrangement of

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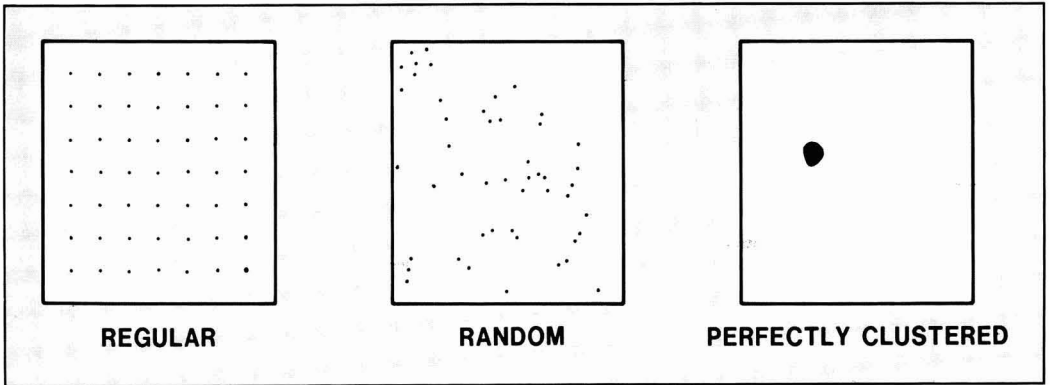


Figure 1—Basic types of defect spatial arrangements

defects is often very difficult to relate to any specific coating system property. For a random arrangement of defects to occur, one would expect that the physical and chemical properties would have to be very uniform and homogeneous over the entire surface of the coating system.

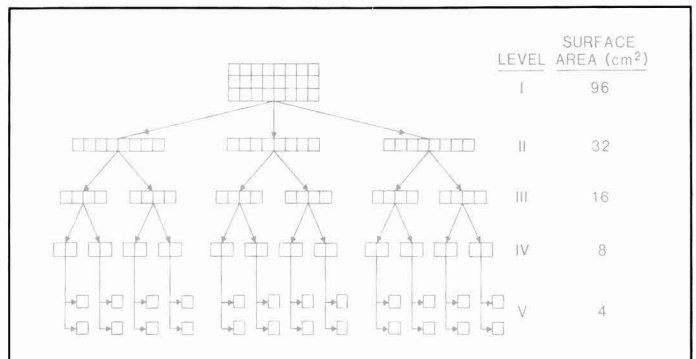
For a clustered arrangement, in contrast to a random arrangement, the position of a defect is dependent on the position of other defects. Many possible cluster patterns exist. In the extreme (Figure 1), defects are perfectly clustered; that is, all defects are grouped into a small tight mass on the surface of the panel. The average area that circumscribes the defects can be used to further characterize cluster patterns. A measure of this is the scale of clustering. For a coating system displaying superclustering, at least two scales of clustering are needed. The first characterizes the surface area covered by the individual defects while the second characterizes the surface area covered by the clusters. Estimates of the different scales of clustering are important, because they can be useful in helping to isolate the possible causes and mechanisms of coating failure. This can be accomplished by surveying the chemical and physical properties of the coating system to find those properties operating at the same scale as that of the defects. If these properties superimpose on the defect sites, then a possible causative agent for defects has been identified.

Although these descriptive presentations are useful, they must be converted into a mathematical equivalent in order to perform any meaningful analysis. This is done through the use of an index. The mathematical basis for this index is as follows.

In a random arrangement, it is assumed that the properties of a coating system are homogeneous over a surface area, *S*. This area, *S*, is divided into *n* identical subregions each having surface area *s*, where *s* = *S*/*n*. (Theoretically, it does not matter whether the subregions are identical in shape or equal in size. It is important that the sizes of the defects are small, relative to that of the sampling areas³). The panel is then placed into an adverse environment for a prespecified exposure time after which it is removed and evaluated to determine the number and type of defects in each subregion. Assume that *m* defects are observed and are randomly distributed over *S*. It can be argued that, relative to the number of possible defect sites in *S*, the number of observed defects, *m*, is very small; thus the probability that any of these sites is occupied is small. Since the number of possible sites is very large and the probability that any one site will be occupied is very small, it can easily be shown,⁴⁻⁶ via a binomial distribution, that the occurrence of exactly *k* defects (*k* ≤ *m*) in any subregion is a Poisson variate with distribution

$$P(k;\lambda s) = \frac{e^{-\lambda s}(\lambda s)^k}{k!} \text{ for } k = 0, 1, 2, \dots \quad (1)$$

Figure 2—Nested analysis of variance hierarchy



where

$P(k; \lambda s)$ is the probability of observing exactly k defects in a subregion s ; and

λ is the expected number of defects in subregion s .

The expected number and the variance of the defects in subregion s are determined from equation (1). The expected number of defects, $E(k)$, or the mean number of observed defects in subregion s , is given by

$$E(k) = \lambda s \quad (2)$$

and the variance of the number of observed defects in this subregion is given by

$$\text{var}(k) = \lambda s. \quad (3)$$

Hence, for a random arrangement of defects, the mean and the variance of the number of defects in a subregion are identical.

The var-mean ratio,⁷ which is obtained by dividing the variance by the mean number of defects, provides a convenient index for classifying the three types of defect spatial arrangements. Thus, for a random spatial arrangement of defects, the

$$\text{var-mean ratio} = 1. \quad (4)$$

For a regular spatial arrangement of defects, the

$$\text{var-mean ratio} < 1 \quad (5)$$

and for a clustered pattern, the

$$\text{var-mean ratio} > 1. \quad (6)$$

The var-mean ratio for a clustered pattern ranges from a value greater than one to infinity. In general, as the var-mean ratio increases, the defects become more clustered. As the var-mean ratio approaches infinity, the defects become perfectly clustered.

The var-mean ratio is not the only possible index.⁵ Many other indices are available and are often used to complement the var-mean ratio index. This is advantageous, because each index measures a slightly different attribute of the spatial arrangement. Regardless of which index or combination of indices is used, however, they all have at least two weaknesses, which are:

- (1) index results are greatly affected by the size of the sampling subregion⁸; and
- (2) the indices do not provide an indication of the scale of clustering.

Since the estimate of the scale of clustering is important for helping to isolate possible causes and mechanisms of failure, this latter deficiency is critical in that it does not provide information which would be useful in determining the causes of coating system failures.

These deficiencies can be corrected through the use of a nested analysis of variance procedure.⁹⁻¹¹ (For this analysis, a square panel is better than a rectangle, since the blocks at each level are always formed by dividing by two and, more importantly, a square can only be sectioned in one way; while a rectangle can be sectioned in several different ways⁹). In the nested analysis of variance procedure, a hierarchy of sampling blocks (Figure 2) is created such that (1) the size and shape of the blocks at every level are identical, (2) the blocks at any level can be connected to form the block at a lower level, and (3) the

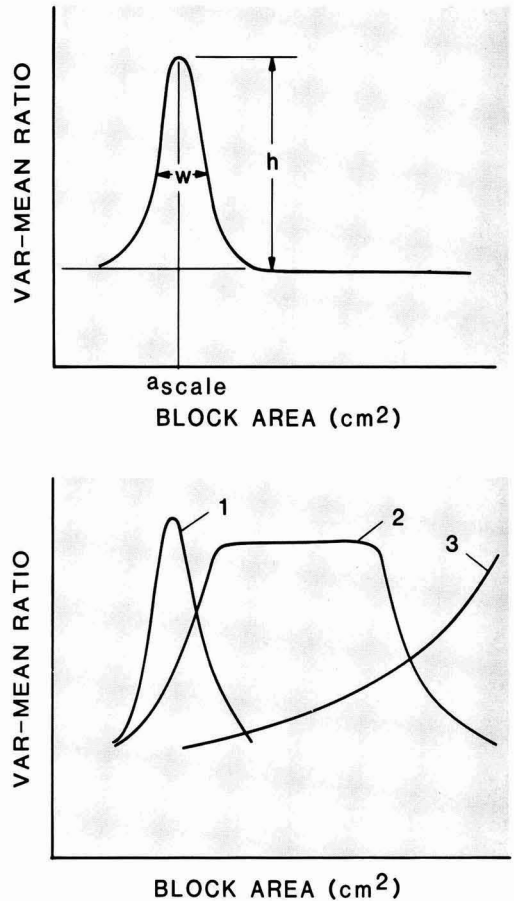


Figure 3—Hypothetical scale of clustering vs time curves

total area of all of the blocks at each hierarchy level is the same, but the number of blocks vary. As seen in Figure 2, the lowest level in the hierarchy is the sample grid pattern used in evaluating the coated panels (see Experimental Procedure). To get the next higher level in the hierarchy, the grid is divided into two or more adjacent groups of blocks, each group having the same size and shape as every other one at that level. This separation process continues until only the elemental blocks remain.

Once the hierarchy of blocks has been established, the mean and variance of the number of defects (corrosion, blisters, or corrosion plus blisters) is computed at every level. The mean number of defects per unit area is the same at every level. The variance, however, depends on the spatial arrangement of defects. In the case of a random arrangement of defects, the variance is equal to the mean number of defects at every level; thus, the var-mean ratio is always one. If defects are clustered, however, the variance differs from one hierarchy level (block area) to another. The block area, at which the variance is at its maximum, is equal to the scale of clustering.^{8,12} This has been verified via simulations.^{12,13} The scale of clustering can be graphically determined by

plotting the var-mean ratio vs block area (Figure 3). This diagram can be characterized by three parameters as follows: (1) the scale of clustering, a_{scale} , (2) the intensity of the peak at the scale of clustering, h , and (3) the half-width range in block size area over which clustering occurs, w . In Figure 3, three hypothetical var-mean ratio vs block size area curves are plotted. In curve 1, the intensity of the peak is very sharp and the half width size is narrow. This indicates that the defects are clumped into clusters of one size having a scale of clustering equal to a_{scale} . In curve 2, the intensity peak is high, but the half-width is broad indicating that clustering is occurring over several block sizes. A broad half-width is usually indicative of superclustering. In curve 3, clustering is occurring, but at a block area greater than that sampled.

The nested analysis of variance procedure has proved to be very useful in many technical disciplines.⁷ This analysis procedure is not without its weaknesses, however. As one goes toward the lower levels in the hierarchy (larger block sizes), fewer degrees of freedom are available for determining the variance. As the degrees of freedom decrease, the level of confidence in the estimate of the variance decreases; consequently, for large block areas, a maximum may be observed when, in fact, it is not a true maximum.^{7,14} Even with this weakness, the analysis procedure can be justified because it gives consistent, reproducible results in many applications⁷ and in ecology, the scale of clustering has been successfully correlated with both environmental and species factors.¹

EXPERIMENTAL PROCEDURE

The experimental procedure was described in detail by Martin and McKnight in previous reports.¹⁵⁻¹⁶ The parts of the experiment which are relevant to the proposed procedure are highlighted.

In this experiment, two coatings were subjected to three temperature/relative humidity environments for exposure times up to 3000 hr. The two coatings were a clear acrylic and a pigmented alkyd. Both coatings were similar to commercial formulations. Both coatings were applied by a flat blade film applicator in a single pass to a thickness of 50 μm over sandblasted, hot-rolled, steel plate substrates having a surface profile between 51 and 127 μm

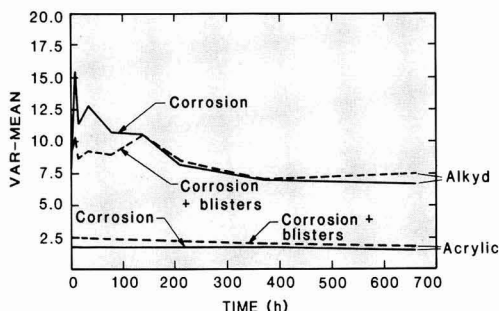


Figure 4—Var-mean ratio vs time for corrosion plus blisters for the alkyd and the acrylic coating systems exposed at 80°C and 95% RH

(2 to 5 mils). The application procedures were the same for both coatings. After curing for at least four weeks at approximately 22°C and 45% relative humidity (RH), the panels were subjected to one of three temperatures (60°, 70°, and 80°C) and 95% RH.

For each temperature/RH level and for each coating type, a set of 15 panels was randomly selected (2 coating types \times 3 temperature levels \times 15 panels = 90 panels). Each set of panels was exposed in a relative humidity cabinet for a predetermined period of time. At the end of this interval, the panels were removed, evaluated, and then put back into the humidity cabinet. This procedure was repeated up to 11 times throughout the exposure.

The panels were visually evaluated by placing a transparent grid over each test panel.¹⁵ The grid was sectioned into a 3 \times 8 matrix of square blocks, each block having dimensions of 20 mm \times 20 mm. The grid was located using a hole in the border of the panel as a reference point. This hole ensured that all of the 24 blocks covered the same area from one evaluation to another. During each evaluation, the number, size, and type of defect were tabulated in each block for every panel. For the proposed spatial analysis, only the number of defects and their location are important. The locations of the defects were known from the block number.

RESULTS AND DISCUSSION

The var-mean ratio was computed for each coating system, defect type (corrosion and corrosion plus blisters), temperature, and exposure time. This index was then plotted against time for the two different coating systems and for both defect types. Two typical plots are displayed in Figures 4 and 5. Figures 4 and 5 show that defects in the acrylic system are randomly distributed (var-mean ratio value is close to one), whereas defects in the alkyd coating system are clustered (var-mean ratio value is far greater than one). Hence, for the two coating systems studied, the differences in the spatial arrangement of defects are distinct. In comparing changes in the var-mean ratio over time for corrosion with that of corrosion plus blisters, it was invariably found that the two trends followed each other very closely (Figure 4). Hence, knowledge of the trend for one appears to be an adequate predictor for the other.

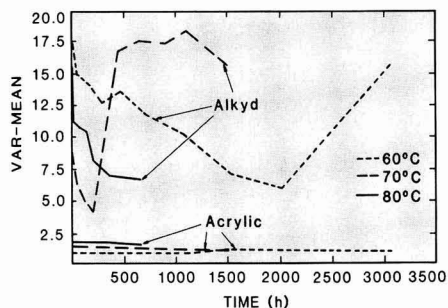


Figure 5—Var-mean ratio vs time for corrosion at three temperatures

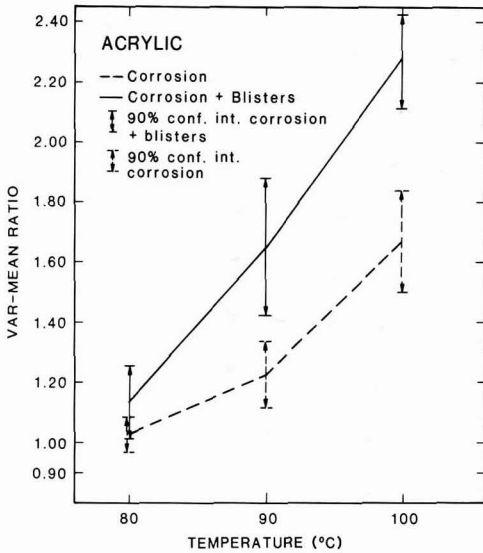


Figure 6—Average var-mean ratio vs temperature for the acrylic coating

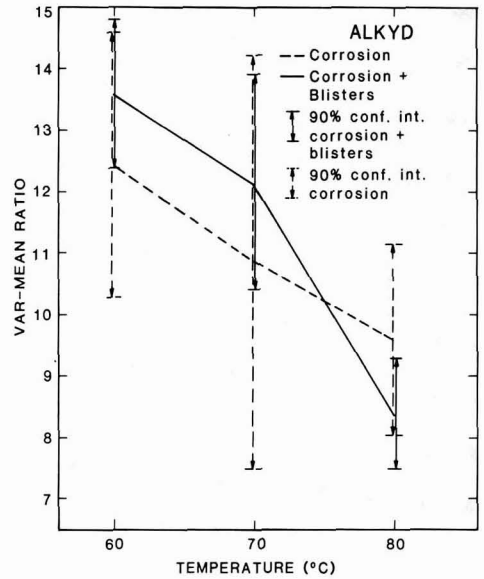


Figure 7—Average var-mean ratio vs temperature for the alkyd coating

From Figure 5, a linear model of the form

$$\text{var-mean ratio} = a + b \times \text{time}, \tag{7}$$

where *a* and *b* are empirical constants, adequately describes changes in the var-mean ratio with time for all temperatures for the acrylic coating system. For the alkyd coating system, changes in the var-mean ratio over time are more complex since the trends are not consistent from one temperature to another. Lacking a better model, however, equation (7) was used in modeling changes in the var-mean ratio of the alkyd coating defects over time. It was hypothesized that the slope, *b*, of the var-mean ratio is zero. This hypothesis was tested using appropriate linear regression techniques. In the majority of the cases, this hypothesis could not be rejected. The following are exceptions. For the acrylic coating, a negative slope for corrosion plus blisters is significant at 70° and 80° C. For the alkyd coating system, a positive slope for the corrosion and corrosion plus blisters is significant at 70° C.

Since the hypothesis of zero slope was usually true, the average var-mean ratio was determined for each coating, defect type, and temperature from all exposure times. These average var-mean ratios for corrosion and corrosion plus blisters are tabulated in Table 1 and are plotted vs temperature in Figures 6 and 7. A 90% confidence band is located around each average var-mean ratio. For the acrylic coating system, the average var-mean ratio tends to increase with increasing temperature; that is, the defects change from a random pattern to one which borders on being slightly clustered. For the alkyd coating system, the average var-mean ratio tends to decrease; that is, the defects tend to change from being very clustered to being less clustered. At this time, sufficient data is not available to give a plausible explanation for these phenomena.

The scale of clustering was determined for the alkyd coating system using a nested analysis of variance procedure. This was done for a hierarchical design like that depicted in Figure 2. The alkyd var-mean ratio vs block size diagrams for corrosion plus blisters are displayed in Figure 8 for all exposure times at all three temperatures. From Figure 8, two maximums are observed. The first occurs around 8 to 16 cm², while the second occurs at a block size area greater than 96 cm² (the maximum size of the test panel). The smaller scale of clustering (8 to 16 cm²) is observed at all treatment levels. The larger clustering scale (greater than 96 cm²) is not as consistent, especially at the 70° C exposure. From Figure 3, the first scale of clustering describes the surface area covered by the individual defects while the second scale of clustering (superclustering) describes the surface area covered by the cluster groups. The inconsistency of the superclustering scale for different exposure times can not

Table 1—Average Var-mean Ratio for Two Coating Systems On Steel by Defect Type and Temperature

| Defect Type | Acrylic | | | Alkyd | |
|---|------------|---------------------|-----------|---------------------|-----------|
| | Temp. (°C) | Avg. Var-mean Ratio | Std. Dev. | Avg. Var-mean Ratio | Std. Dev. |
| (1) Corrosion 60 | | 1.03 | 0.11 | 12.42 | 3.73 |
| (2) Corrosion 70 | | 1.23 | 0.20 | 10.86 | 6.16 |
| (3) Corrosion 80 | | 1.67 | 0.31 | 9.58 | 2.85 |
| (4) Corrosion plus . . . 60 blisters | | 1.14 | 0.20 | 13.59 | 2.07 |
| (5) Corrosion plus . . . 70 blisters | | 1.65 | 0.42 | 12.15 | 3.21 |
| (6) Corrosion plus . . . 80 blisters | | 2.27 | 0.28 | 8.36 | 1.63 |

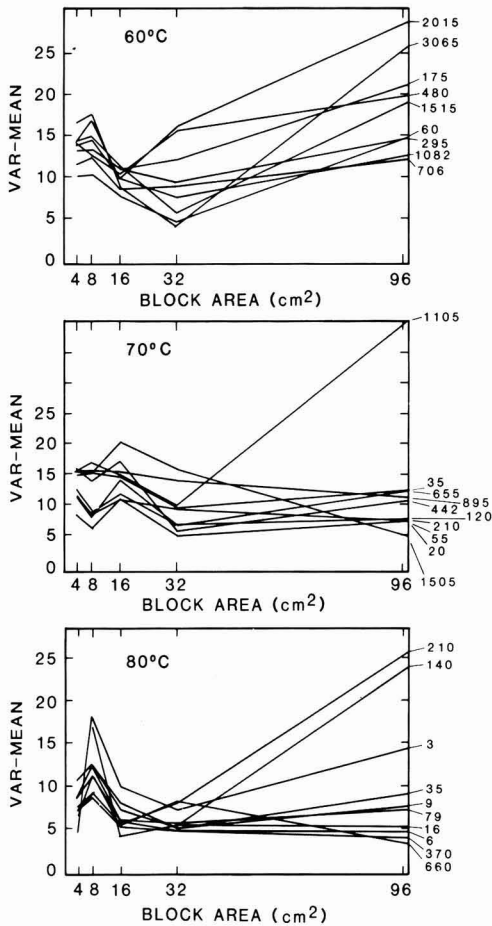


Figure 8—Corrosion scale of clustering curves at different exposure times for the alkyd coating exposed at 60°, 70°, and 80° C and 95% RH

be explained at this time. It is felt that a square test panel with greater surface area would have been more useful in studying this superclustering phenomenon.

SUMMARY AND CONCLUSIONS

The spatial arrangement of corrosion and blister spots over the surface of a panel appears to be characteristic to both the coating system and the environment to which the coated panels are exposed. For this reason, a morphometric transformation of the spatial arrangement of defects may be useful in categorizing the degradation of different coating systems. One such morphometric transformation is the variance-to-mean ratio (var-mean ratio). The var-mean ratio separates spatial patterns into three distinct classes—regular, random, and clustered. For clustered arrangements, it is important to determine the scale of clustering; that is, to have a measure of the surface area covered by an individual cluster. This descriptor should be useful in determining the causes and mecha-

nisms of coating failure by helping to isolate those chemical and physical properties of a coating system which have the same scale as the scale of clustering. An estimate of the scale of clustering can be obtained through nested analysis of variance techniques.

In this study, the spatial pattern and the scale of clustering were determined for two different coating systems—an acrylic and an alkyd. Panels from both systems were exposed to one of three temperatures (60°, 70°, and 80° C) and 95% RH. The spatial analysis results of this experiment are as follows:

- (1) For short exposure times, the spots of corrosion and corrosion plus blisters on the acrylic coating appear to be randomly distributed over the surfaces of the panels, whereas defects on the alkyd coating system are clustered.
- (2) With increased exposure time, the arrangement of defects for the acrylic coating system shows either no significant change in the original var-mean ratio or becomes slightly clustered. For the alkyd coating, the arrangement of defects either displays no change or becomes less clustered.
- (3) Changes over time in the var-mean ratio for corrosion spots closely follow changes in the var-mean ratio for corrosion plus blister, implying that monitoring either might often be sufficient for predicting the trend of the other.
- (4) Finally, for the alkyd coating system, two scales of clustering were identified. The first scale occurs between 8 and 16 cm² and is associated with the surface area individual defects circumscribe. The second scale occurs at a surface area greater than 96 cm² and is associated with the surface area by the individual clusters circumscribe.

It is concluded, therefore, that the proposed spatial analysis techniques provide a useful method for categorizing and predicting the performance of different coating systems with respect to the spatial arrangements of defects, and that the proposed analysis may provide an important tool for identifying the causes of coating degradation.

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SPECIALTY POLYMERS & COMPOSITES

Dissolving Power of Solvents And Solvent Blends for Polymers

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A convenient quantitative definition for the dissolving power, \mathcal{S} , of a solvent for a substance, B, is the difference between the chemical potentials of B in its own phase and in the solution, divided by RT (where R is the gas constant and T is the absolute temperature). When \mathcal{S} is positive, more solute can be dissolved. When \mathcal{S} is negative, phase separation is expected. In the case of polymers, \mathcal{S} can be replaced by \mathcal{S}_m calculated for one repeating unit. According to the prediction method of Hansen using three solubility parameters, \mathcal{S}_m should be proportional to the difference $R_A^2 - 4({}^s\delta_d - {}^p\delta_d)^2 - ({}^s\delta_p - {}^p\delta_p)^2 - ({}^s\delta_h - {}^p\delta_h)^2$ where R_A is the radius of the solute sphere of solubility. In this work a new prediction method based on \mathcal{S}_m is proposed. This method takes into account entropy changes and is based on a more correct treatment of the hydrogen bonds. The new equation giving \mathcal{S}_m contains known characteris-

tics such as the molar volume of the solvent (\bar{V}_s), the molar volume of the repeating unit of the polymer (\bar{V}_m), and the so-called "structuration" factor (b_s), of the solvent, related to the presence or the absence of H-bond chains. This equation also contains a few parameters that must be measured (1) for the solvent: a modified solubility parameter ${}^s\delta'$, determined from the solubility of solid alkanes in the given solvent; and (2) for the polymer: its modified solubility parameter ${}^p\delta'$, a characteristic constant, A , and the stability constants, K , of the hydrogen bonds the polymer can form with the main different groups of solvents.

The predictions of the two methods are compared with the experimental data for three polymers—PVAC, PMMA, and PEMA—in some 25 solvents and their binary blends.

INTRODUCTION

Solvent formulation is a major technical problem in the coatings industry. A solvent blend must have a suitable viscosity, an appropriate evaporation rate, and it must satisfy economic and legislative constraints. But the first criterion for selecting a solvent blend should be its capacity to dissolve the resin. Because of these numerous requirements and the high number of resins and solvents available, the selection of the solvent blends will be best carried out with the aid of a computer program. Solvent characteristics such as viscosity and evaporation rate correspond to well-known concepts and can be presented in numerical terms.

The object of this paper is to propose a quantitative definition of the dissolving power of a solvent for a given polymer on the basis of thermodynamic considerations. We show the way in which this dissolving power is predicted in Hansen's method using three solubility parameters. We propose a new approach for estimating the dissolving power. Finally, we compare the predictions of the two methods with the experimental data.

DISCUSSION

Quantitative Definition for the Dissolving Power of Solvents and Their Blends

A substance, B, dissolves in a solvent when it has more affinity for the solvent and the solution than for its own phase. From a thermodynamic point of view, the affinity of B for a given phase is related to its chemical potential, μ_B , in this phase. The affinity is as high as the chemical potential is low. Therefore, if μ_B^0 is the chemical potential of B in its own phase and μ_{Bsol} is its potential in the

This paper is dedicated to Professor G.J. Smets, former President of the International Union of Pure and Applied Chemistry. Portions of the article were presented at the 10th International Conference in Organic Coatings Science and Technology, in Athens, Greece (1984), and at the 17th FATIPEC Congress, in Lugano, Switzerland (1984), and are reprinted here with their permission.

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solution, B will have a greater affinity for the solution when the difference, $\mu_B^* - \mu_{Bsol}$ is positive.

The dissolving power, \mathcal{S} , of a solvent for B is quantitatively expressed by

$$\mathcal{S}_B = \frac{\mu_B^* - \mu_{Bsol}}{RT} \quad (1)$$

where R is the gas constant ($R = 8.315 \text{ JK}^{-1}\text{mol}^{-1}$) and T the absolute temperature. The introduction of the factor RT in the definition of \mathcal{S} makes this quantity dimensionless and avoids the choice of units. The chemical potential, μ_{Bsol} , depends on the volume fraction, ϕ_B , of

the solute in the solution and increases with this quantity. Therefore, \mathcal{S}_B will refer to a particular ϕ_B .

When \mathcal{S}_B is positive, the affinity of B for the solvent is greater than that for its own phase, and more solute can be dissolved. The reverse occurs when \mathcal{S}_B is negative and phase separation can then be expected. When \mathcal{S}_B equals zero, an equilibrium is reached and this particular value of ϕ_B corresponds to saturation.

From a thermodynamic point of view, \mathcal{S} is the sum of two terms with a well-defined physical meaning

$$\mathcal{S} = \frac{-\Delta H_{transf}}{RT} + \frac{\Delta S_{transf}}{R} \quad (2)$$

The first term, ΔH_{transf} , takes into account the heat absorbed by the system when one mole of the substance B is transferred from its own phase into solution. The second term is the corresponding change in entropy.

When the substance B is a polymer with r repeating segments, the dissolving power, \mathcal{S}_p , can be represented by an equation of the form

$$\mathcal{S}_p = r\mathcal{S}_m + \text{end terms} \quad (3)$$

where \mathcal{S}_m is the "segmental" solvent power defined as

$$\mathcal{S}_m = \frac{\mu_m^* - \mu_{msol}}{RT} \quad (4)$$

μ_{msol} and μ_m^* are the chemical potentials of the repeating segment in the solution and its own phase, respectively. Note that \mathcal{S}_m characterizing the dissolving power of a given solvent for a given polymer segment is not necessarily the same for other polymers of the same type. For instance, it will decrease when an amorphous polymer becomes semi-crystalline. It also depends on the polymer molecular weight: \mathcal{S}_m will be larger when the molecular weight is lower.

When the degree of polymerization is large (high value of r), the influence of the end groups can be neglected and \mathcal{S}_p will have the sign of \mathcal{S}_m . A polymer can therefore be dissolved at a given volume fraction, ϕ_p , in a given solvent or solvent blend when \mathcal{S}_m is positive or zero.

When the degree of polymerization is small, as in the case of oligomers, the contributions of the end groups to the dissolving power, \mathcal{S}_p , can no longer be neglected.

Dissolving Power of Pure Solvents

PREDICTION OF THE DISSOLVING POWER ACCORDING TO HANSEN'S APPROACH: The most widely used method for predicting the capacity of a pure solvent to dissolve a given polymer is that of Hansen.¹ In this method, each polymer and each solvent is characterized by three solubility parameters, namely: δ_d , representing the dispersion forces; δ_p , representing the polar forces; and δ_h , representing hydrogen bonds. Therefore, polymers and solvents can be represented by points in a three-dimensional plot using the three solubility parameters as axes (with the δ_d scale doubled).

Each polymer point may constitute the center of a sphere, the so-called sphere of solubility, of radius R_A , known as the radius of interaction. Solvents falling within this sphere should dissolve the polymer and those outside

Table 1—Known Characteristics of Solvents and Polymers Used in the Present Approach (Values at 25°C)

| Solvents | $\bar{V}_m/\text{cm}^3\text{mol}^{-1}$ | b_s |
|---------------------------------|--|-------|
| Alkanes | | |
| n-Pentane | 116.1 | 0 |
| n-Hexane | 131.6 | 0 |
| n-Heptane | 147.5 | 0 |
| n-Octane | 163.5 | 0 |
| n-Decane | 195.9 | 0 |
| n-Dodecane | 228.6 | 0 |
| n-Pentadecane | 277.7 | 0 |
| n-Hexadecane | 294.1 | 0 |
| Cyclohexane | 108.8 | 0 |
| Aromatic Hydrocarbons | | |
| Benzene | 89.4 | 0 |
| Toluene | 106.9 | 0 |
| p-Xylene | 123.9 | 0 |
| Halogenated Hydrocarbons | | |
| Dichloromethane | 64.5 | 0 |
| Chloroform | 80.5 | 0 |
| Tetrachloromethane | 97.1 | 0 |
| Esters | | |
| Methylformate | 62.1 | 0 |
| Methylacetate | 79.8 | 0 |
| Ethylacetate | 98.5 | 0 |
| n-Butylacetate | 132.5 | 0 |
| n-Hexylacetate | 165.8 | 0 |
| Ethyl propionate | 115.5 | 0 |
| Ketones | | |
| Acetone | 74.0 | 0 |
| Methylethylketone | 90.2 | 0 |
| Diethylketone | 106.4 | 0 |
| Methyl-isobutylket | 125.8 | 0 |
| Di(isopropyl)ket | 140.4 | 0 |
| Monohydric Alcohols | | |
| Methanol | 40.7 | -1 |
| Ethanol | 58.7 | -1 |
| 1-Propanol | 75.1 | -1 |
| 2-Propanol | 76.9 | -1 |
| 1-Butanol | 92.0 | -1 |
| 2-Butanol | 92.4 | -1 |
| 1-Pentanol | 108.6 | -1 |
| 1-Hexanol | 125.2 | -1 |
| 1-Octanol | 157.7 | -1 |
| 1-Decanol | 191.6 | -1 |
| Water | 18.1 | -2 |
| Polymers | | |
| PVAC (MW = 86000) | 78.3 | |
| PMMA (MW = 60000) | 84.2 | |
| PEMA (MW = 126000) | 103.8 | |

the sphere should not. This sphere of solubility refers to a particular value of ϕ_p .

In terms of dissolving power, this means that all points inside the sphere are expected to have a positive \mathcal{F}_m , whereas the contrary should happen for the points outside the sphere. According to the approach with three parameters, the dissolving power, \mathcal{F}_m , can be given by the following relation:

$$\frac{\mathcal{F}_m}{C} = R_A^2 - 4({}^s\delta_d - {}^p\delta_d)^2 - ({}^s\delta_p - {}^p\delta_p)^2 - ({}^s\delta_h - {}^p\delta_h)^2 \quad (5)$$

where C is a constant for a given polymer at a given temperature.

The surface of the solute sphere of solubility is thus the "ensemble" of all possible combinations of ${}^s\delta_d$, ${}^s\delta_p$, and ${}^s\delta_h$ for solvents with a dissolving power equal to zero.

The values of the seven parameters appearing in equation (5) were recently compiled by Barton² for a wide variety of solvents and polymers. Some values taken from this compilation are given in Tables mentioned later in this text (Tables 2 and 3).

Let us, for example, calculate by means of equation (5) the dissolving power of methylethylketone (MEK) and that of benzene for polyvinylacetate (PVAC). For MEK, we find

$$\begin{aligned} \frac{\mathcal{F}_m}{C} &= (13.7)^2 - 4(16.0 - 20.9)^2 - (9.0 - 11.3)^2 - (5.1 - 9.6)^2 \\ &= +66 \text{ MPa} \end{aligned}$$

For benzene:

$$\begin{aligned} \frac{\mathcal{F}_m}{C} &= (13.7)^2 - 4(18.4 - 20.9)^2 - (0.0 - 11.3)^2 - (2.0 - 9.6)^2 \\ &= -23 \text{ MPa} \end{aligned}$$

According to these predictions, the dissolving power of MEK for PVAC is positive and this solvent should dissolve the polymer—which it actually does. The calculated dissolving power of benzene for the same polymer is negative. In fact, this solvent dissolves PVAC.

The main weakness of Hansen's approach lies in the neglecting of entropy effects in the dissolving power. As shown by equation (2), the dissolving power depends not only on the changes in the energy of the cohesion forces when passing from one phase to the other, but also on the changes in the entropy. The approach of Hansen considers these additional effects of entropy changes as constant for a given solute and includes them in the value of R_A . But, as a matter of fact, these terms are not constant. They depend, among other things, on the molar volume, \bar{V}_s , of the solvent.

Let us give the following example: The normal alkanes do not dissolve PVAC or polymethylmethacrylate (PMMA) at room temperature, but they can be used as diluent of a true solvent, such as acetone or methylacetate. According to Hansen's approach, decane would be always a better diluent than pentane because its solubility parameters are more favorable. A higher percentage of decane could then be used before phase separation occurs. As can be seen from the numerous examples given later in Tables 5 and 6, the reverse is always observed. The reason is that the effect of the solubility parameters is

completely overshadowed by an entropic effect, related to the molar volume, \bar{V}_s , which favors the solubility when \bar{V}_s decreases.

A second point that is highly questionable in Hansen's approach is the use of a "hydrogen bonding" parameter, δ_h .³⁻⁵ A hydrogen bond is an interaction between two sites of opposite nature: a proton donor site, as the hydrogen atom of an O-H group; and a proton acceptor site, as the electron pairs of a CO group. Some molecules, such as CHCl_3 , have only a proton donor site, whereas others, such as MEK possess only acceptor sites. A distinction should be made between the capacity of a molecule to act as proton donor and its capacity to act as proton acceptor and these two different characteristics can by no means be represented by a single parameter, δ_h . The last term in equation (5) is therefore meaningless from a fundamental point of view.

DISSOLVING POWER OF PURE SOLVENTS IN THE PRESENT APPROACH: The new approach presented here takes into account the possible entropy changes that influence the dissolving power and replaces the hydrogen bonding term which appears in equation (5) with a more correct expression. As in the case of Hansen's approach, it uses a limited number of parameters which have to be determined experimentally. However, it also introduces in the calculation of \mathcal{F} known characteristics of polymer and solvent.

KNOWN CHARACTERISTICS OF SOLVENTS AND POLYMERS USED IN THE PRESENT APPROACH: These characteristics are the molar volumes \bar{V}_s of the solvent and \bar{V}_m of the repeating unit of the polymer. A new characteristic introduced here is the so-called "structuration" factor, b_s , of the solvent which is related to the presence of H-bond chains between the molecules of the solvent.

The \bar{V}_s of the solvent is obtained from its molecular weight, M_s , and its density, ρ_s , following the equation

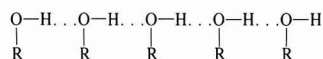
$$\bar{V}_s = \frac{M_s}{\rho_s} \quad (6)$$

To obtain \bar{V}_m , one calculates the molecular weight, M_m , of the repeating unit of the polymer from its formula and divides it by the density, ρ_p , of the pure polymer:

$$\bar{V}_m = \frac{M_m}{\rho_p} \quad (7)$$

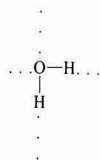
The structuration factor, b_s , is zero for all the solvents which do not form H-bond chains. This is the case for alkanes, aromatic hydrocarbons, ethers, esters, ketones, halohydrocarbons, nitroalkanes, nitrobenzene, acetone, and so on.

The structuration factor, b_s , equals -1 for all the solvents which form long single H-bond chains, for instance, alcohols

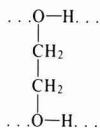


Other cases with $b_s = -1$ are phenols, formamide, and formic acid.

The b_s equals -2 for the solvents where the molecules are involved in *double* chains like water



or diols



The origin of this structuration factor will be reported elsewhere.⁶ A list of the known characteristics of solvents is given in *Table 1*.

EQUATIONS FOR THE DISSOLVING POWER OF PURE SOLVENTS:

Dissolving power in absence of polymer-solvent and polymer-polymer hydrogen bonding—In the simple case where no hydrogen bond is formed between the polymer segments or between polymer and solvent, the dissolving power, \mathcal{F}_m , is given by the following equation:

$$\mathcal{F}_m = -A - \frac{\bar{V}_m}{RT} (1 - \phi_p)^2 (\delta' - \rho\delta'')^2 + (0.5 + b_s) (1 - \phi_p) \frac{\bar{V}_m}{\bar{V}_s} \quad (8)$$

This equation is a simplified expression of a general equation we derived for the solubility of model crystalline compounds as solid alkanes in a great number of solvents.^{7,8} It only contains three *a priori* unknown parameters, namely A , $\rho\delta'$ and δ'' .

The A parameter is related to the necessity of fluidizing the polymer before bringing it into the solution. A is a constant for a given polymer at a given temperature. Although different in nature, the A term plays a role similar to that of R_A^2 in equation (5).

The second term

$$D = \frac{\bar{V}_m}{RT} (1 - \phi_p)^2 (\delta' - \rho\delta'')^2 \quad (9)$$

describes the changes of the non-specific cohesion forces accompanying the transfer of the solute from its own phase to the solvent. This term has the same meaning as in the method using three solubility parameters but it only refers to dispersion and dipolar forces at the exclusion of hydrogen bonds. The corresponding parameters, δ' and $\rho\delta''$, and therefore called "modified non-specific" solubility parameters of the solvent and of the polymer.

The last term

$$B = (0.5 + b_s) (1 - \phi_p) \frac{\bar{V}_m}{\bar{V}_s} \quad (10)$$

corresponds to entropy changes. These are not considered in Hansen's method. It must be noted that equation (10) does not introduce unknown parameters.

The present approach will calculate the solvent power of MEK for PVAC as:

$$\begin{aligned} \mathcal{F}_m &= -0.234 - \frac{78.3 (21.02 - 19.50)^2 (0.9)^2}{2479} \\ &+ (0.5 + 0) \frac{78.3}{90.2} (0.9) = + 0.10 \end{aligned}$$

In the case of benzene:

$$\begin{aligned} \mathcal{F}_m &= -0.234 - \frac{78.3 (18.95 - 19.50)^2 (0.9)^2}{2479} \\ &+ (0.5 + 0) \frac{78.3}{89.4} (0.9) = + 0.15 \end{aligned}$$

Both values are positive, predicting that both solvents dissolve PVAC as is actually observed.

Dissolving power in presence of polymer-solvent hydrogen bonding—In this case, a term has to be added to equation (8)

$$H = \epsilon_n (1 + K \frac{(1 - \phi_p)}{\bar{V}_s}) \quad (11)$$

where K is the stability constant (in $\text{cm}^3 \text{mole}^{-1}$) of the polymer-solvent hydrogen bond.

As a matter of fact, $(1 - \phi_p)/\bar{V}_s$ is the concentration of the active sites of the solvent. This equation is similar to that used in analytical chemistry to describe the influence of a given concentration of ligand on the solubility of a salt.

Equation (11) holds at low polymer concentrations (a few percent). When ϕ_p becomes larger, expressions that are more elaborate but which do not introduce new parameters have to be used.

To a first approximation, it is assumed that K for a particular polymer at a particular temperature will have the same value for all solvents belonging to the same group (for instance, the alcohols).

Equation (11) replaces the term $(\delta_n - \rho\delta_n)^2$ of equation (5).

For polymers which form H-bonds with the solvent, the dissolving power can therefore be calculated from

$$\mathcal{F}_m = -A - D + B + H \quad (12)$$

D , B and H are being calculated from equations (9), (10), and (11), respectively.

Dissolving power in presence of polymer-polymer hydrogen bonding—Hydrogen bonding between two polymer segments only takes place when the segments bear O-H or N-H groups.

In this case an additional term, C , must be subtracted from equations (8) or (12). This term depends on the stability constant K_{pp} of the segment-segment H-bonds and is given to a good approximation by

$$C = \epsilon_n \left(\frac{1 + K_{pp}/\bar{V}_m}{1 + K_{pp}\phi_p/\bar{V}_m} \right) \quad (13)$$

The complete equation giving \mathcal{F}_m is thus

$$\begin{aligned} \mathcal{F}_m &= -A - \frac{\bar{V}_m}{RT} (\delta' - \rho\delta'')^2 (1 - \phi_p)^2 + (0.5 + b_s) \frac{\bar{V}_m}{\bar{V}_s} (1 - \phi_p) \\ &+ \epsilon_n (1 + K(1 - \phi_p)/\bar{V}_s) - \epsilon_n (1 + K_{pp}/\bar{V}_m) / (1 + K_{pp}\phi_p/\bar{V}_m) \end{aligned} \quad (14)$$

DETERMINATION OF THE PARAMETERS USED IN THE PRESENT APPROACH: The parameters required for the calculation of the dissolving power are: the modified solubility parameter ${}^s\delta'$ of the solvent; the modified solubility parameter ${}^p\delta'$ of the polymer; and the characteristic constant A for this polymer. Moreover, if the polymer segment bears specific groups which are active on hydrogen bonding, the stability constants K have to be known for the different groups of solvents.

For polymers that can form segment-segment H-bonds, the term C (or the stability constant K_{pp}) must also be known.

Determination of the solubility parameters ${}^s\delta'$ of the solvents—The general form of equation (8) can be applied for calculating the solubility ϕ_B of solid alkanes in all possible solvents. For these crystalline substances, A is equal to the molar free energy of melting divided by RT. This quantity is accurately known from calorimetric measurements on the pure crystals. At the saturation, ϕ_B equals zero and, when measuring experimentally ϕ_B , all terms in equation (8) are known at the exception of the difference (${}^s\delta' - {}^p\delta'$). Taking arbitrarily a value ${}^p\delta'$ equal to 16.00 MPa^{1/2} for octacosane, the value of ${}^s\delta'$ can then be deduced. The method works fairly well for most solvents, with the exception of liquid hydrocarbons.

The solubility of solid alkanes in liquid hydrocarbons is generally less sensitive to the value of ${}^s\delta'$. For these liquid hydrocarbons, we prefer to use ${}^s\delta'$ values which were found by trial and error methods and which fit at best the experimental solubilities of polymers.

The values of ${}^s\delta'$ are listed in Table 2. They are compared with the Hansen's parameters compiled by Barton and with the Hildebrand parameter, δ_H , of these solvents.

As can be seen from Table 2, for solvents with a low polarity, the δ' values are not very different from the Hildebrand's values. However, for strong polar solvents, δ' is generally two or three units larger. For hydrogen bonded solvents, δ' is always much smaller than δ_H because δ' only refers to the non-specific cohesion forces.

Determination of the parameters characterizing the polymer—In principle, each polymer parameter, (A , ${}^p\delta'$ or the constants K for the hydrogen bonds with the various groups of solvents) can be determined by a single determination of a cosolvency limit, adding increasing amounts of a non-solvent to a good solvent and determining the cloud point by visual observation. The minimal number of such independent determinations is thus at least two and depends on the number of K values taken into consideration. For the determination of A and ${}^p\delta'$, it is advisable to use solvent pairs which do not form H-bonds with the polymer. Of course, when a larger number of experimental cosolvency limits is available, the A , ${}^p\delta'$, and K values can be adapted so as to best fit the experimental data. In Table 3, we give the values determined for three polymers, namely polyvinylacetate Vinnapas UW1 (Wacker Chemie, abbreviated PVAC), polymethylmethacrylate low molecular weight (Aldrich Janssen Chimica, PMMA), polyethylmethacrylate sec-

ondary standard (Aldrich Janssen Chimica, PEMA). For the sake of comparison, Table 3 also contains the Hansen's parameter of similar polymers taken from the compilation work of Barton.²

Comparison between the predictions and the experimental data for pure solvents—For pure solvents, the validity of both Hansen's approach and the present one can be tested by checking if solubility or insolubility is in fact observed when the calculated values of ϕ_m/C [equation (5)] or ϕ_m [equation (14)] are respectively positive or negative.

Table 2—Solubility Parameters of Solvents at 25°C^a

| Solvent | δ' | δ_d^b | δ_p^b | δ_h^b | δ_H^c |
|---------------------------------|-----------|--------------|--------------|--------------|--------------|
| Alkanes | | | | | |
| n-Pentane | 15.47 | 14.5 | 0.0 | 0.0 | 14.3 |
| n-Hexane | 15.65 | 14.9 | 0.0 | 0.0 | 14.9 |
| n-Heptane | 15.75 | 15.3 | 0.0 | 0.0 | 15.1 |
| n-Octane | 15.82 | 15.5 | 0.0 | 0.0 | 15.6 |
| n-Decane | 15.89 | 15.8 | 0.0 | 0.0 | — |
| n-Dodecane | 15.92 | 16.0 | 0.0 | 0.0 | 16.2 |
| n-Pentadecane | 15.94 | 16.3 | 0.0 | 0.0 | — |
| n-Hexadecane | 15.95 | 16.4 | 0.0 | 0.0 | — |
| Cyclohexane | 16.00 | 16.8 | 0.0 | 0.2 | 16.8 |
| Aromatic Hydrocarbons | | | | | |
| Benzene | 18.95 | 18.4 | 0.0 | 2.0 | 18.8 |
| Toluene | 18.50 | 18.0 | 1.4 | 2.0 | 18.2 |
| o-Xylene | — | 17.8 | 1.0 | 3.1 | 18.0 |
| p-Xylene | 18.00 | — | — | — | — |
| Halogenated Hydrocarbons | | | | | |
| Dichloromethane | 20.53 | 18.2 | 6.3 | 6.1 | 19.8 |
| Chloroform | 18.77 | 17.8 | 3.1 | 5.7 | 19.0 |
| Tetrachloromethane | 17.06 | 17.8 | 0.0 | 0.6 | 17.6 |
| Esters | | | | | |
| Methylformate | 22.87 | — | — | — | 20.9 |
| Methylacetate | 21.71 | 15.5 | 7.2 | 7.6 | 19.6 |
| Ethylacetate | 20.79 | 15.8 | 5.3 | 7.2 | 18.6 |
| n-Butylacetate | 19.73 | 15.8 | 3.7 | 6.3 | 17.4 |
| n-Hexylacetate | 19.17 | — | — | — | — |
| Ethyl propionate | 20.07 | — | — | — | 18.2 |
| Ketones | | | | | |
| Acetone | 22.10 | 15.5 | 10.4 | 7.0 | 20.2 |
| Methylethylketone | 21.02 | 16.0 | 9.0 | 5.1 | 19.0 |
| Diethylketone | 20.28 | 15.8 | 7.6 | 4.7 | 18.0 |
| Methylisobutylketone | 20.02 | 15.3 | 6.1 | 4.1 | 17.2 |
| Di(isopropyl)ketone | 19.45 | — | — | — | 16.4 |
| Monohydric alcohols | | | | | |
| Methanol | 19.25 | 15.1 | 12.3 | 22.3 | 29.6 |
| Ethanol | 17.75 | 15.8 | 8.8 | 19.4 | 26.0 |
| 1-Propanol | 17.32 | 16.0 | 6.8 | 17.4 | 24.3 |
| 2-Propanol | 17.53 | 15.8 | 6.1 | 16.4 | 23.5 |
| 1-Butanol | 16.96 | 16.0 | 5.7 | 15.8 | 23.3 |
| 2-Butanol | 16.50 | 15.8 | 5.7 | 14.5 | 22.1 |
| 1-Pentanol | 16.75 | 16.0 | 4.5 | 13.9 | 22.3 |
| 1-Hexanol | 16.65 | — | — | — | 21.9 |
| 1-Octanol | 16.50 | 17.0 | 3.3 | 11.9 | (21.1) |
| 1-Decanol | 16.37 | 17.6 | 2.7 | 10.0 | (20.4) |
| Water | 20.50 | 15.6 | 16.0 | 42.3 | 47.9 |

(a) "Modified Solubility Parameter" δ' : MPa^{1/2}; Hansen's parameters δ_d : MPa^{1/2}, δ_p : MPa^{1/2}, and δ_h : MPa^{1/2}; Hildebrand's parameter δ_H : MPa^{1/2}.

(b) A.F.M. Barton, "CRC Handbook of Solubility Parameters and Other Cohesion Parameters," CRC Press, Boca Raton FL, 1983, Table 5, p. 153.

(c) *Ibid.*, Table 2, p. 142.

Table 3—Parameters of the Polymers

| Hansen's Parameters ^a | | | |
|----------------------------------|-----------------------------|-----------------------------|------------------------|
| $\delta_d/\text{MPa}^{1/2}$ | $\delta_p/\text{MPa}^{1/2}$ | $\delta_h/\text{MPa}^{1/2}$ | $R_A/\text{MPa}^{1/2}$ |
| PVAC.....20.9 | 11.3 | 9.6 | 13.7 |
| PMMA.....18.6 | 10.5 | 7.5 | 8.6 |
| PEMA.....17.6 | 9.7 | 4.0 | 10.6 |

Parameters Used in the Present Treatment

| A | $\delta'/\text{MPa}^{1/2}$ | K_{CHCl_3} ($\text{cm}^3\text{mol}^{-1}$) | K_{ROH} ($\text{cm}^3\text{mol}^{-1}$) | $K_{\text{H}_2\text{O}}$ ($\text{cm}^3\text{mol}^{-1}$) |
|---------------|----------------------------|---|--|--|
| PVAC....0.234 | 19.5 | 40 | 95 | 1400 |
| PMMA...0.247 | 20.3 | 40 | 50 | 750 |
| PEMA...0.212 | 19.2 | 40 | 100 | 900 |

(a) Taken from A. F. M. Barton, "Handbook of Solubility Parameters and Other Cohesion Parameters," CRC Press, Boca Raton, FL 1983, p. 296

In Table 4, the values of $\$m/C$ calculated by means of equation (5) based on Hansen's approach and $\$m$ calculated according to the new method are compared with the observed solubility or insolubility for the three polymers cited above.

For the 78 systems considered, the predictions based on Hansen's approach are correct in 61 cases (78%), whereas those based on the new approach correspond with the reality in 77 cases (99%). It must be emphasized that for

the systems considered here, the number of *a priori* unknown parameters ($\delta', A, \rho\delta', K_{\text{CHCl}_3}, K_{\text{ROH}}, K_{\text{H}_2\text{O}}$) used for the calculation of $\$m$ is not larger than in the case of Hansen's method ($R_A, \delta_d, \delta_p, \delta_h, \rho\delta_d, \rho\delta_p, \rho\delta_h$). For both methods, the calculation of the dissolving power of pure solvents only requires a few seconds with the aid of a pocket calculator.

Dissolving Power of Binary Solvent Blends

DISSOLVING POWER AND COSOLVENCY LIMITS IN BINARY BLENDS: The study of the solubility of polymers or other substances in binary blends allows us to test more quantitatively the validity of the different prediction methods.

Consider a polymer dissolved in a good solvent (subscript 1) for which the dissolving power, $\$m$, is positive. Now add to the first solvent a non-solvent (subscript 2). There will come a point where the polymer just starts to precipitate out of the solution. *The composition of the blend at this "cloud point" (ϕ_{2lim}) is that for which the $\$m$ is zero.*

It is therefore possible to compare the calculated value of ϕ_{2lim} corresponding to a zero value of the dissolving power with the experimental one obtained by performing the titration. This can be done for the Hansen's method and for the present one.

Table 4—Predictions of Solubility or Insolubility Based on Hansen's Parameters (equation 5) And on the Present Approach (equation 14) Experimental Solubility (Yes) or Insolubility (No). ($\phi_B = 10$ at 25°C)

| Solvent | PVAC | | | PMMA | | | PEMA | | |
|----------------------------|--------------------|-----------|------|--------------------|-----------|------|--------------------|-----------|------|
| | Hansen $\$m/C$ MPa | This $\$$ | Exp. | Hansen $\$m/C$ MPa | This $\$$ | Exp. | Hansen $\$m/C$ MPa | This $\$$ | Exp. |
| 1 Pentane..... | -196 | -0.35 | no | -160 | -0.56 | no | -36 | -0.28 | no |
| 2 Octane..... | -149 | -0.36 | no | -131 | -0.57 | no | -15 | -0.31 | no |
| 3 Decane..... | -136 | -0.39 | no | -124 | -0.59 | no | -11 | -0.35 | no |
| 4 Hexadecane..... | -113 | -0.44 | no | -112 | -0.64 | no | -4 | -0.41 | no |
| 5 Cyclohexane..... | -96 | -0.22 | no | -103 | -0.41 | no | +1 | -0.13 | no |
| 6 Benzene..... | -23 | +0.15 | yes | -67 | +0.13 | yes | +12 | +0.31 | yes |
| 7 Toluene..... | -2 | +0.07 | yes | -41 | +0.02 | yes | +39 | +0.21 | yes |
| 8 Dichloromethane..... | +121 | +0.29 | yes | +54 | +0.34 | yes | +95 | +0.45 | yes |
| 9 Chloroform..... | +66 | +0.56 | yes | +13 | +0.53 | yes | +66 | +0.73 | yes |
| 10 Tetrachloromethane..... | -59 | -0.02 | yes | -87 | -0.15 | no | +7 | +0.11 | yes |
| 11 Methylacetate..... | +50 | +0.08 | yes | +25 | +0.17 | yes | +76 | +0.16 | yes |
| 12 Ethylacetate..... | +42 | +0.08 | yes | +16 | +0.13 | yes | +70 | +0.18 | yes |
| 13 n-Butylacetate..... | +15 | +0.03 | yes | -5 | +0.03 | yes | +58 | +0.13 | yes |
| 14 Acetone..... | +64 | +0.07 | yes | +35 | +0.18 | yes | +85 | +0.13 | yes |
| 15 Methyl ethylketone..... | +66 | +0.10 | yes | +39 | +0.16 | yes | +100 | +0.19 | yes |
| 16 Diethylketone..... | +46 | +0.08 | yes | +26 | +0.11 | yes | +95 | +0.19 | yes |
| 17 Methylisobutylket..... | +5 | +0.04 | yes | -1 | +0.05 | yes | +78 | +0.14 | yes |
| 18 Methanol..... | -109 | +0.03 | yes | -197 | -0.46 | no | -254 | -0.19 | no |
| 19 Ethanol..... | -19 | -0.01 | no | -102 | -0.50 | no | -139 | -0.15 | no |
| 20 1-Propanol..... | +11 | -0.06 | no | -65 | -0.53 | no | -86 | -0.17 | no |
| 21 2-Propanol..... | +10 | -0.04 | no | -56 | -0.49 | no | -67 | -0.14 | no |
| 22 1-Butanol..... | +22 | -0.12 | no | -45 | -0.57 | no | -53 | -0.21 | no |
| 23 1-Pentanol..... | +27 | -0.17 | no | -30 | -0.60 | no | -23 | -0.24 | no |
| 24 1-Octanol..... | +58 | -0.25 | no | -8 | -0.63 | no | +8 | -0.30 | no |
| 25 1-Decanol..... | +70 | -0.30 | no | -1 | -0.66 | no | +27 | -0.34 | no |
| 26 Water..... | -1016 | -1.84 | no | -1203 | -2.88 | no | -1410 | -4.19 | no |
| Correct Predictions..... | 16/26 | 25/26 | | 22/26 | 26/26 | | 23/26 | 26/26 | |

Table 5—Cosolvency Limits in Volume Percentage of the Alkane [Experimental (italics), Calculated According to the Hansen's Parameters (First Figure) and According to the Present Approach (Last Figure)]

| PVAC | n-C ₅ H ₁₂ | | | n-C ₁₀ H ₂₂ | | | n-C ₁₅ H ₃₂ | | | n-C ₁₆ H ₃₄ | | |
|----------------------|----------------------------------|----|----|-----------------------------------|----|----|-----------------------------------|----|----|-----------------------------------|----|----|
| Benzene | 0 | 30 | 44 | 0 | 21 | 38 | 0 | 18 | 35 | — | — | — |
| Toluene | 0 | 18 | 29 | 0 | 16 | 24 | — | — | — | 0 | 14 | 22 |
| Dichloromethane | 49 | 59 | 60 | 57 | 48 | 54 | — | — | — | 61 | 34 | 47 |
| Tetrachloromethane | 0 | 2 | 0 | 0 | 1 | 0 | — | — | — | — | — | — |
| Methylacetate | 30 | 42 | 41 | 41 | 32 | 30 | 47 | 24 | 23 | — | — | — |
| Ethylacetate | 24 | 39 | 40 | 33 | 30 | 32 | 38 | 24 | 26 | — | — | — |
| Butylacetate | 10 | 28 | 27 | 14 | 21 | 21 | 17 | 17 | 17 | — | — | — |
| Acetone | 39 | 43 | 38 | 51 | 32 | 26 | — | — | — | — | — | — |
| Methylethylketone | 35 | 39 | 43 | 46 | 28 | 34 | — | — | — | 52 | 22 | 27 |
| Methylisobutylketone | 3 | 22 | 30 | 5 | 19 | 23 | — | — | — | 8 | 13 | 18 |

| PMMA | n-C ₅ H ₁₂ | | | n-C ₆ H ₁₄ | | | n-C ₈ H ₁₈ | | | n-C ₁₀ H ₂₂ | | | n-C ₁₅ H ₃₂ | | |
|----------------------|----------------------------------|----|----|----------------------------------|----|----|----------------------------------|----|----|-----------------------------------|----|----|-----------------------------------|----|----|
| Benzene | 0 | 30 | 27 | — | — | — | — | — | — | 0 | 23 | 25 | 0 | 19 | 22 |
| Toluene | 0 | 17 | 8 | — | — | — | — | — | — | 0 | 13 | 7 | 0 | 12 | 6 |
| Dichloromethane | 40 | 50 | 49 | — | — | — | — | — | — | 44 | 49 | 45 | 46 | 39 | 41 |
| Tetrachloromethane | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Methylacetate | 25 | 38 | 36 | — | — | — | 31 | 35 | 34 | 33 | 32 | 31 | 37 | 27 | 27 |
| Ethylacetate | 15 | 29 | 32 | — | — | — | 19 | 28 | 30 | — | — | — | 23 | 23 | 24 |
| Butylacetate | 0 | 16 | 15 | — | — | — | — | — | — | 0 | 14 | 13 | 0 | 12 | 11 |
| Acetone | — | — | — | 40 | 38 | 36 | — | — | — | — | — | — | — | — | — |
| Methylethylketone | — | — | — | 34 | 35 | 35 | — | — | — | — | — | — | 43 | 26 | 26 |
| Methylisobutylketone | — | — | — | 0 | 18 | 20 | — | — | — | — | — | — | 0 | 14 | 14 |

| PEMA | n-C ₅ H ₁₂ | | | n-C ₆ H ₁₄ | | | n-C ₁₀ H ₂₂ | | | n-C ₁₅ H ₃₂ | | | n-C ₁₆ H ₃₄ | | |
|----------------------|----------------------------------|----|----|----------------------------------|----|----|-----------------------------------|----|----|-----------------------------------|----|----|-----------------------------------|----|----|
| Benzene | 58 | 59 | 64 | — | — | — | 77 | 48 | 57 | 87 | 37 | 51 | — | — | — |
| Toluene | 68 | 57 | 55 | — | — | — | 85 | 43 | 47 | — | — | — | 94 | 38 | 41 |
| Dichloromethane | 85 | 76 | 74 | — | — | — | 95 | 68 | 67 | — | — | — | 98 | 51 | 60 |
| Tetrachloromethane | 66 | 36 | 32 | — | — | — | — | — | — | 96 | 25 | 23 | — | — | — |
| Methylacetate | 82 | 61 | 60 | — | — | — | 94 | 50 | 46 | 98 | 36 | 36 | — | — | — |
| Ethylacetate | 79 | 59 | 61 | — | — | — | 93 | 49 | 50 | 97 | 39 | 41 | — | — | — |
| Butylacetate | 74 | 54 | 54 | — | — | — | 90 | 44 | 44 | 96 | 37 | 37 | — | — | — |
| Acetone | — | — | — | 89 | 63 | 56 | — | — | — | — | — | — | — | — | — |
| Methylethylketone | — | — | — | 88 | 63 | 62 | — | — | — | 97 | 42 | 42 | — | — | — |
| Methylisobutylketone | — | — | — | 82 | 57 | 54 | — | — | — | 97 | 39 | 37 | — | — | — |

DISSOLVING POWER OF BINARY BLENDS ACCORDING TO THE THREE PARAMETERS METHOD: In Hansen's method, the parameters of the mixture are generally calculated from those of the individual solvent components using the linear relationship:

$$^s\delta = \phi_1^s\delta + \phi_2^s\delta \quad (15)$$

where ϕ_1 and ϕ_2 are the volume fractions in the solvent blend. This can be done for the three parameters (δ_d , δ_p , δ_h). The values so obtained are put in equation (5) in order to calculate \mathcal{S}_m/C for the blend.

Equation (15) is based on the assumption of a *random mixing* of the molecules of both solvents. Consider a 50/50 v/v blend of MEK and hexane. By introducing a solute in the blend, some contacts between solvent molecules have to be broken. In the hypothesis of random mixing, 50% of these contacts are ketone-alkane contacts, 25% are ketone-ketone contacts, and 25% are alkane-alkane contacts. Such distribution leads to equation (15).

But as a matter of fact, the dipole-dipole interactions will favor the ketone-ketone contacts. Consequently, the frequency of ketone-ketone contacts will be much greater than 25%. This leads to a segregation of the two solvents favoring the contacts between molecules of the same kind

and decreasing the frequency of contacts between molecules of different kind.

This effect is still greater when one of the solvents forms hydrogen bonded chains and the other does not, as, for instance, in the system ethanol-hexane. In this blend, at not too low values of ϕ_1 , practically all O-H groups are involved in H-bond chains with other ethanol molecules. This leads to a very important segregation of the molecules of both solvents.

In such cases, the use of equation (15) becomes highly questionable.

DISSOLVING POWER OF BINARY BLENDS IN THE PRESENT APPROACH:

Dissolving power in absence of polymer-solvent and polymer-polymer hydrogen bonding—The parameter A characterizing the pure polymer keeps the same constant value in pure solvents and in solvent mixtures (in the same way, R_A remains constant in the method of three parameters).

The value of the B term is given to a good approximation by the additive expression

$$B = \phi_1 B_1 + \phi_2 B_2 \quad (16)$$

wherein B_1 and B_2 are the values of these terms in the pure solvents 1 and 2.

When the *random mixing* of both solvents is assumed, the D term will be given by:

$$D = \frac{\bar{V}_m}{RT} (1 - \phi_p)^2 (\phi_1^{s1}\delta' + \phi_2^{s2}\delta' - \rho\delta')^2 \quad (17)$$

If, on the contrary, a *complete segregation* of the two solvents is assumed, this means that the 1–2 contacts are completely negligible near the 1–1 and 2–2 contacts, and the equation will be

$$D = \frac{\bar{V}_m}{RT} (1 - \phi_p)^2 \{ \phi_1^{s1}\delta' - \rho\delta' \}^2 + \phi_2^{s2}\delta' - \rho\delta' \}^2 \quad (18)$$

In fact, the study of the solubility of solid alkanes in binary solvent blends showed that the real situation was intermediate between the complete segregation of the solvent molecules 1 and 2 and their random mixing. Of course, this was observed in the cases where the two solvents were sufficiently unlike from the point of view of the polarity. Introducing a Boltzmann factor and taking the solubility parameter $^{s1}\delta'$ and $^{s2}\delta'$ of both solvents into account, we calculated corrected values of fractions of contacts f_{11} , f_{22} , and f_{12} . These values are intermediate between the fractions of contacts of solvent molecules calculated using the random mixing model and those calculated using the complete segregation model.

We so obtain an equation intermediate between equation (17) and (18), corresponding to a partial segregation of the solvents:

$$D = \frac{\bar{V}_m}{RT} (1 - \phi_p)^2 \left\{ f_{11}^{s1}\delta' - \rho\delta' \right\}^2 + f_{22}^{s2}\delta' - \rho\delta' \}^2 + f_{12}^{s1}\delta' - \rho\delta' \}^{s2}\delta' - \rho\delta' \} \quad (19)$$

This equation, which gives the value of D , is somewhat extensive but only makes use of the parameters appearing in the two previous equations with no new unknown parameters. This calculation of D for the blend can be easily performed with a computer.

To find the values of A and $\rho\delta'$ of a given polymer, the cosolvency limits ϕ_{2lim} for two different blends of a good solvent and a non-solvent have to be determined (choosing systems where no polymer-solvent H-bonds can be formed). The values of A and $\rho\delta'$ are then adapted to make the dissolving power

$$\mathcal{F} = -A - D + B \quad (20)$$

equal to zero at the two cosolvency limits.

With these values of A and $\rho\delta'$, the cosolvency limits can be calculated for all the other blends where no polymer-solvent H-bonding has to be taken into account.

In Table 5 the cosolvency limits calculated in this way are compared with those predicted by equation (5) and with the experimental ones.

The agreement between experiment and prediction is markedly better for the present method: *the standard deviation between the calculated and experimental cosolvency limits is only five volume percent*, whereas it reaches 16 volume percent for the three parameters method.

Table 6—Cosolvency Limits in Volume Percentage of the Second Solvent at 25°C [Experimental (italics), Calculated by the Method of Three Parameters (First Figures), Calculated by the Present Method (Last Figures)]

| PVAC | (Three Parameters) | (Experimental) | (This Method) |
|------------------------|-----------------------|-----------------------|-----------------------|
| Chloroform-Pentane | 0*–33 ^a | 0*–67 ^a | 0*–68 ^a |
| Chloroform-Decane | 0*–40 ^a | 0*–54 ^a | 0*–65 ^a |
| Chloroform-Pentadecane | 0*–43 ^a | 0*–43 ^a | 0*–62 ^a |
| Methanol-Pentane | 29–57 | 0*–31 ^a | 0*–36 ^a |
| Ethanol-Pentane | 8–54 | <i>ins. wh. range</i> | <i>ins. wh. range</i> |
| Methanol-Water | <i>ins. wh. range</i> | 0*–37 ^a | 0*–43 ^a |
| Ethanol-Water | <i>ins. wh. range</i> | 4–51 | 0.2–47 |
| 1-Propanol-Water | 0*–3 ^a | 4–57 | 0.5–48 |
| 2-Propanol-Water | 0*–4 ^a | 4–55 | 0.3–49 |
| PMMA | | | |
| Chloroform-Pentane | 0*–13 ^a | 0*–61 ^a | 0*–54 ^a |
| Chloroform-Octane | 0*–15 ^a | 0*–58 ^a | 0*–53 ^a |
| Chloroform-Decane | 0*–15 ^a | 0*–54 ^a | 0*–52 ^a |
| Chloroform-Pentadecane | 0*–16 ^a | 0*–44 ^a | 0*–50 ^a |
| Chloroform-Hexadecane | 0*–16 ^a | 0*–42 ^a | 0*–49 ^a |
| Methanol-Water | <i>ins. wh. range</i> | <i>ins. wh. range</i> | <i>ins. wh. range</i> |
| Ethanol-Water | <i>ins. wh. range</i> | 15–20 | 9–16 |
| 1-Propanol-Water | <i>ins. wh. range</i> | 8–34 | 7–20 |
| 2-Propanol-Water | <i>ins. wh. range</i> | 7–34 | 6–22 |
| PEMA | | | |
| Chloroform-Pentane | 0*–79 ^a | 0*–78 ^a | 0*–76 ^a |
| Chloroform-Decane | 0*–92 ^a | 0*–74 ^a | 0*–71 ^a |
| Chloroform-Hexadecane | 0*–97 ^a | 0*–55 ^a | 0*–67 ^a |
| Methanol-Water | <i>ins. wh. range</i> | <i>ins. wh. range</i> | <i>ins. wh. range</i> |
| Ethanol-Water | <i>ins. wh. range</i> | 4–18 | 3–15 |

(a) 0*—soluble in pure solvent 1.

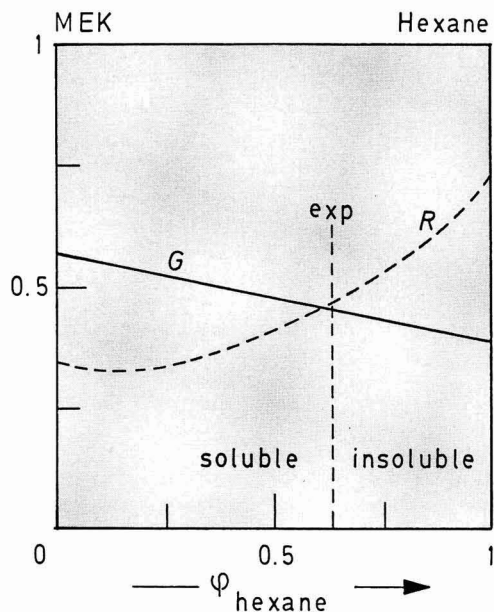


Figure 1—"Red" (R) and "Green" (G) solubility functions for PMMA in binary blends of MEK and hexane as a function of the volume fractions of hexane at 25°C. The solvent power, S_m , of a given blend corresponds to the vertical difference between G and R

Dissolving power of binary blends with polymer-solvent hydrogen bonds—In binary blends, the H term is given to a first approximation by

$$H = \ln \left(1 + \frac{K_1 \phi_1 (1 - \phi_p)}{\bar{V}_{s1}} + \frac{K_2 \phi_2 (1 - \phi_p)}{\bar{V}_{s2}} \right) \quad (21)$$

wherein K_1 and K_2 are the stability constants for the hydrogen bonds the polymer can form with solvent 1 and solvent 2. Again, this equation holds for small values of ϕ_p . At higher values of ϕ_p , a more elaborate expression (which does not contain new parameters) must be used.

Solvents which can form hydrogen bonds with the polyvinylesters considered in this paper are, for instance, chloroform, alcohols, and water. Alcohols and water are structured solvents for which, according to equation (10), the corresponding B term is negative. The competition between the positive H term and the negative B term in these structured solvents often leads to the appearance of a "true cosolvency" related to the existence of a maximum in the dissolving power, S , as a function of ϕ_2 . The polymer is then soluble neither in solvent 1 nor in solvent 2 but becomes soluble in binary mixtures of the two solvents between given limits of ϕ_2 .

In Hansen's approach the existence of a true cosolvency is explained by the fact that the points of the pure solvents lie both outside the solute sphere but that the straight line joining them crosses this sphere in two points.

According to the present approach, the cosolvency limits correspond to the values of ϕ_2 for which the dissolving power given by equation (12) equals zero.

The determination of one experimental cosolvency point with a solvent belonging to a given group allows us

to find the K value characterizing this group. Indeed, this K value is that which makes the previous sum, using the experimental ϕ_{2lim} value, equal to zero.

This K value can then be used for all the solvents belonging to this group. This allows the prediction of the various cosolvency limits.

In Table 6, these cosolvency limits are compared with those deduced from the method of three parameters [equations (5) and (15)] and with the experimental limits.

Again, the agreement between the predicted limits and the experimental ones is much better for the proposed methods where the standard deviation is of the order of 7 volume percent. For the chloroform-systems, the standard deviation for the method with three parameters reaches 27%. For systems with alcohols or water given in Table 6, the quantitative predictions of the method with three parameters seem to be rather unreliable.

Again it should be noted that the calculated values listed in the last column of Table 6 necessitate no more parameters (A , ${}^p\delta'$, ${}^{s1}\delta'$, ${}^{s2}\delta'$, K_{CHCl_3} , K_{ROH} , K_{H_2O}) than those computed by Hansen's method (R_A , ${}^s\delta_{d1}$, ${}^s\delta_{d2}$, ${}^s\delta_{p1}$, ${}^s\delta_{p2}$, ${}^s\delta_{h1}$, ${}^s\delta_{h2}$, ${}^p\delta_d$, ${}^p\delta_p$, ${}^p\delta_h$).

Graphical representation of the dissolving power in binary blends—For this purpose, it is convenient to split the dissolving power, S , into two parts:

$$G = B + H \quad (22)$$

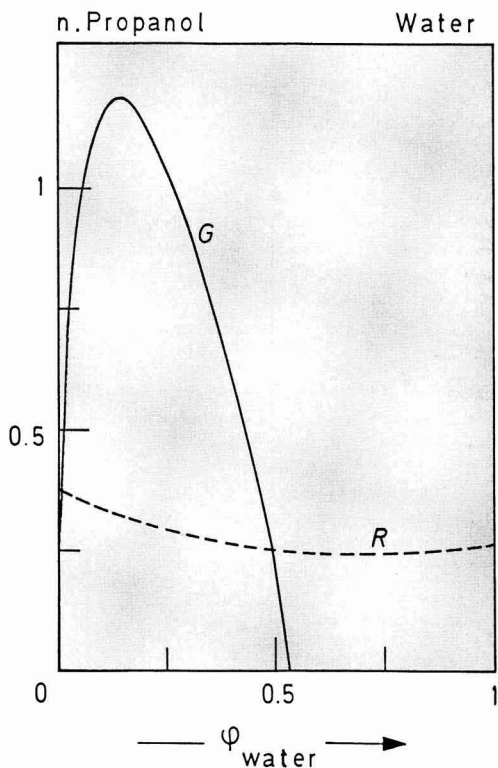


Figure 2—"Red" (R) and "Green" (G) solubility functions for PVAC in binary blends of 1-propanol and water as a function of the volume fraction of water at 25°C. Appearance of true cosolvency: the G function cuts the R function in two points

is the sum of the factors which can exert a positive influence on the solubility, and

$$R = A + D + C \quad (23)$$

is the sum of the factors which exert a negative influence on the solubility.

The dissolving power is the difference between these two functions:

$$\mathcal{F} = G - R \quad (24)$$

From the characteristics of the polymer (A , ${}^{\rho}\delta'$, \bar{V}_m and, eventually, K), those of solvent 1 (${}^s1\delta'$, \bar{V}_{s1} , b_{s1}) and those of solvent 2 (${}^s2\delta'$, \bar{V}_{s2} , b_{s2}), the computer calculates B , H , D and determines the G and R functions for a hundred different values of ϕ_2 going from $\phi_2 = 0$ (pure solvent 1) to $\phi_2 = 1$ (pure solvent 2). This procedure is illustrated in Figure: 1 and 2. When G lies beyond R , the dissolving power is positive and the polymer is expected to dissolve. The cosolvency limit corresponds to the value of ϕ_2 where the two curves G and R cross each other.

SUMMARY

In order to be used in computers, the capacity of a blend to dissolve a given resin has to be presented in a numerical form. A convenient quantitative definition for the dissolving power of a solvent for a polymer is the difference

$$\mathcal{F}_m = \frac{\mu_m - \mu_{msol}}{RT} \quad (4)$$

where μ_m and μ_{msol} are the chemical potentials of the repeating unit in its own phase and in solution. The last one refers to a particular value, ϕ_p , of the volume fraction of the polymer in the solution. When \mathcal{F}_m is positive, more polymer can be dissolved; when \mathcal{F}_m is negative for this particular value of ϕ_p , phase separation is expected.

According to Hansen's three parameter method, the sign of the dissolving power of a solvent for a polymer can be found from the equation

$$\frac{\mathcal{F}_m}{C} = R_A^2 - 4({}^s\delta_d - {}^{\rho}\delta_d)^2 - ({}^s\delta_p - {}^{\rho}\delta_p)^2 - ({}^s\delta_h - {}^{\rho}\delta_h)^2 \quad (5)$$

where C is a constant, the value of which does not influence the sign of \mathcal{F}_m , R_A is the radius of the solute solubility sphere, and the δ 's are the various solubility parameters (dispersion forces, dipole-dipole interactions and H-bonds) of solvent and polymer.

The weakness of Hansen's method lies in the fact that it neglects the entropy effects. In fact, \mathcal{F}_m always contains two terms

$$\mathcal{F}_m = \frac{-\Delta H_{transf}}{RT} + \frac{\Delta S_{transf}}{R} \quad (2)$$

ΔH_{transf} being the heat absorbed when a repeating segment of the polymer is transferred from its own phase into the solution and ΔS_{transf} is the corresponding change in entropy. In Hansen's method, the last term is assumed to be independent of the solvent and included in the radius R_A . A second point which is questionable in this approach is the use of the hydrogen bond parameter δ_h to describe the influence of H-bonds on the solubility. Indeed, an hydrogen bond is an interaction between sites

of opposite nature and it is meaningless to try to describe by an unique parameter the capacity to act as proton donor and the capacity to act as proton acceptor.

A new method is then presented for the calculation of \mathcal{F}_m , which (1) takes entropy effects into account, and (2) replaces the last term of equation (5) with a more correct expression.

The new equation giving \mathcal{F}_m contains characteristics of the solvent and of the polymer which are known *a priori*: \bar{V}_s , the molar volume of the solvent; \bar{V}_m , the molar volume of the repeating unit of the polymer; and b_s , the so-called structuration factor of the solvent. For all solvents that do not contain H-bond chains b_s is zero; for solvents with single chains (alcohols) b_s equals -1 ; and for solvents with double chains (water) b_s equals -2 . The new equation also contains a few parameters: modified "non-specific" solubility parameters, ${}^s\delta'$ and ${}^{\rho}\delta'$, of solvent and polymer; a so-called "fluidization" constant, A , which characterizes each polymer at a given temperature; the stability constants, K , of the hydrogen bonds between the polymer segment and the main group of H-bond active solvents; and the stability constant, K_{pp} , of segment-segment H-bonds.

The equation giving the dissolving power is

$$\begin{aligned} \mathcal{F}_m = & -A - \frac{\bar{V}_m}{RT} ({}^s\delta' - {}^{\rho}\delta')^2 (1 - \phi_p)^2 + (0.5 + b_s) \frac{\bar{V}_m}{V_s} (1 - \phi_p) \\ & + \ln(1 + K(1 - \phi_p)/\bar{V}_s) - \ln((1 + K_{pp}/\bar{V}_m)/(1 + K_{pp}\phi_p/\bar{V}_m)) \end{aligned} \quad (14)$$

For pure solvents, the calculation of \mathcal{F}_m by means of this equation and the finding of its sign, from the values of A , ${}^{\rho}\delta'$, ${}^s\delta'$, K , K_{pp} , can be carried out in a few seconds with a pocket calculator just as that of \mathcal{F}_m/C from equation (5) using R_A , ${}^s\delta_d$, ${}^s\delta_p$, ${}^s\delta_h$, ${}^{\rho}\delta_d$, ${}^{\rho}\delta_p$, ${}^{\rho}\delta_h$.

The sign of \mathcal{F}_m for three polymers, PVAC, PMMA, and PEMA, in a wide variety of solvents is correctly predicted in more than 95% of the cases using equation (12), whereas the agreement is only 78% for equation (5).

For binary solvent blends with volume fractions ϕ_1 and ϕ_2 , the three parameters method calculates the solubility parameters of the blend using the additive function in volume fractions:

$$\delta_{blend} = \phi_1\delta_1 + \phi_2\delta_2 \quad (15)$$

This equation is based on the assumption of a random mixing of the molecules of both solvents.

In the present method, a computer program calculates the second term of equation (14) with an equation assuming partial segregation of the molecules of both solvents without introducing new parameters. The third and fourth terms are calculated from those of the individual solvents by weighting them on the volume fraction basis.

In binary blends, the cosolvency limits are those for which \mathcal{F}_m is zero. The validity of the approaches can therefore be checked by comparing the calculated and the experimental cosolvency limits. In absence of H-bonds, the method with three parameters predicts the limits for the considered polymers with a standard deviation of 16 volume percent. This reduces to five volume percent in the present approach. For solvent blends containing alcohols

or water, where the quantitative limits predicted by the three parameters method are rather unreliable, the present approach still gives good results.

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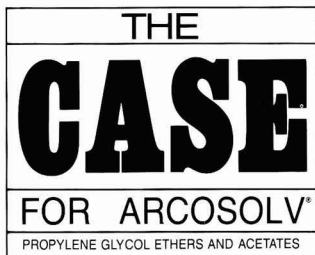
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|------------------------------|--|------------------|-----------------------------|----------------------|-------------------------------------|
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| Glycol Ethers | | | | | |
| ARCOSOLV® PM | Propylene Glycol Methyl Ether (PGME) | 90.1 | 66 | 10.4 | ∞ |
| ARCOSOLV® DPM | Dipropylene Glycol Methyl Ether (DPGME) | 148.2 | 2 | 9.6 | ∞ |
| — | Ethylene Glycol Ethyl Ether (EGEE) | 90.1 | 32 | 9.9 | ∞ |
| — | Ethylene Glycol Butyl Ether (EGBE) | 118.2 | 6 | 8.9 | ∞ |
| Glycol Ether Acetates | | | | | |
| ARCOSOLV® PMAC | Propylene Glycol Methyl Ether Acetate (PGMEA) | 132.2 | 34 | 9.2 | 18.5/5.6 |
| — | Ethylene Glycol Ethyl Ether Acetate (EGEEA) | 132.2 | 20 | 9.4 | 23.8/6.5 |
| ARCOSOLV® DPMAC | Dipropylene Glycol Methyl Ether Acetate (DPGMEA) | 190.2 | <1 | 8.3 | 12.3/3.5 |
| — | Ethylene Glycol Butyl Ether Acetate (EGBEA) | 160.2 | 3 | 8.6 | 1.1/1.6 |

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Equations for Calculating Homolog Solubility Parameters

II: Simple Equations Based on Chain Length

Charles H. Fisher
Roanoke College*

Linear equations are provided for correlating homolog solubility parameters with numbers of carbons, molecular weights, molar volumes, refractive indices, and boiling points. The linear equations can be used to evaluate some published solubility parameters and to estimate new ones. In some instances, logarithmic and reciprocal equations are superior to the linear equations. The limiting (or infinite-length n-alkane) solubility parameter may be 8.2H or 16.8 (S.I.).

LINEAR EQUATIONS

Because of the importance and usefulness^{1,2} of solubility parameters (δ), many equations have been proposed for calculating them.¹⁻³ The simplest type of equation ($\delta = b + mC$, where b , m , and C are intercept, slope, and number of carbons, respectively) has been proposed³ for the homologs shown in *Table 1*. The present paper presents similar linear equations for correlating solubility parameters (solpars) with homolog chain length [(L), measured conveniently by number of carbons or molecular weight, (M)] for many additional homologs (*Table 2*).

Linear expressions [eq. (1)-(36) in *Tables 1* and *2*] are simple to use and have the additional advantage of providing a basis for correlating solpars with properties and property functions that also are linear with chain length, e.g., molecular weight, (M); molar volumes ($V = M/d$); M/n ; and T^2 ; where d , n , and T are density, refractive index, and boiling point (K), respectively. This

use of the linear relations for the C₇-C₁₅ n-alkanes is illustrated by eq. (37)-(40) and *Table 3*:

$$\delta = 6.8136 + 0.0064878M \quad (37)$$

(Corr. coeff., 0.996303)

$$\delta = 6.6411 + 0.0055879V \quad (38)$$

(Corr. coeff., 0.996498)

$$\delta = 6.7729 + 0.0095504M/n_D^{25} \quad (39)$$

(Corr. coeff., 0.996263)

$$\delta = 6.8201 + 0.000004606T^2 \quad (40)$$

(Corr. coeff., 0.995051)

Where expressions (such as $P = b' + m'C$) for correlating properties or property functions (P) with C are available, equations for correlating δ with P can be calculated (b'' is $b - m''b'$ and m'' is m/m'):

$$\begin{aligned} \delta &= b + mC \\ P &= b' + m'C \\ \delta &= b'' + m''P \end{aligned}$$

Another advantage of linear equations ($\delta = b + mC$) is that they can be divided by other linear equations to get expressions that correlate δ/P ratios with chain lengths:

$$\begin{aligned} \delta &= b + mC \\ P &= b' + m'C \\ \frac{\delta}{P} (C + b'/m') &= b/m' + m/m'C \end{aligned}$$

Dividing the P equation by the δ equation would give P/δ ratios.

The intercepts (b) and slopes (m) of the *Table 1* and *2* equations are approximately related to each other by eq. (41):

$$b = 8.18 - 14.17 m \quad (41)$$

This suggests that the limiting solpar [indicated when m in eq. (41) is zero] is approximately 8.2H or 16.78 (S.I.).

*Chemistry Dept., Salem, VA 24153.

Table 1—Equations^a Correlating Homolog Solubility Parameters (\$_s) with the Number of Carbons (C)^{b,c}

| Eq. | Homologs | Carbon Range | Intercept (b) | Slope (m) | Corr. Coeff. (r) |
|-------|--------------------------------|--------------|---------------|-----------|------------------|
| 1 ... | R ₂ NH | 6-12 | 7.6607 | 0.056071 | 0.9798 |
| 2 ... | RCl | 3-6 | 8.3650 | 0.005000 | 0.5000 |
| 3 ... | RC ₆ H ₅ | 9-16 | 8.7980 | -0.020964 | -0.8699 |
| 4 ... | Acetates | 5-8 | 9.0221 | -0.049286 | -0.9198 |
| 5 ... | RCHO | 4-6 | 9.4500 | -0.09000 | -1.000 |
| 6 ... | Et ketones | 6-8 | 9.2000 | -0.10000 | -0.9853 |
| 7 ... | Vinyl esters | 4-6 | 9.8350 | -0.19500 | -0.9990 |
| 8 ... | Cyclohexanes | 8-18 | 8.0427 | -0.012328 | -0.9559 |

(a) \$ = b + mC.

(b) From Ref. 3; agreement between literature and calculated values is good even for the equations with low correlation coefficients.

(c) R = n-alkyl.

Seymour⁶; the other solpars are from Hoy.⁷ It was assumed the n-hexyl n-hexanoate solpar (8.29 Hildebrands) is valid for the isomeric n-butyl n-octanoate. The n-hexyl ether solpar of 8.00 was used as the ethyl decyl ether value. A programmed calculator was used to develop least squares equations. Hildebrands can be multiplied by 2.046 to obtain S. I. solpars; equations can be multiplied by 2.046 to obtain expressions for calculating S. I. solpars:

$$\text{n-Alkane Hildebrands} = 6.7576 + 0.096606C \quad (9)$$

$$\text{n-Alkane S. I. solpars} = 13.826 + 0.19766C \quad (42)$$

The Hildebrand values calculated by the *Table 2* equations are compared with the literature solpars in *Tables 4-6*.

Fisher and Huddle⁴ have shown how limiting properties (P_{∞}) can be used advantageously in calculations and in developing equations.

The alkyl phthalate data are from Burrell⁵ and

LOGARITHMIC AND RECIPROCAL EQUATIONS

The simple linear equations (*Tables 1 and 2*), which appear to be general for homologous series over substantial and useful chain lengths (except for the lowest

Table 2—Equations^a Correlating Homolog Solubility Parameters (\$_s)^b with Number of Carbons (C)^c

| Eq. | Homologs | Carbon Range | Total Members | Intercept (b) | Slope (m) | Corr. Coeff. (r) |
|----------|---|--------------|---------------|---------------|-----------|------------------------|
| 9 | n-Alkanes | 6-15 | 10 | 6.7576 | 0.096606 | 0.993181 |
| 10 | 2-MeAlkanes | 6-10 | 5 | 6.1920 | 0.14200 | 0.990612 |
| 11 | 3-MeAlkanes | 6-10 | 5 | 6.2900 | 0.13900 | 0.997756 |
| 12 | 1-Alkenes | 6-10 | 5 | 6.5440 | 0.13000 | 0.998465 |
| 13 | Cyclopentanes | 6-15 | 11 | 7.4020 | 0.068909 | 0.990499 |
| 14 | o-R Toluenes | 8-11 | 4 | 10.110 | -0.13500 | -0.983152 |
| 15 | m, p-R Toluenes | 7-11 | 5 | 9.5710 | -0.094000 | -0.985659 |
| 16 | EtOR | 3-12 | 4 | 7.3633 | 0.052667 | 0.987470 |
| 17 | ROR ^d | 4-12 | 3 | 7.2933 | 0.058750 | 0.999925 |
| 18 | CH ₂ CHOR | 4-6 | 3 | 7.7283 | 0.02500 | 0.866025 |
| 19 | ROCH ₂ CH ₂ OR | 6-10 | 4 | 8.6717 | -0.048286 | -0.783003 |
| 20 | CH ₃ CO(OCH ₂ CH ₂) ₂ OR | 7-10 | 3 | 11.756 | -0.27357 | -0.983241 |
| 21 | Esters, branched ^e | 8-16 | 3 | 7.5917 | 0.021250 | 0.914807 |
| 22 | RCOOBu ^f | 6-12 | 3 | 9.0279 | -0.063214 | -0.962013 |
| 23 | RCOOR ^d | 4-12 | 3 | 9.1733 | -0.077500 | -0.967648 |
| 24 | R Acrylates | 5-9 | 3 | 8.9200 | -0.03000 | -0.654654 ^a |
| 25 | R Phthalates | 12-20 | 5 | 11.640 | -0.14000 | -0.989949 |
| 26 | Aldehydes, branched ^g | 4-8 | 3 | 9.1183 | -0.087500 | -0.996616 |
| 27 | MeCOR | 3-8 | 4 | 10.098 | -0.16059 | -0.999893 |
| 28 | EtCOR | 4-8 | 4 | 10.451 | -0.26600 | -0.988240 |
| 29 | RCOR ^d | 3-7 | 3 | 10.277 | -0.23000 | -0.992215 |
| 30 | ROH | 5-12 | 8 | 11.643 | -0.16119 | -0.989763 |
| 31 | sec-Alcohols | 6-10 | 5 | 12.008 | -0.32500 | -0.989732 |
| 32 | iso-Alcohols | 5-10 | 3 | 12.775 | -0.33500 | -0.999666 |
| 33 | Acids, branched ^h | 4-8 | 3 | 12.927 | -0.24000 | -0.999711 |
| 34 | RNH ₂ | 3-6 | 3 | 9.2450 | -0.13500 | -0.981981 |
| 35 | R ₂ NH | 4-12 | 4 | 7.8157 | 0.040571 | 0.908504 |
| 36 | R ₃ N ⁱ | 6-12 | 3 | 7.1233 | 0.056667 | 0.914807 |

(a) \$ = b + mC; The fit is reasonably good even for equations having poor correlation coefficients.

(b) Except phthalates (Ref. 6), data are from Hoy.⁷

(c) R = n-Alkyl.

(d) Symmetrical.

(e) Isobutyl isobutyrate, 2-ethylbutyl ethylbutyrate, and 2-ethylhexyl ethylhexanoate.

(f) Hexyl compound solpar used for C₁₂.

(g) Isobutyraldehyde, 2-ethylbutyraldehyde, and 2-ethylhexaldehyde.

(h) Isobutyric, 2-ethylbutyric, and 2-ethylhexanoic acids.

(i) (Et)₃N; (Bu)₂MeN; and (Bu)₃N.

Table 3—Comparison of Literature and Calculated n-Alkane Solubility Parameters (Hildebrands)^{a, b}

| Carbons | M ^c | d ₄ ²⁵ | v ²⁵ | n _D ²⁵ | M/n _D ²⁵ | Solpar | T, K | Calc'd solpars | | | |
|---------|----------------|------------------------------|-----------------|------------------------------|--------------------------------|--------|-------|----------------|--------|--------|--------|
| | | | | | | | | Eq. 37 | Eq. 38 | Eq. 39 | Eq. 40 |
| 7 | 100.21 | .6795 | 147.5 | 1.3851 | 72.34 | 7.50 | 371.6 | 7.46 | 7.47 | 7.46 | 7.46 |
| 8 | 114.23 | .6985 | 163.5 | 1.3951 | 81.88 | 7.54 | 398.9 | 7.55 | 7.55 | 7.55 | 7.55 |
| 9 | 128.26 | .7138 | 179.7 | 1.4031 | 91.41 | 7.64 | 424.0 | 7.65 | 7.65 | 7.65 | 7.65 |
| 10 | 142.29 | .7263 | 195.9 | 1.4097 | 100.9 | 7.72 | 447.4 | 7.74 | 7.74 | 7.74 | 7.74 |
| 11 | 156.31 | .7366 | 212.2 | 1.4150 | 110.5 | 7.80 | 469.1 | 7.83 | 7.83 | 7.83 | 7.83 |
| 12 | 170.34 | .7452 | 228.6 | 1.4195 | 120.0 | 7.91 | 489.5 | 7.92 | 7.92 | 7.92 | 7.92 |
| 13 | 184.37 | .7528 | 244.9 | 1.4234 | 129.5 | 8.04 | 508.7 | 8.01 | 8.01 | 8.01 | 8.01 |
| 14 | 198.39 | .7593 | 261.3 | 1.4268 | 139.0 | 8.11 | 526.8 | 8.10 | 8.10 | 8.10 | 8.10 |
| 15 | 212.42 | .7650 | 277.7 | 1.4298 | 148.6 | 8.19 | 543.9 | 8.19 | 8.19 | 8.19 | 8.18 |

(a) Densities and refractive indices from Rossini;⁸ boiling points from Zwolinski,⁹ and solpars from Hoy.⁷

(b) Hildebrands can be multiplied by 2.046 to obtain solpars in S. I. units.

(c) Molecular weight = 2.016 + 14.027C.

members), can be recommended for evaluating the accuracy of many published solubility parameters and calculating numerous new ones.

However, solpars are not strictly linear with chain length (L), and hence it would not be expected that the $\$ = b + m L$ equations will be found suitable in all instances.

A linear expression [eq. (9), Table 2] is reasonably satisfactory for the C₆-C₁₅ n-alkanes. When n-pentane is included, however, the linear relation [eq. (43)] is less satisfactory than eq. (44)-(51) for the C₅-C₁₂ n-alkanes (Table 7).

$$\$ = 6.5745 + 0.11476C. \quad (r = 0.96745) \quad (43)$$

$$\$ = 5.5682 + 2.1718 \log C. \quad (r = 0.98703) \quad (44)$$

$$\log \$ = 0.76246 + 0.12625 \log C. \quad (r = 0.98484) \quad (45)$$

$$\log \$ = 0.93090 - 0.41764/C. \quad (r = 0.99330) \quad (46)$$

$$\$ = 8.4638 - 7.1679/C. \quad (r = -0.99319) \quad (47)$$

$$\$^2 = 70.711 - 106.95/C. \quad (r = -0.99272) \quad (48)$$

$$\$^{1/2} = 2.9146 - 1.3126/C. \quad (r = -0.99329) \quad (49)$$

$$C/\$ = 0.12881 + 0.11621C. \quad (r = 0.99985) \quad (50)$$

$$C\$ = -7.2883 + 8.4783C. \quad (r = 0.99989) \quad (51)$$

The logarithmic relation [eq. (44)] proposed by Seymour^{2,3} gives a much better fit than eq. (43). The limiting solpar indicated by eq. (46)-(51) range from 8.41 to 8.61. These values are somewhat higher than the limiting solpars (7.7-8.2) reported¹⁰ for amorphous polyethylene. The reciprocal expressions [eq. (46)-(51)], which are relatively simple, give good agreement between literature and calculated values.

Eq. (50) and (51) have the additional attraction that C\$ and C/\$ are linear with chain length.

Eq. (48) correlates cohesive energy density ($\2) with reciprocal carbons.

For those instances in which the $\$ = b + m L$ equations are inadequate, eq. (44)-(51) are recommended. Of

Table 4—Comparison of Literature^a and Calculated Solubility Parameters^b

| Carbons | n-Alkanes | | 1-Alkenes | | Cyclo-pentanes | | R Toluenes | | EtOR | | ROR | | ROCCOR | |
|---------|-----------|-------|-----------|--------|----------------|--------|------------|--------|------|--------|------|--------|--------|--------|
| | Lit. | Eq. 9 | Lit. | Eq. 12 | Lit. | Eq. 13 | Lit. | Eq. 15 | Lit. | Eq. 16 | Lit. | Eq. 17 | Lit. | Eq. 19 |
| 3 | — | — | — | — | — | — | — | — | 7.56 | 7.52 | — | — | — | — |
| 4 | — | — | — | — | — | — | — | — | 7.53 | 7.57 | 7.53 | 7.53 | — | — |
| 5 | — | — | — | — | — | — | — | — | — | 7.63 | — | — | — | — |
| 6 | 7.27 | 7.34 | 7.31 | 7.32 | 7.83 | 7.82 | — | — | 7.68 | 7.68 | — | 7.65 | 8.35 | 8.38 |
| 7 | 7.50 | 7.43 | 7.47 | 7.45 | 7.92 | 7.88 | 8.93 | 8.91 | — | 7.73 | — | — | 8.42 | 8.33 |
| 8 | 7.54 | 7.53 | 7.59 | 7.58 | 7.96 | 7.95 | 8.83 | 8.82 | — | 7.78 | 7.76 | 7.76 | 8.22 | 8.29 |
| 9 | 7.64 | 7.63 | 7.71 | 7.71 | 8.01 | 8.02 | 8.69 | 8.73 | — | 7.84 | — | — | — | — |
| 10 | 7.72 | 7.72 | 7.84 | 7.84 | 8.05 | 8.09 | 8.62 | 8.63 | — | 7.89 | — | 7.88 | 8.20 | 8.19 |
| 11 | 7.80 | 7.82 | — | — | 8.15 | 8.16 | 8.57 | 8.54 | — | 7.94 | — | — | — | — |
| 12 | 7.91 | 7.92 | — | — | 8.20 | 8.23 | — | — | 8.00 | 8.00 | 8.00 | 8.00 | — | — |
| 13 | 8.04 | 8.01 | — | — | 8.26 | 8.30 | — | — | — | 8.05 | — | — | — | — |
| 14 | 8.11 | 8.11 | — | — | 8.38 | 8.37 | — | — | — | — | — | — | — | — |
| 15 | 8.19 | 8.21 | — | — | 8.50 | 8.44 | — | — | — | — | — | — | — | — |
| 16 | — | — | — | — | 8.50 | 8.50 | — | — | — | — | — | — | — | — |

(a) Ref. 7.

(b) Equations from Table 2.

Table 5—Comparison of Literature^a and Calculated Solubility Parameters (δ)^b

| Carbons | Ether esters | | Esters ^c | | n-Bu esters | | Esters Sym. ^d | | Acrylates | | Phthalates | | Aldehydes ^e | |
|---------|--------------|--------|---------------------|--------|-------------|--------|--------------------------|--------|-----------|--------|------------|--------|------------------------|--------|
| | Lit. | Eq. 20 | Lit. | Eq. 21 | Lit. | Eq. 22 | Lit. | Eq. 23 | Lit. | Eq. 24 | Lit. | Eq. 25 | Lit. | Eq. 26 |
| 4 | — | — | — | — | — | — | 8.91 | 8.86 | 9.38 | — | — | — | 8.76 | 8.77 |
| 5 | — | — | — | — | — | — | — | — | 8.81 | 8.77 | — | — | — | 8.68 |
| 6 | — | — | — | — | 8.69 | 8.65 | — | 8.71 | — | 8.74 | — | — | 8.61 | 8.59 |
| 7 | 9.90 | 9.84 | — | — | — | 8.59 | — | — | 8.63 | 8.71 | — | — | — | 8.51 |
| 8 | 9.48 | 9.57 | 7.74 | 7.76 | 8.46 | 8.52 | 8.46 | 8.55 | — | 8.66 | — | — | 8.41 | 8.42 |
| 9 | — | 9.29 | — | 7.78 | — | 8.46 | — | — | 8.69 | 8.65 | — | — | — | — |
| 10 | 9.05 | 9.02 | — | 7.80 | — | 8.40 | — | 8.40 | — | 8.62 | 10.7 | — | — | — |
| 11 | — | 8.75 | — | 7.83 | — | 8.33 | — | — | — | 8.59 | — | — | — | — |
| 12 | — | 8.47 | 7.89 | 7.85 | 8.29 | 8.27 | 8.29 | 8.24 | — | — | 10.0 | 9.96 | — | — |
| 13 | — | — | — | 7.87 | — | — | — | — | — | — | — | — | — | — |
| 14 | — | — | — | 7.89 | — | — | — | — | — | — | 9.7 | 9.68 | — | — |
| 15 | — | — | — | 7.91 | — | — | — | — | — | — | — | — | — | — |
| 16 | — | — | 7.91 | 7.93 | — | — | — | — | — | — | 9.3 | 9.40 | — | — |
| 18 | — | — | — | — | — | — | — | — | — | — | 9.1 | 9.12 | — | — |
| 20 | — | — | — | — | — | — | — | — | — | — | 8.9 | 8.84 | — | — |

(a) Phthalate data from Refs. 5 and 6; other solpars from Ref. 7.
 (b) The ether esters are acetates of diglycol mono-ethers.
 (c) Isobutyl isobutyrate 2-ethylbutyl ethylbutyrate, and 2-ethylhexyl ethylhexanoate.
 (d) Ethyl acetate, butyl butyrate, and hexyl hexanoate.
 (e) Isobutyraldehyde, 2-ethylbutyraldehyde, and 2-ethylhexaldehyde.

Table 6—Comparison of Literature^a and Calculated Solubility Parameters

| Carbons | MeCOR | | RCOR | | ROH | | iso-Alcohols | | Acids ^b | | RNH ₂ | | R ₃ N | |
|---------|-------|-------------------|------|--------|-------|--------|--------------|--------|--------------------|--------|------------------|--------|------------------|--------|
| | Lit. | Eq. 27 | Lit. | Eq. 29 | Lit. | Eq. 30 | Lit. | Eq. 32 | Lit. | Eq. 33 | Lit. | Eq. 34 | Lit. | Eq. 36 |
| 3 | 9.62 | 9.62 | 9.62 | 9.59 | 12.18 | — | 11.45 | — | — | — | 8.87 | 8.84 | — | — |
| 4 | 9.45 | 9.46 | — | — | 11.60 | — | 11.24 | — | 11.96 | 11.97 | 8.66 | 8.71 | — | — |
| 5 | 8.99 | 9.30 ^c | 9.06 | 9.13 | 10.83 | 10.84 | 11.09 | 11.10 | — | 11.73 | — | 8.57 | — | — |
| 6 | 8.63 | 9.13 ^c | — | — | 10.77 | 10.68 | — | 10.77 | 11.50 | 11.49 | 8.45 | 8.44 | 7.42 | 7.46 |
| 7 | 8.98 | 8.97 | 8.70 | 8.67 | 10.50 | 10.51 | — | 10.43 | — | 11.25 | — | — | — | — |
| 8 | 8.81 | 8.81 | — | — | 10.30 | 10.35 | 10.12 | 10.10 | 11.00 | 11.01 | — | — | — | — |
| 9 | 8.22 | 8.65 ^c | — | 8.21 | 10.12 | 10.19 | — | 9.76 | — | 10.77 | — | — | 7.72 | 7.63 |
| 10 | — | — | — | — | 10.03 | 10.03 | 9.41 | 9.43 | — | — | — | — | — | — |
| 11 | — | — | — | — | 9.85 | 9.87 | — | — | — | — | — | — | — | — |
| 12 | — | — | — | — | 9.78 | 9.71 | — | — | — | — | — | — | 7.76 | 7.80 |

(a) Ref. 7.
 (b) Isobutyric, 2-ethylbutyric, and 2-ethylhexanoic acids.
 (c) The C₅, C₆, and C₉ Me ketones were omitted in developing eq. (27).

Table 7—n-Alkanes: Literature^a and Calculated Solubility Parameter Fit Using Different Equations

| Carbons | Lit. | Equation Number | | | | | | | | | |
|---------|------|-----------------|------|-------|------|------|------|------|------|------|--|
| | | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | |
| 5 | 7.02 | 7.15 | 7.09 | 7.09 | 7.04 | 7.03 | 7.02 | 7.03 | 7.04 | 7.02 | |
| 6 | 7.27 | 7.26 | 7.26 | 7.26 | 7.27 | 7.27 | 7.27 | 7.27 | 7.27 | 7.26 | |
| 7 | 7.50 | 7.38 | 7.40 | 7.40 | 7.43 | 7.44 | 7.45 | 7.44 | 7.43 | 7.44 | |
| 8 | 7.54 | 7.49 | 7.53 | 7.52 | 7.56 | 7.57 | 7.57 | 7.57 | 7.56 | 7.57 | |
| 9 | 7.64 | 7.61 | 7.64 | 7.64 | 7.66 | 7.67 | 7.67 | 7.67 | 7.66 | 7.67 | |
| 10 | 7.72 | 7.72 | 7.74 | 7.74 | 7.75 | 7.75 | 7.75 | 7.75 | 7.75 | 7.75 | |
| 11 | 7.80 | 7.84 | 7.83 | 7.83 | 7.82 | 7.81 | 7.81 | 7.81 | 7.82 | 7.82 | |
| 12 | 7.91 | 7.95 | 7.91 | 7.92 | 7.87 | 7.87 | 7.86 | 7.87 | 7.88 | 7.87 | |
| 100 | — | 18.05 | 9.91 | 10.35 | 8.45 | 8.39 | 8.35 | 8.42 | 8.51 | 8.41 | |
| ∞ | — | ∞ | ∞ | ∞ | 8.53 | 8.46 | 8.41 | 8.49 | 8.61 | 8.48 | |

(a) Ref. 7.

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these, eq. (47), (50), and (51) are particularly attractive. Molecular weights (and other properties and property functions that are linear with L) can presumably be substituted for C in eq. (43)-(51).

SUMMARY

Linear equations of the simplest type ($\$ = b + mC$) that correlate homolog solubility parameters (\$) with number of carbons (C) are presented for the members of 34 homologous series. Such linear equations provide the basis for correlating solpars with other properties (or property functions) that also are linear with C; this is illustrated by equations that correlate n-alkane solpars with molecular weight, molar volume, M/n , and T^2 , where M, n, and T are molecular weight, refractive index, and boiling point (K), respectively. The intercepts (b) and slopes (m) of the linear equations suggest that the limiting or infinite-length n-alkane solubility parameter (useful in

calculations and equation development) is approximately 8.2 H or 16.78 (S.I.). In some instances, logarithmic and reciprocal equations are superior to the linear equations for correlating solpars with chain length. The limiting solpar indicated by the reciprocal equations is slightly higher than the solpar (7.7-8.2) of polyethylene.

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Use of a Flocculation Gradient Monitor For Quantifying Titanium Dioxide Pigment Dispersion in Dry and Wet Paint Films

D.J. Rutherford and L.A. Simpson
Tioxide Group PLC*

The degree of pigment flocculation in a dry paint film can be determined by measuring the amount of infrared radiation which is back-scattered as a function of film thickness. This results in the calculation of flocculation gradient. However, the use of this technique has been limited by the necessity for a relatively expensive spectrophotometer. A simple and inexpensive apparatus for measuring flocculation gradient, which is referred to as a Flocculation Gradient Monitor, has therefore been designed, built, and tested. The advantages and disadvantages of the use of flocculation gradient in practice are discussed.

In addition, pigment flocculation in the wet paint (or millbase) has been quantified using a similar principle to determine back-scatter measurement (R_w^{40}) for only one wet film thickness. For this purpose, a wet cell, 40 μm thick, is used to encapsulate the paint. Since the technique is quick, it is suitable as an online quality control test which can be used at any stage of a paint manufacturing process.

INTRODUCTION

Pigment flocculation can adversely affect the optical performance^{1,2,3} of a paint film, and certain protective/decorative properties such as durability⁴ and metal marking.⁵ A coating containing flocculated pigment will therefore invariably be inferior in performance to one of

similar composition but containing well dispersed pigment.

Thus, there is a need to quantify the degree of pigment flocculation in a paint system. It is well known that the scattering efficiency of electromagnetic radiation by spherical particles is, among other factors, a function of their diameter and of the wavelength of the incident radiation, such that for a given wavelength there is an optimum diameter for maximum scattering efficiency (e.g., see Kerker⁶). If, for example, the mean diameter increases, the wavelength scattered most effectively will increase accordingly, and the converse applies. To provide good opacity and whiteness, the mean particle size (approximately 0.24 μm) of titanium dioxide is therefore controlled to give maximum scattering of radiation which is in the center of the visible region of the spectrum (i.e., wavelength = 0.55 μm). However, if the mean particle size of titanium dioxide is increased by flocculation, then longer wavelength radiation will be preferentially scattered. This concept was used to advantage by Balfour and Hird⁷ to quantify pigment flocculation in a dry paint film.

The method used by Balfour and Hird involved measuring the amount of infrared radiation (wavelength = 2.5 μm) which was back-scattered by a paint film as a function of film thickness. The technique consisted of applying the paint under study to polyester sheet (125 μm thick) using wire wound applicator bars to give nominal wet film thicknesses of 24, 36, 50, and 60 μm . The paint was either oven-dried or allowed to air dry, then a 36 cm^2 square was cut out of each drawdown and the back-scatter (relative to barium sulphate) of radiation of 2.5 μm wavelength was measured. Each square was weighed, the paint removed, and the polyester square re-weighed.

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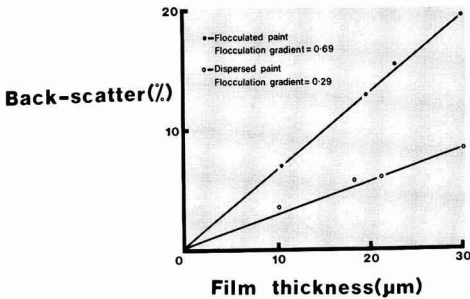


Figure 1—Relationship between back-scatter and film thickness for a dispersed and a flocculated paint

From this measurement, and the density of the dry paint, film thickness was calculated. A plot of percentage back-scatter (relative to barium sulphate) against film thickness produced a straight line (for film thickness values up to about 30 μm) whose gradient increased with increasing flocculation. Consequently, this gradient was referred to as flocculation gradient.

In Figure 1, typical plots are shown for two decorative alkyd gloss paints which are identical in composition except that one contains a flocculating agent, and it is evident that the well dispersed paint has the lower flocculation gradient. It is important to note that if thicker films were produced (i.e., greater than 30 μm) the relationship between back-scatter and film thickness would be non-linear.

REVIEW OF PREVIOUS WORK ON FLOCCULATION GRADIENT

As previously mentioned, pigment flocculation can affect the optical properties of a paint, and therefore flocculation gradient has been used extensively to determine if flocculation is responsible for a deterioration in certain properties, such as opacity, color and gloss. The following examples, which have been published by Balfour and Hird,⁷ and Balfour⁸ will serve to illustrate the advantage in measuring flocculation gradient.

Opacity

To study the effect of flocculation on opacity, a series of paints containing a general purpose rutile grade of titanium dioxide pigment at a pigment volume concentration (PVC) of 17.5% in a long oil soya modified alkyd was prepared. The paints varied only in the degree of flocculation, which was controlled by the quantity of flocculating agent incorporated in the paints.

Opacity was measured by applying films in a similar manner to a polyester sheet at nominal wet film thicknesses of 50, 60, 75, and 100 μm using applicator bars, and measuring the reflectance of the dry films over standard black and white tiles using the green filter of a Gardner XL-23 Colorimeter. Contrast ratio was calculated as follows:

$$\text{Contrast ratio} = \frac{\text{Reflectance over black substrate}}{\text{Reflectance over white substrate}} \times 100$$

Graphs of contrast ratio against wet spreading rate were produced, and the opacity taken as the contrast ratio at a spreading rate of 20 m²/liter.

In Figure 2, opacity is plotted against flocculation gradient, and it can be seen that an increase in flocculation gradient results in a decrease in opacity, and that for a well dispersed paint (e.g., flocculation gradient = 0.2) an increase in gradient of 0.1 leads to a 0.4% loss of opacity which would be visually evident.

Color

A similar series of paints to that above (i.e., 17.5% PVC pigmented alkyd) was applied to white art board at a nominal wet film thickness of 100 μm by means of an applicator bar. After drying, the color of each film was measured using a Gardner XL-23 Colorimeter, and a color index calculated as follows:

$$\text{Color index} = \frac{\text{Red reflectance} - \text{Blue reflectance}}{\text{Green reflectance}} \times 100$$

where increasing values of color index indicate greater yellowness (Note: a pressed sample of magnesium oxide would have a color index of zero).

Flocculation gradient was also measured, and in Figure 3 these values are plotted against color index. It is evident that flocculation has little effect on color for paints which are reasonably dispersed (i.e., for flocculation gradients up to 0.5), whereas a significant increase in yellowness occurs with the severely flocculated paints.

Gloss

The gloss exhibited by a gloss emulsion paint is particularly sensitive to the grade of titanium dioxide pigment used.⁹ To produce a range of gloss values, a paint based on an acrylic copolymer was selected and pigmented with various rutile grades of titanium dioxide pigment which were similar in crystal size, although the inorganic surface treatments were different. The PVC of each film was 20%. Films of each paint were drawn down on glass panels using an applicator bar to produce a wet film thickness of 100 μm, and after drying, gloss was

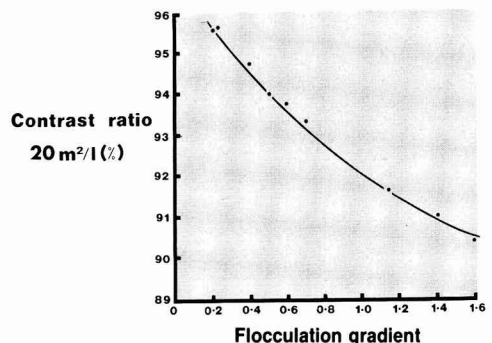


Figure 2—Effect of flocculation on opacity

measured using a Byk-Mallinckrodt glossmeter with a 20° head.

Flocculation gradient was also measured and plotted against gloss as shown in *Figure 4*. It can be seen that the flocculation gradient values are relatively high (not unusual for emulsion paints) and that gloss decreases with increasing gradient.

Correlation Between Dispersion, Assessed Using Electron Microscopy, And Flocculation Gradient

The measurement of flocculation gradient is a sensitive and reproducible technique which quantifies the degree of flocculation of titanium dioxide pigment in a dry paint film. In order to give a visual appreciation of the meaning of flocculation gradient, the series of flocculated air-drying alkyd paints previously described was prepared for examination by scanning electron microscopy.

Specimen preparation for the electron microscope involved etching the surface of each film using excited oxygen so as to remove the organic binder, thereby leaving the pigment particles exposed and undisturbed. Gold was then deposited onto the etched surface to improve its conductivity, and the examination was carried out using an I.S.I. Super IIIA scanning electron microscope. Further details about the etching technique for assessing pigment dispersion are given by Simpson.¹⁰

In *Figure 5*, flocculation gradient values are given together with typical electron micrographs of the etched films. It can be seen that there is a good correlation between flocculation gradient and the state of the pigment dispersion, although with the severely flocculated paints (i.e., those with gradients in excess of 0.68) the visual differences in dispersion are small. It is also interesting to note that flocculation gradient is sufficiently sensitive to detect small changes in dispersion (see, for example, the paints with flocculation gradient values of 0.25 and 0.27), although some of these differences would have, for example, little effect on opacity.

FLOCCULATION GRADIENT MONITOR

A spectrophotometer with an integrating sphere attachment was used by Balfour and Hird,⁷ to measure the scattered infrared radiation. However, because the

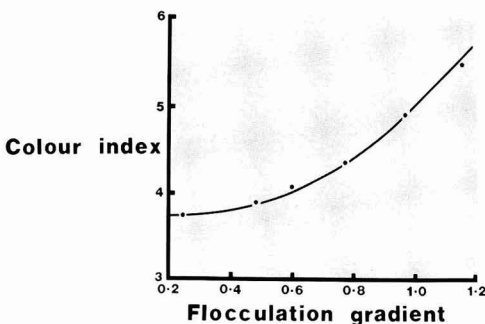


Figure 3—Effect of flocculation on color

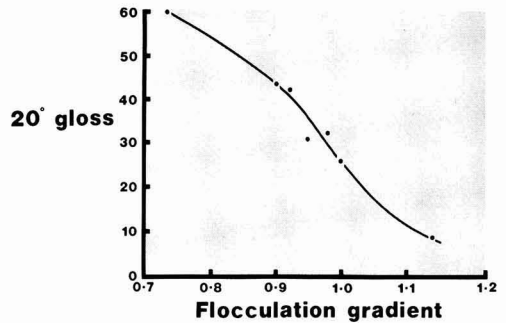


Figure 4—Effect of flocculation on gloss

measurement of flocculation gradient only involves monochromatic radiation, a complete spectrophotometer, a relatively expensive piece of equipment, is not essential. Therefore, it was decided to design a simple flocculation gradient apparatus which is referred to as a Flocculation Gradient Monitor so that the technique could be more widely used.

A schematic diagram of the apparatus which was built for measuring back-scattered infrared radiation from a paint film is shown in *Figure 6(a)* and a photograph of the instrument is given in *Figure 6(b)*. The infrared source is a tungsten filament lamp (General Electric Limited) which is powered by a regulated d.c. power supply (Coutant Electronics Limited) such that the operating voltage and current are approximately 5 volts and 6 amps, respectively. The infrared radiation passes through a collimating lens and a narrow band interference filter (Grubb Parsons Limited) transmitting a mean wavelength of 2.54 μm with a band width of 0.12 μm . This monochromatic radiation is then chopped at a frequency of 400 Hz (using a light chopper supplied by Rofin Limited) after which it passes through two collimating lenses into a barium sulphate coated integrating sphere (Macam Photometrics Limited) where it is incident on the surface of the paint film under study. The angle of incidence is approximately 5°, and therefore a radiation trap is positioned in the sphere to remove the specular component.

The back-scattered radiation which is incident on the interior of the integrating sphere is detected using a lead sulphide photoconductive cell (Mullard Ltd). The output from the detector is fed into a lock-in amplifier (Brookdeal Electronics Ltd) which also receives the chopped incident signal. Thus, amplification is only carried out on a signal which has a frequency corresponding to that of the chopper. The amplified back-scattered signal is displayed on a digital voltmeter.

The percentage of back-scatter from a film relative to barium sulphate is measured by using a disc of compressed barium sulphate initially placed over the specimen port, and noting the amplified detector signal (V_B). The paint film (on its substrate) under study is then positioned over the port, and the new signal recorded (V_F). The back-scatter value is calculated as follows:

$$\% \text{ Back-scatter} = \frac{V_F}{V_B} \times 100$$

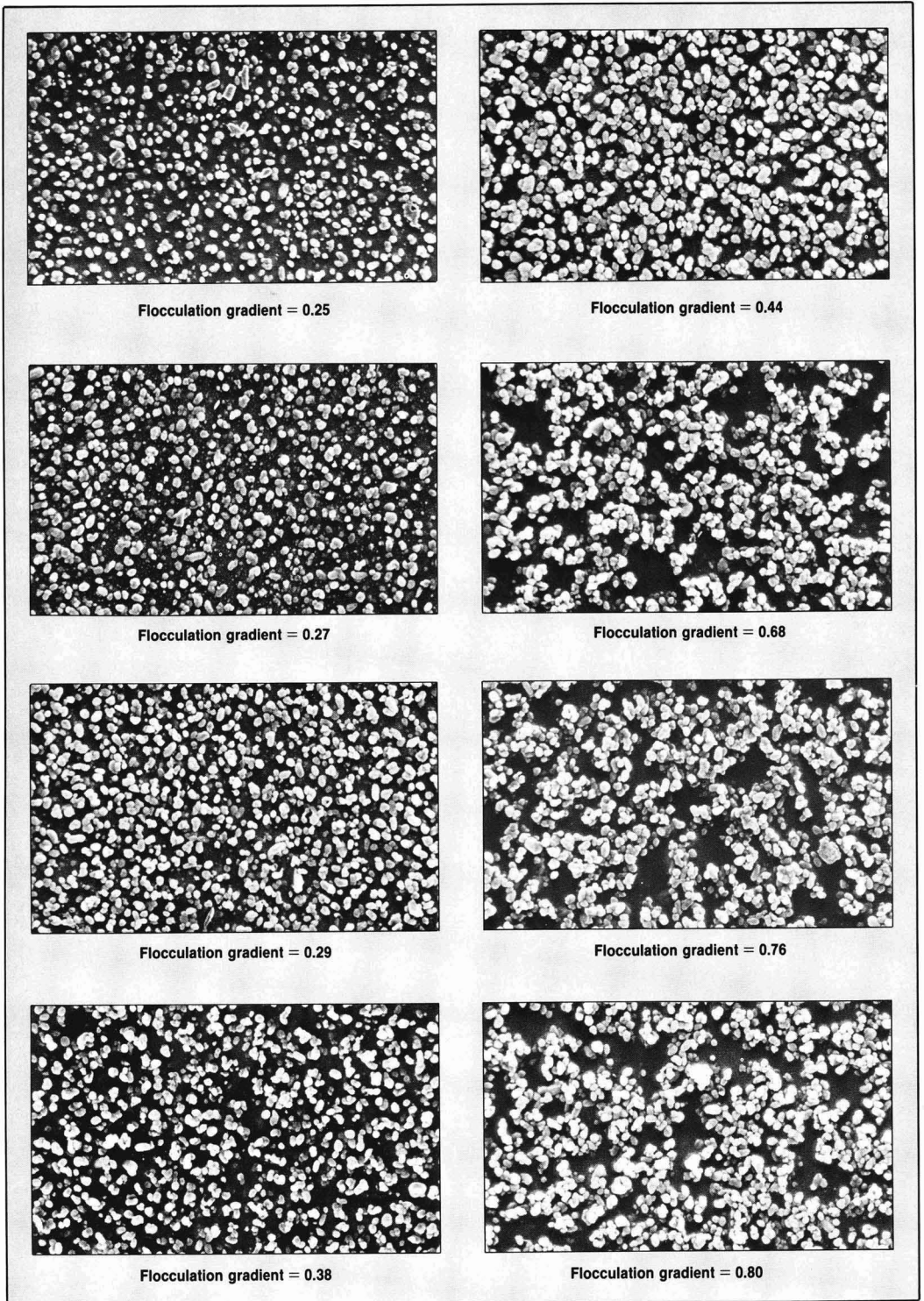


Figure 5—Relationship between pigment dispersion and flocculation gradient

When using this instrument, a warm-up period of 60 minutes is required before steady state conditions are reached.

FACTORS OTHER THAN DISPERSION WHICH AFFECT FLOCCULATION GRADIENT

Apart from pigment flocculation, there are several factors which affect the absolute value of flocculation gradient, and therefore these must be taken into consideration before conclusions regarding the state of pigment dispersion in a paint can be made.

Pigment Loading

To study the effect of pigment concentration on flocculation gradient, a series of paints was prepared by Balfour and Hird⁷ at five levels of pigment concentration (i.e., 10.0, 12.5, 15.0, 17.5, and 20.0% PVC) using a rutile grade of titanium dioxide pigment and a long oil soya modified alkyd. At each PVC, four levels of flocculating agent were used.

The flocculation gradient of each paint was measured (including the additive-free paints) and the results are given in Table 1. The results show that for the dispersed paints, flocculation gradient is unaffected whereas for the flocculated paints, an increase in PVC produces an increase in gradient; the more flocculated the paint, the greater the increase in gradient.

For the dispersed paints, the absence of any pronounced effect of PVC on flocculation gradient is possibly because with increasing PVC there is an increase in the number of well dispersed pigment particles which increase the refractive index of the medium surrounding the few flocculates. Consequently, the scattering power of the flocculates tends to decrease. However, with a flocculated paint, there is very little increase in the refractive index of the medium with increasing PVC because there are a considerable number of large particles which only affect the scattering of the infrared radiation. Thus, increasing the PVC for a flocculated paint will increase the scattering between flocculates and dispersed pigment/medium.

Thus, a comparison of flocculation gradients between

Table 1—Relationship Between Flocculation Gradient and PVC

| PVC | Flocculation Gradient | | | | |
|------|---------------------------|------|------|------|------|
| | Increasing Flocculation → | | | | |
| 10.0 | 0.33 | 0.36 | 0.42 | 0.49 | 0.55 |
| 12.5 | 0.34 | 0.39 | 0.44 | 0.55 | 0.66 |
| 15.0 | 0.32 | 0.37 | 0.44 | 0.58 | 0.72 |
| 17.5 | 0.36 | 0.40 | 0.49 | 0.63 | 0.81 |
| 20.0 | 0.34 | 0.40 | 0.49 | 0.68 | 0.87 |

flocculated paints should only be carried out if the pigment loadings are similar.

Extender and Entrapped Air

Extender particles are generally much larger in size than titanium dioxide pigment, and therefore one would expect the presence of extender to have a significant effect on flocculation gradient, although the relatively low refractive index of extenders would tend to reduce the expected value.

To determine the effect of extender type and size on flocculation gradient, various extenders (i.e., two calcites, two china clays, one dolomite, and one talc) were incorporated into a long oil soya modified alkyd such that the PVC was 10%. Flocculation gradient was determined for each extender, with results given in Table 2, together with mean particle size data for the extenders. It is evident from Table 2 that particle size rather than extender type is the most important factor which affects flocculation gradient (i.e., flocculation gradient increases with particle size, and extenders with a mean size of 2.0 μm or less have zero gradient) and that the values are low compared with titanium dioxide pigment.

However, if air is present in a film due, e.g., to the fact that the PVC is in excess of the critical¹¹ PVC (CPVC), then the infrared scattering efficiency of an extender particle would increase due to an increase in refractive index difference between extender and paint film matrix. In addition, the presence of microvoids

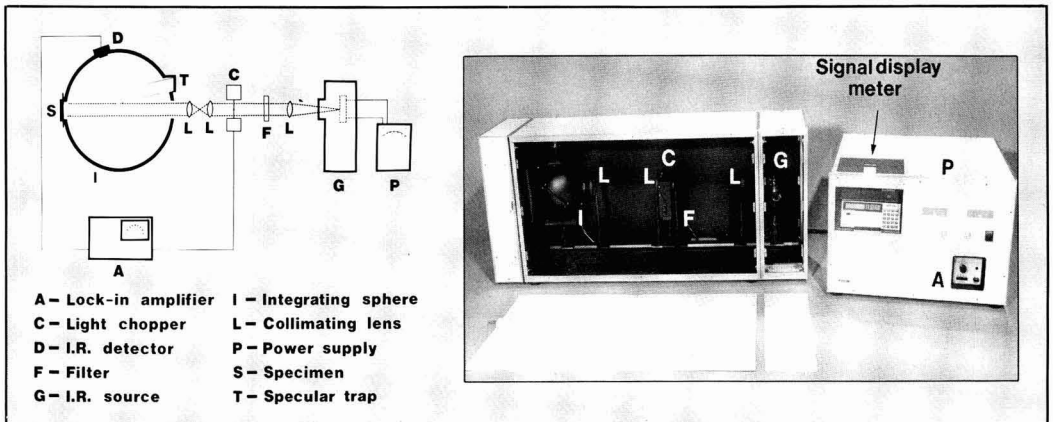


Figure 6—The Flocculation Gradient Monitor: (a) schematic diagram and (b) photograph

Table 2—Influence of Extender Type on Flocculation Gradient For Paints at 10% PVC

| Extender Type | Mean Size of Extender (μm) | Flocculation Gradient |
|------------------|---|-----------------------|
| Calcite | 15.0 | 0.12 |
| Calcite | 2.3 | 0.04 |
| China clay | 2.0 | 0.00 |
| China clay | 0.4 | 0.00 |
| Dolomite | 8.0 | 0.07 |
| Talc | 6.0 | 0.06 |

which are formed between the extender particles when the PVC is greater than the CPVC could also contribute to infrared scattering. The subject of scattering by microvoids is discussed in some detail by Seiner.¹² Thus, flocculation gradient would be expected to increase with increasing PVC, when a paint is formulated above the CPVC. This effect is shown in Table 3 where flocculation gradient values for "paints" (based on the same resin as above) containing only talc at PVC's of 10, 20, 40, and 50% are given. The CPVC for this series of paints was between 10% and 20%, determined using a Gilsonite™ stain, and it can be seen from the results that a significant increase in flocculation gradient has occurred when the PVC is either equal to or greater than 20%. Obviously, a similar effect would occur if the above paints containing only titanium dioxide pigment were formulated above the CPVC.

The effect of adding extender to a titanium dioxide pigmented paint would, therefore, increase flocculation gradient, assuming the particle size of the extender was sufficiently large or that the paint was formulated above the CPVC. Thus, if it is intended to compare flocculation gradients of paints which contain extender and titanium dioxide pigment (e.g., semigloss/matt emulsion paints or undercoats), it is important to ensure that the same extender is used and that the paints are at a similar PVC.

Apart from air which is formed when the PVC is in excess of the CPVC, there are other ways by which air entrapment in a film can influence infrared scattering and hence affect flocculation gradient. For example, if an emulsion paint exhibits incomplete coalescence, then, depending on the amount of air present, flocculation gradient could increase in value. Similarly, if titanium dioxide pigment shows poor wetting, then again one might expect that flocculation gradient would be affected since microvoids may be present in some of the agglomerated pigment. However, titanium dioxide pigments generally disperse rapidly in most media, and if

Table 3—Effect of PVC on Flocculation Gradient For Paints Containing Only Talc

| PVC | Flocculation Gradient |
|----------|-----------------------|
| 10 | 0.06 |
| 20 | 0.95 |
| 40 | 1.50 |
| 50 | 2.00 |

Table 4—Influence of Organic Tinter On Flocculation Gradient

| Tinter | Level of Tinter (%) | Flocculation Gradient | L | a | b |
|--------------------------|---------------------|-----------------------|-------|------|------|
| None (control) | — | 0.25 | 95.1 | -1.2 | +2.2 |
| Toluidine Red | 0.05 | 0.25 | 93.8 | +1.5 | +2.6 |
| | 0.10 | 0.24 | 92.7 | +3.4 | +2.6 |
| | 0.20 | 0.24 | 90.90 | +6.0 | +2.4 |
| Phthalocyanine | 0.05 | 0.25 | 92.4 | -3.7 | -2.5 |
| | 0.10 | 0.25 | 90.3 | -5.0 | -5.5 |
| | 0.20 | 0.26 | 87.3 | -6.3 | -9.6 |
| Carbon Black | 0.05 | 0.22 | 90.8 | -1.4 | -0.2 |
| | 0.10 | 0.20 | 88.1 | -1.7 | -1.5 |
| | 0.20 | 0.19 | 84.2 | -2.1 | -2.9 |

poor wetting/dispersion is evident, generally it is only a small percentage (e.g., 1% or less by weight) of the pigment which is responsible for this problem. Thus, the amount of entrapped air is small and its effect on flocculation gradient is minimal. Balfour and Hird⁷ clearly showed that pigment agglomerates in an alkyd paint had little effect on flocculation gradient, which suggests that the flocculation gradient technique cannot be used to assess the degree of wetting of a pigment during milling.

Tinter

Since a considerable amount of paint is tinted, it is important to know the extent to which a colorant might affect flocculation gradient. Generally, the particle size of an organic tinter is either comparable with or less than that of titanium dioxide pigment. Thus, assuming the tinter is well dispersed and does not exhibit any unusual absorption characteristics in the infrared region, one would not expect any change in flocculation gradient.

To investigate this, a 20% PVC alkyd paint based on a general purpose rutile grade of titanium dioxide pigment was prepared, to which was added 0.05, 0.10, and 0.20% tinter, based on weight of pigment. The tinters examined were Toluidine Red, Phthalocyanine Blue, and Carbon Black. Drawdowns were prepared, from which flocculation gradient and color (i.e., L, a and b values—CIE 1976) were measured. In Table 4, the measured values are given, and it can be seen that for the maximum level of tinter, a significant change in color has occurred for all three tinters. However, with regard to flocculation gradient, neither Toluidine Red nor Phthalocyanine Blue has affected the value, whereas with Carbon Black, a gradual

Table 5—Wet and Dry Flocculation Gradients

| Pigment | Flocculation Gradient (Wet) | Flocculation Gradient (Dry) |
|---------|-----------------------------|-----------------------------|
| A | 0.10 | 0.23 |
| B | 0.15 | 0.33 |
| C | 0.18 | 0.38 |
| D | 0.25 | 0.56 |

reduction in gradient has occurred with increasing level of tinter. This reduction is presumably due to the absorption of infrared by the carbon, since a microscopic examination of the dried paint films showed no differences in pigment dispersion.

Thus, if the flocculation gradients of paints which contain tinter are compared, it is important to ensure that the tinter composition is the same since the presence of Carbon Black in any of the paints will result in a reduction in flocculation gradient. Obviously, if tinter (apart from Carbon Black) in a paint is extremely flocculated, then this could cause an increase in flocculation gradient, with the extent depending on the type and amount of tinter.

MEASUREMENT OF FLOCCULATION IN THE WET PAINT

Wet Flocculation Gradient

Flocculation gradient gives an indication of the degree of pigment dispersion in a dry paint film. However, there is no reason why the technique cannot be adopted for examining wet paints. To determine the possibility of this, it was decided to measure infrared back-scatter from wet alkyd paint films of varying thickness (i.e., between 6 and 50 μm) which had been applied to glass using wire wound applicator bars. A cardboard spacer was placed around the perimeter of the wet film to prevent paint from being transferred to the integrating sphere. It was evident that a linear relationship between back-scatter and wet film thickness existed, just as with dry films, and therefore a wet flocculation gradient was possible. In an extension of this study, four different rutile grades of titanium dioxide pigment (i.e., pigments A, B, C, and D) which were known to exhibit different degrees of dispersion were selected, and dispersed in a long oil soya modified alkyd such that the PVC of the final paint was 17.5%. Flocculation gradients of both wet and dry paint films were determined, with the results given in *Table 5*. It is clearly evident from these results that the order of performance in terms of flocculation gradient value is the same for both wet and dry paint films, and that the gradient of the dry film is greater than that of the wet paint. The former result probably confirms that wet flocculation gradient is a significant parameter, whereas the latter finding suggests that pigment flocculation has occurred on drying, a result which is well known. However, it must be appreciated that there are differences between wet and dry paint films other than pigment dispersion that would inevitably affect flocculation gradient (e.g., change in refractive index of medium and pigment loading on drying).

Wet Cell Measurement (R_w^{40})

The measurement of wet flocculation gradient has potential, but taking measurements from a drying paint film is obviously not satisfactory. Consequently, a cell was designed to encapsulate a wet paint of known thickness. A schematic diagram of the cell is shown in *Figure 7(a)* and a photograph is given in *Figure 7(b)*. The

Table 6—Paint Formulations

| Parts by Weight | | | | | | |
|--|------|------|------|------|------|------|
| Titanium dioxide... pigment | 100 | 100 | 100 | 100 | 100 | 100 |
| Long oil soya..... modified alkyd (20% NV) | 40 | 40 | 40 | 40 | 40 | 40 |
| Flocculating additive | 0 | 0.25 | 0.5 | 0.75 | 1.0 | 1.25 |
| To the above millbase add | | | | | | |
| Long oil soya..... modified alkyd (70% NV) | 167 | 167 | 167 | 167 | 167 | 167 |
| Driers | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 | 13.9 |
| Methyl ethyl..... ketoxime | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Pigment volume concentration in the millbase = 33.7% | | | | | | |
| Pigment volume concentration in the wet paint = 8.7% | | | | | | |
| PVC = 17.5% | | | | | | |

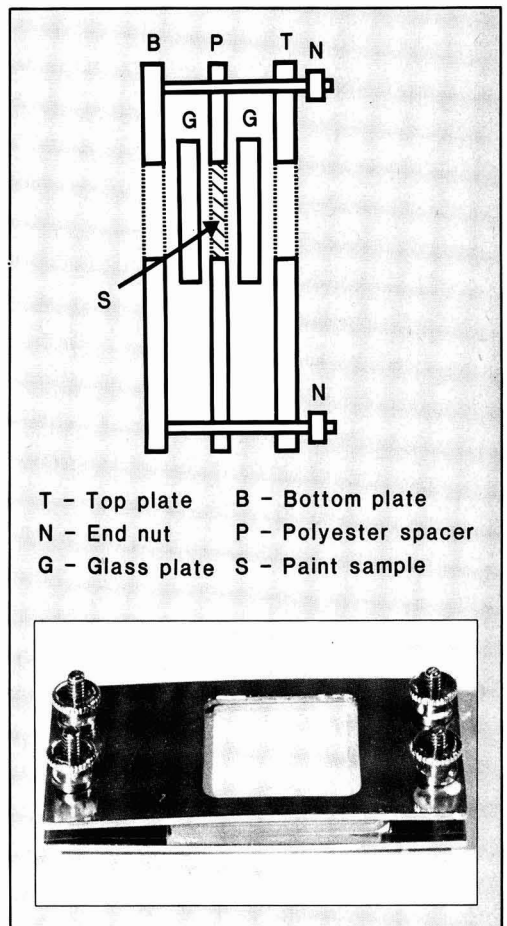


Figure 7—The wet cell: (a) schematic diagram and (b) photograph

cell consists of a spacer, cut from polyester sheet of known thickness, which is clamped between two 16 cm² glass plates. The cell is held rigidly between two 8 cm × 4 cm metal plates (with 9 cm² apertures) which are compressed by means of end nuts. By varying the thickness of the wet paint film, it is possible to obtain a "wet flocculation gradient." However, since it was felt that the technique would be more applicable as a quality control test if only one film thickness was used, back-scatter measurements were carried out using only a 40 μm thick polyester spacer. Since some of the infrared radiation which is incident on the wet cell is reflected by the glass plates, back-scatter values are recorded when the cell is empty (V_E) and full (V_S). Knowing the back-scatter value for the barium sulphate disc (V_B), a percentage back-scatter value for the wet sample (R_w^{40}) is obtained using the following equation.

$$R_w^{40} = \frac{V_S - V_E}{V_B} \times 100$$

where the subscript W is used to denote that a wet back-scatter value was taken, and the superscript 40 identifies the fact that the film was 40 μm thick.

For a given paint system, increasing values of R_w^{40} indicate an increase in pigment flocculation. Like dry flocculation gradient, R_w^{40} is affected by pigment concentration, the type and amount of extender, and certain organic tinters. In addition, the type and amount

of solvent used in the paint affects the value since many solvents¹³ absorb infrared radiation.

Correlation Between R_w^{40} And Flocculation Gradient

To compare wet cell measurements with flocculation gradient, a series of flocculated air-drying alkyd paints similar to the one illustrated in *Figure 5* was evaluated in terms of R_w^{40} and flocculation gradient. Wet cell measurements were also carried out on the various millbases which contained increasing amounts of a flocculating agent (see formulation details in *Table 6*).

In *Figure 8*, R_w^{40} (paint) is plotted against flocculation gradient (dry film) and it is evident that the relationship between both measurements is good since an increase in R_w^{40} results in an increase in flocculation gradient. It was mentioned in the preceding review section that, for a well dispersed paint, an increase in gradient of 0.1 would produce a 0.4% loss of opacity which would be visually evident. With reference to *Figure 8*, this means that an increase in R_w^{40} of 3.0% would produce a similar deterioration in opacity. Since the wet cell measurement takes only a few minutes, it is therefore an extremely quick method for quantifying pigment flocculation in the wet paint.

The relationship between R_w^{40} (paint) and R_w^{40} (millbase) is illustrated in *Figure 9* where it can be clearly seen that the correlation between both measurements is

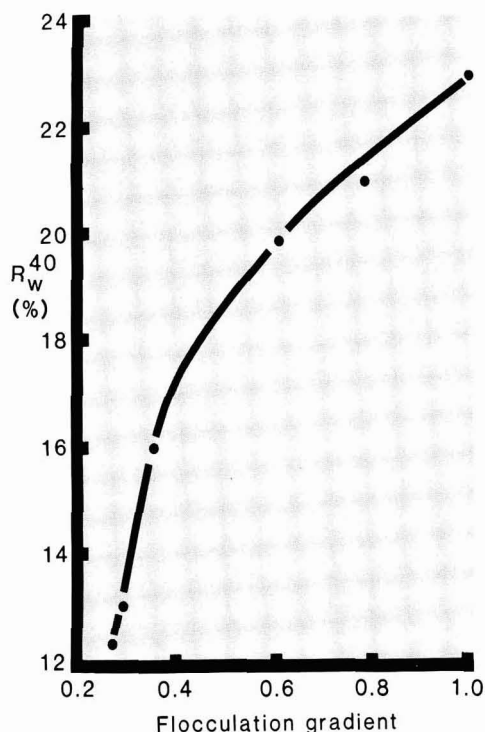


Figure 8—Correlation between R_w^{40} and flocculation gradient, for a series of flocculated paints

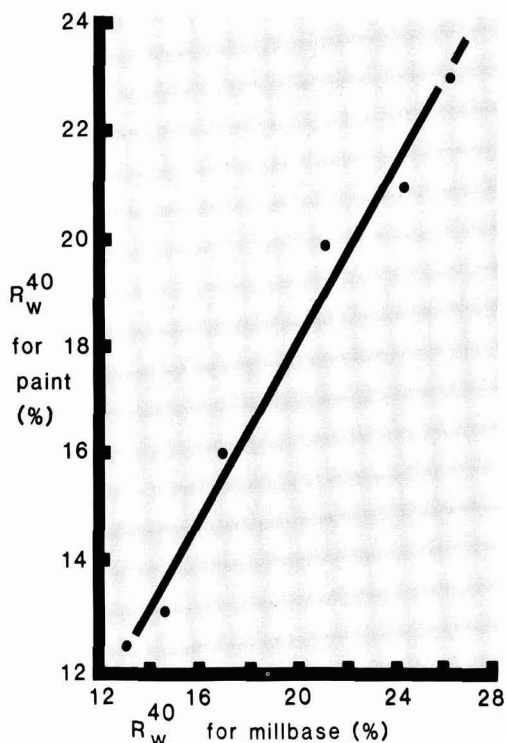


Figure 9—Correlation between R_w^{40} (paint) and R_w^{40} (millbase)

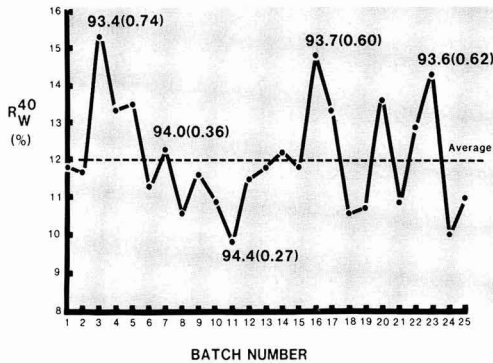


Figure 10—Variation in R_w^{40} as a function of batch number, for a thixotropic air-drying alkyd paint. Opacity and flocculation gradient (in parenthesis) measurements were carried out on selected paints

excellent. Although the absolute values cannot be directly compared since pigment loading and volume concentration of solvent are different for both millbase and paint, it is evident that the presence of flocculation in a paint system can be detected at any stage during its manufacture. Thus, the measurement of R_w^{40} could be used as a quality control test. Further work, which is not reported in this paper, has shown that the wet cell measurement can also be used to quantify pigment dispersion in other paint systems such as decorative aqueous-based paints and industrial stoving finishes.

Use of R_w^{40} as a Quality Control Test

In an attempt to assess the online quality control features of the Flocculation Gradient Monitor and wet cell, the apparatus was set up in one of Europe's major paint manufacturing factories. A variety of aqueous and non-aqueous paint products were evaluated in terms of R_w^{40} during a manufacturing period. The results obtained for one particular product (a thixotropic air-drying alkyd paint) are shown in Figure 10, where R_w^{40} (paint) is plotted against batch number. In addition, opacity which was taken as the contrast ratio at a spreading rate of 20 $m^2/liter$ and flocculation gradient were recorded for selected paints, and these values are given alongside the appropriate results in Figure 10.

It can be seen that there are significant variations in R_w^{40} which are reflected in both opacity and flocculation gradient values. For example, the best batch of paint (number 11) exhibited a R_w^{40} value of 9.8%, an opacity of 94.4%, and a flocculation gradient of 0.27, whereas the worst batch (number 3) had R_w^{40} , opacity, and flocculation gradient values of 15.5%, 93.4% and 0.74, respectively. Clearly, the pigment utilization in batch number 3 is poor due to flocculation (equivalent to wasting approximately 15% titanium dioxide pigment compared with batch number 11) and as a result its optical performance is inferior to all the other samples, although batch numbers 16 and 23 are also not particularly good.

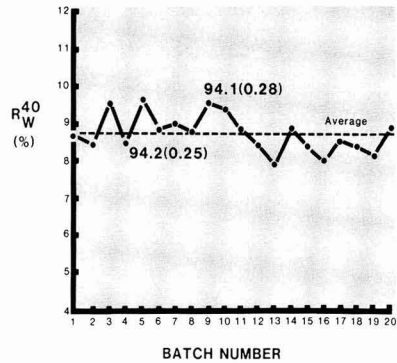


Figure 11—Variation in R_w^{40} as a function of batch number, for a liquid air-drying alkyd paint. Opacity and flocculation gradient (in parenthesis) measurements were carried out on selected paints

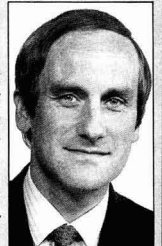
In contrast, results obtained for a liquid air-drying alkyd paint manufactured by the same company indicated that the reproducibility in terms of quality was good, as shown in Figure 11, where R_w^{40} values from 20 batches are plotted. Again, opacity and flocculation gradient measurements are given for selected paints, and it is evident that there is little variation in the optical performance of this product.

Thus, these results and others which are not reported indicate the advantage in monitoring R_w^{40} for quality control purposes, since an indication of paint performance can be rapidly obtained.



D. J. RUTHERFORD joined the Technical Service Department of Tioxide Group PLC in 1969, and currently supervises an application development/weathering section. For the past five years, Mr. Rutherford has worked on a variety of development projects which have culminated in lectures and published papers.

L. A. SIMPSON graduated from London University in 1969, and received a Ph.D. Degree in Polymer Physics from the University of Surrey in 1972. After carrying out one year's development work on powder coatings, Dr. Simpson joined Tioxide Group PLC, where he manages an application development/weathering section. Dr. Simpson has published various papers on topics such as gloss, metal marking and durability, and lectured at many major conferences.



SUMMARY

A Flocculation Gradient Monitor which enables one to measure flocculation gradient has been designed, built, and tested.

Flocculation gradient is a sensitive and reproducible parameter which quantifies the degree of pigment flocculation in a paint, although factors such as pigment loading, and the presence of extender, air, and tinter (e.g., Carbon Black) may influence the absolute value. Thus, to compare the state of pigment dispersion between paints which may contain the above raw materials, it is important to ensure that the paints have a similar titanium dioxide, extender, and tinter composition.

By using a wet cell, pigment flocculation in the wet paint can also be quantified, and since this measurement can be quickly carried out, it is suitable for use in online quality control work.

ACKNOWLEDGMENTS

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Society Meetings

BALTIMORE JAN.

"Understanding Emulsions"

Patrick J. McDonald, of Reichhold Chemicals, Inc., spoke on "THE PRACTICAL APPROACH TO UNDERSTANDING EMULSIONS."

Mr. McDonald stated that there are three basic types of emulsions made: water reducible; latex dispersion; and aqueous dispersion, made by condensation and/or addition. The first synthetic latex was made in 1909 in Germany as a replacement for rubber. He added that the amount of water in a latex could vary from 30 to 85%, and that, contrary to some old beliefs, it is not necessary to use deionized water.

The monomer is the most important ingredient in the latex, emphasized Mr. McDonald. It is the monomer which gives the latex the basic physical properties. Surfactants give critical functions to the latex by controlling the particle size; establishing CMC; helping the mechanical, chemical, and physical stability; and assisting in freeze-thaw stability.

Mr. McDonald also discussed production and quality control. Production involves three stages: set-up time, reaction time, and filtering. In quality control both the wet and dry properties are checked. The wet properties checked include: pH, viscosity, non-volatile, stability, surface tension, and particle size and distribution. The dry properties are color, dry, molecular weight and distribution, and end use properties.

The presentation closed with discussion of the various effects coalescents can exert in the making of paint.

HARRY POTH, *Secretary*

J.F. Roberts, of Dexter-Midland Ltd., spoke on "WATER-DILUTABLE COATINGS."

Mr. Roberts' presentation focused on the advantages and disadvantages of water-dilutable coatings. He cited several advantages to the coatings manufacturer including: minimum cost for new equipment, established formulation technology, and solvent-based technology applicable to water-reducibles.

He also stated the advantages to the applicator which include: lower paint cost, reduced energy costs, no change in established coating processes, easy clean-up of spillages, reduced fire risks, reduced odor, minimum equipment changes, no solvent storage needed, and lower insurance.

Several disadvantages he discussed were: non-corroding equipment is necessary, frost protection is required in storage and during application/curing, and that the substrate needs to be cleaner.

Mr. Roberts then compared some properties of water-reducible alkyds, as used to coat agricultural machinery, with conventional solvent-borne alkyds. His presentation concluded with some typical end uses for water-reducible industrial finishes.

Q. In terms of pollution and safety, are not the cosolvents and amines used in water-reducible resins toxic?

A. Yes, but compare that with the higher total of solvents present in solvent-borne coatings. Water reducibles contribute significantly in reducing the total toxicity/pollution.

Q. Is humidity level important during application?

A. Yes, particularly with air-drying coatings, which could sometimes be stored under such conditions that they never dried!

DAVID M. HEATH, *Secretary*

BIRMINGHAM FEB.

"Doing Business in Japan"

A moment of silence was observed in memory of Club Past-President David Lovegrove and Mr. F.D.H. Sharp, both of whom died recently.

A presentation on "DOING BUSINESS IN JAPAN," was given by Mr. G. Clayton, of Ciba-Geigy.

Mr. Clayton's discussion was based upon his personal experiences of Japan while working for Ciba-Geigy's Plastics and Additives business in Tokyo from 1977 to 1983.

The Japanese business ambition is market domination, Mr. Clayton stated. Their success to date, however, has not been due to innovative products since Japanese patents represent only 5% of the worldwide total. According to Mr. Clayton, the high quality and reliability of Japanese products are ensured by the high investment made in quality control.

Mr. Clayton closed his talk by outlining the requirements for successful business in Japan. He stated that contact should be maintained throughout business ventures and not limited to contract acquisition. Also of importance are quality control and the need to earn the

BIRMINGHAM JAN.

"Water-Dilutable Coatings"

President Roland Staples presented Charles Gilbert, a Past-President of the Club, with a Certificate of Honorary Life Membership in the Club. Mr. Gilbert joined Canning Materials Ltd. in 1933 and retired from there in 1977. In 1943 he became a member of the Club and has held the following offices: Publicity Officer, Secretary, Social Officer, Executive Committee member, and Club President. Mr. Gilbert was made an Honorary Member in 1977 and currently holds the position of Club Historian.



SOUTHERN SOCIETY OFFICERS for 1984-85. (Left to right): President—James E. Geiger; Vice-President—Sal G. Sanfilippo; Secretary—Ronald R. Brown; Treasurer—C. Louis Davis; and Society Representative—Berger Justen

respect of the Japanese through direct competition at home.

DAVID M. HEATH, *Secretary*

CLEVELAND JAN.

Joint Meeting with the CPCA

At the joint meeting with the Cleveland Paint and Coatings Association, J. Woebkenberg discussed the proposed "Right to Know" bill which is presently being considered by the Cleveland City Council. A key point of the proposed legislation,

according to Mr. Woebkenberg, is that it requires an annual workplace contents list which is accessible to the public. A fact sheet on this legislation covering other key aspects was provided by Mr. Woebkenberg.

Jim La Rue, of the Housing Resource Center, spoke on "HAZARDOUS MATERIALS CONCERNS."

Mr. La Rue, "Mr. Fixit," has been rehabilitating houses in the inner city, and recently opened the Housing Resource Center. He explained that he has received many questions from people through his Resource Center on the

safety and hazards of the materials used in rehabilitating houses. Examples of these concerns include: the presence of formaldehyde in insulation and in other building products; the safety of kerosene heaters in houses which are well-sealed; and the toxicity of materials as applied and when burned. Mr. La Rue expressed an interest in getting technical answers to his questions concerning coatings.

MADELYN K. HARDING, *Secretary*

CLEVELAND FEB.

"Colloidal Silica"

Richard Thorton, of Nalco Chemical Co., spoke on "COLLOIDAL SILICA: A UNIQUE PIGMENT FOR THE COATINGS INDUSTRY."

Mr. Thorton outlined the chemistry involved in the preparation of liquid colloidal silica and the properties of the product.

After describing several specific applications for colloidal silica and the benefits derived from its use, Mr. Thorton enumerated several other possible uses.

MADELYN K. HARDING, *Secretary*

KANSAS CITY FEB.

"Paint Examination Techniques"

Society President Steve Busjaeger announced that the joint St. Louis-Kansas City meeting scheduled for June has been cancelled.

James E. Corby, of the Federal Bureau of Investigation, spoke on "PAINT EXAMINATION TECHNIQUES UTILIZED IN THE F.B.I. LABORATORY."

JERRY P. HEFLING, *Secretary*

LOUISVILLE FEB.

"The Dispersion Pilot Plan"

Dr. Marty Feldman, of Nuodex, Inc., spoke on "THE DISPERSION PILOT PLAN: THE SHORTEST DISTANCE BETWEEN THE LAB AND PRODUCTION."

Dr. Feldman began his presentation by describing how pigments are received at coatings manufacturing plants, in either dry powder or pressed cake form. Both forms require a dispersion before the pigment can be used in a coating, explained Dr. Feldman. The purpose of the dispersion is to break down particle size (commonly 20 microns or larger) to one micron or smaller. Without this dispersion, the pigment has no color strength.

The objective of dispersing pigments is to obtain the highest possible pigment

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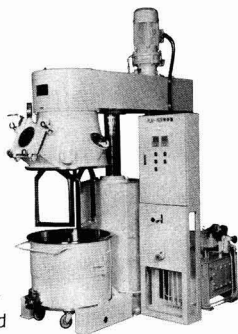
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strength compatible with the equipment available and the time to complete the project, stated Dr. Feldman. He listed four coatings characteristics affected by less than optimum dispersion. They are brightness, gloss, transparency, and stability. The higher the dispersion, the brighter the film and the higher the gloss of the finished coating, he explained. He added that while transparency improves with dispersion, the overall transparency of the film is limited by the inherent opacity of the pigment. Dr. Feldman concluded that the finer the particle size, the more stable the dispersion, because as the diameter of the pigment particle increases, so does its tendency to settle.

The presentation closed with a discussion of the four factors affecting the dispersion choices.

KEN HYDE, *Secretary*

NEW ENGLAND FEB.

"Importance of Communications"

Richard L. Connors, of Anna Maria College, discussed the "IMPORTANCE OF COMMUNICATIONS."

To introduce his topic, Mr. Connors stated that one major problem in business today, stress, is due to a lack of communication between administration and working staff.

In his presentation, Mr. Connors discussed perceptions and how individuals act on their own perceptions. Because everyone is fixed in their own perception of the real world and feel that they communicate well within this perception, there is no common ground between two parties trying to communicate. According to Mr. Connors, this can be related to the underlying reasons of stress. To emphasize this point, Mr. Connors stated that 35% of a group or gathering will actually hear exactly the opposite of what is being said because these individuals come with a preconceived idea of what is being discussed.

Mr. Connor stated two rules of good communication: be clear within yourself of what is your own goal and clearly communicate what you really need.

KEVIN MULKERN, *Secretary*

NORTHWESTERN FEB.

"Classification of Organic Pigments"

A presentation on "CLASSIFICATION OF ORGANIC PIGMENTS AND SOME BASIC MEASUREMENT TECHNIQUES," was given by Hugh Smith, of Sun Chemical Co.

Mr. Smith explained that there are two ways to classify pigments: by color index and by chemistry. Historically, organic



LOUISVILLE SOCIETY OFFICERS For 1984-85. (Seated, left to right): Vice-President—Joyce Specht St. Clair; President—Ed Thomasson; and Past-President—John Lanning. (Standing): Society Representative—James Hoeck; Secretary—Ken Hyde; and Treasurer—Howard Ramsey

pigments have been developed by synthesizing intensity colored, insoluble products.

In closing, Mr. Smith stated that current product development means crystal development. More recent developments include polymeric dispersants and chemical reactions on pigment surfaces.

LARRY BRANDENBURGER, *Secretary*

PHILADELPHIA DEC.

"Accelerated Weathering"

Virgil Lyons, of the Atlas Electric Co., discussed "ACCELERATED WEATHERING."

Mr. Lyons gave a brief history on the development of techniques to test dye fading. In 1918, when the U.S. dye industry was just getting started, a U/V testing device using a carbon arc as the ultraviolet source was used. In 1927, the industry added water spray and called the device a Weather-Ometer. Mr. Lyons stated that other controls for temperature and humidity were added, as well as changes in the carbon arc to give different radiance characteristics.

Also discussed by Mr. Lyons were recent advances in testing techniques. Fluorescent sun lamps are a recent development and, in his opinion, not as good as a Weather-Ometer. Further accelerated testing is possible by outside exposure in Arizona or Florida through specialized test fences. Other sites are available for other conditions, including atmospheric contaminants.

Mr. Lyons presentation came to a close with an explanation of the methods of timing the devices, the types of cycles, and equipment specifications.

DONALD F. DENNY, *Secretary*

PITTSBURGH FEB.

"Job Inspection and Instrumentation"

In this joint meeting with the Pittsburgh Section of the National Association of Corrosion Engineers, Ken Tator and Eric Kline, of KTA-Tator, Inc., discussed "JOB INSPECTION AND INSTRUMENTATION" and "FAILURE."

Mr. Kline addressed the topics of job inspection and instrumentation. Inspection deals with surface preparation and design considerations. He mentioned two kinds of surface preparation: chemical treatment and blast cleaning. According to Mr. Kline, there are six elements which contribute to a successful or unsuccessful job. They include clean air supply, the correct pressure at the nozzle, the temperature at the substrate, the dew point, the type of blast used, and the surface profile. Instruments are available which can measure all of these factors.

Mr. Kline pointed out that the application of the coating is inspected. First the method of application is examined to determine if the dry film thickness is adequate. He then discussed those factors which influence the dry film thickness, including: the machinery used—conventional or airless; the straining procedure;

the viscosity of the coating as it is being applied; and the proper mixing of the components. Several instruments are available to determine the toughness of the paint film, the thickness of the coating on the substrate, the adhesion to the substrate, and the intercoat adhesion, he added.

Mr. Tator presented a talk on "FACTORS CONTRIBUTING TO FAILURE." His list of factors included dry spray, mill scale, peaks not covered, compatibility problems, and over-cure and under-cure of the coatings.

ANTHONY J. ISACCO, *Secretary*

PITTSBURGH MAR.

Past-Presidents' Night

President Clifford Schoff introduced the 13 Past-Presidents in attendance.

Robert Feller, of Carnegie-Mellon University, was presented with his 25-Year Membership pin.

Technical Chairman Richard Trudel announced that a newsletter will be published in May containing information on software available for the coatings industry.

George Goodwin, of Daniel Products, spoke on "COMPOSITE VS SINGLE DISPERSANTS IN COLORANTS AND COATINGS."

Mr. Goodwin began his presentation by stating that no single dispersing agent is good enough. Three benefits of composite dispersants discussed were: improved manufacturing process; improved product stability; and easier use of end products.

To prove these points, Mr. Goodwin prepared beakers of long oil alkyd made with no dispersants, single dispersants, and composite dispersants. Various pig-

ments were then added to the solution. Initial reaction and long term stability were watched, as were color development, viscosity, and other factors.

According to Mr. Goodwin, the experiment proved that the manufacturing process was improved because the composite dispersant solutions showed faster pigment wetting, higher pigment loading in mill base at grinding consistency, reduced air entrapment, higher production rates and improved color development with less powerful equipment.

The product stability improved with the composite dispersants as was shown by less change in the degree of deflocculation of the pigment, improved gloss stability, less viscosity change, and less settling, he explained.

In conclusion, Mr. Goodwin mentioned that the experiment proved that composite dispersants allowed for an easier use of end products by showing a better flow from containers, an easier incorporation into bases, and an improved compatibility with a wider range of tint bases.

ANTHONY J. ISACCO, *Secretary*

ST. LOUIS JAN.

"Barrier Pigments"

Steve Stoltz, of Mosel Chemical Co., presented a brief report on the HMIS (Hazardous Materials Identification System) seminar which was held in Kansas City, MO.

Dr. Rolf Odenthal, of Mobay Chemical Corp., spoke on the "INFLUENCE OF BARRIER PIGMENTS IN PERFORMANCE OF PRIMERS."

Dr. Odenthal began with a brief history of natural and synthetic iron oxides, the mechanism of water permeation, parameters in formulation, and new synthetic iron oxide pigments. He emphasized the

advantages claimed for synthetic iron oxides including more uniformity, easier processing, more uniform color development and control particle size.

Dr. Odenthal explained that critical pigment volume concentration (CPVC) is dependent upon oil absorption and that optimum pigment volume concentration is a key factor.

Micronization was also mentioned by Dr. Odenthal. He stated that it does not change particle size distribution or predominant particle size. Micronization does lower the residue for better performance.

Dr. Odenthal discussed the important part played by particle size in salt sprays and in other moisture properties. He also mentioned that surface modification or combination with calcium and/or zinc enhances corrosion resistance. At close to CPVC, active pigments show superior results, while at low pigment volume concentrations, active and inactive pigments are approximately equal.

According to Dr. Odenthal, water diffusion and permeation curves seem to be the same for both treated and untreated iron oxides.

MERLE D. HELD, *Secretary*

WESTERN NEW YORK . . . FEB.

"Acrylic Blend Lattices"

Educational Committee Chairman Jim Price presented a \$300 check to John Y. Yeager III, the first recipient of the Society's Education Scholarship.

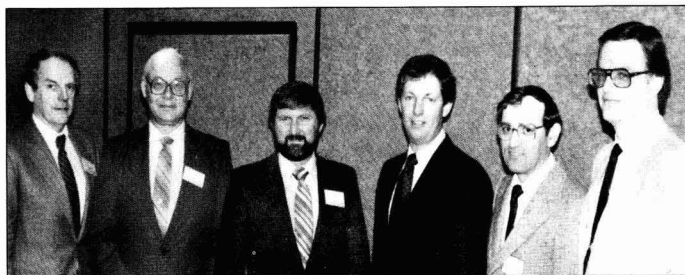
Dr. Ted Del Donno, of Rohm and Haas Co., spoke on "ACRYLIC BLEND LATTICES."

Dr. Del Donno centered his presentation around the problems in developing a blend of an acrylic emulsion with water reducible alkyds. The plan, according to Dr. Del Donno, was to speed up the slow dry times and early water resistance of the alkyd without sacrificing its good gloss and metal protection.

The compatibility of the alkyds with thermoplastic acrylic emulsions was checked by casting clear films on glass and recording the Y-axis value, stated Dr. Del Donno. This was done by placing a black standard under the film and reading the Y-values using a Hunter Color Meter. He added that the stability of the blends could be improved by lowering pH, lowering temperature, lowering the transition metal driers, and/or lowering the concentration of the emulsion and type.

Dr. Del Donno concluded with an explanation of the hydrolysis of the ester linkage of the alkyds.

MICHAEL DEPIETRO, *Secretary*



PACIFIC NORTHWEST SOCIETY OFFICERS for 1984-85. (Left to right): Society Representative—Deryk Pawsey; Administrative Secretary—William Shackelford; President—Ottwin Schmidt; Secretary—Dennis Hatfield; Treasurer—Yvon Poitras; and Past-President—Robert Hogg

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| 13 | "Amino Resins in Coatings"—W. L. Hensley and W. E. McGinty. (Dec. 1969) | |
| 14 | "Silicone Resins for Organic Coatings"—R. W. Clope and M. A. Glaser. (Jan. 1970) | |
| 15 | "Urethane Coatings"—D. Lasovick. (July 1970) | |
| 16 | "Dispersion and Grinding"—M. H. Schaffer. (Sept. 1970) | |
| 17 | "Acrylic Resins"—Gerould Allyn. (Mar. 1971) | |
| 18 | "Phenolic Resins"—R. D. McDonald. (Mar. 1971) | |
| 19 | "Vinyl Resins"—G. M. Powell. (Apr. 1972) | |
| 20 | "Epoxy Resins"—R. A. Allen. (Apr. 1972) | |
| 21 | "Nitrocellulose and Organosoluble Cellulose Ethers in Coatings"—E. C. Hamilton and L. W. Early, Jr. (Sept. 1972) | |
| 22 | "Plasticizers"—J. K. Sears. (June 1974) | |
| 23 | "Interior Finishes"—Murray Abriss and Oliver Volk. (Apr. 1976) | |
| 24 | "Exterior House Paint"—G. G. Schurr. (May 1977) | |
| 25 | "Automotive Finishes"—Ralph Williams. (July 1977) | |
| 26 | "Corrosion and the Preparation of Metallic Surfaces for Painting"—Clive H. Hare. (Feb. 1978) | |
| 27 | "Anti-Corrosive Barrier and Inhibitive Primers"—Clive H. Hare. (Feb. 1979) | |

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Constituent Society Meetings and Secretaries

BALTIMORE (Third Thursday—Eudowood Gardens, Towson, MD; EDWARD B. COUNTRYMAN, Bruning Paint Co., 601 S. Haven St., Baltimore, MD 21214. Virginia Section—Fourth Wednesday, Ramada Inn-East, Williamsburg, VA).

BIRMINGHAM (First Thursday—meeting sites vary). D.M. HEATH, Holden Surface Ctg. Ltd., Bordesley Green Rd., Birmingham B9 4TQ England.

CHICAGO (First Monday—meetings alternate between Sharko's in Villa Park and Como's in Chicago). RON KLEINLEIN, Sherwin-Williams Co., 10909 S. Cottage Grove Ave., Chicago, IL 60628.

C-D-I-C (Second Monday—Sept., Jan., Apr., June in Columbus; Oct., Dec., Mar., May in Cincinnati; Nov., Feb., in Dayton). JOSEPH W. STOUT, Hanna Chemical Coatings, P.O. Box 147, Columbus, OH 43216.

CLEVELAND (Third Tuesday—meeting sites vary). MADELYN HERDING, Sherwin-Williams Co., P.O. Box 6027, Cleveland, OH 44101.

DALLAS (Thursday following second Wednesday—Executive Inn, near Lovefield Airport). ASHWIN V. PARIKH, Union Carbide Corp., 2326 Lonacker Dr., Garland, TX 75041.

DETROIT (Fourth Tuesday—meeting sites vary). CAROLYN GESSNER, Inmont Corp., 26701 Telegraph, P.O. Box 5009, Southfield, MI 48086.

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

HOUSTON (Second Wednesday—Sonny Look's, Houston, TX) DAVID SATZGER, O'Brien Corp., P.O. Box 14509, Houston, TX 77221.

KANSAS CITY (Second Thursday—Cascone's Restaurant, Kansas City, MO). JERRY P. HEFLING, Loctite Auto & Consumer, 3255 Harvester Rd., Kansas City, KS 66115.

LOS ANGELES (Second Wednesday—Steven's Steak House, Commerce, CA). RAY DIMAIO, Koppers Co., P.O. Box 22066, Los Angeles, CA 90022.

LOUISVILLE (Third Wednesday—Breckinridge Inn, Louisville, KY). KEN HYDE, Reliance Universal, Inc., Louisville, KY 40233.

MEXICO (Fourth Thursday—meeting sites vary). ROSA MA. ROJAS, Mobil Atlas, S.A. de C.V., Poniente 146 No. 700, 02300 Mexico, D.F., Mexico.

MONTREAL (First Wednesday—Bill Wong's Restaurant). VIJAY SHARMA, Swing Paints Ltd., 2100 St. Patrick St., Montreal, Que., Canada.

NEW ENGLAND (Third Thursday—Hillcrest Function Facilities, Waltham). KEVIN MULKERN, Samuel Cabot, 229 Marginal St., Chelsea, MA 02150.

NEW YORK (Second Tuesday—Landmark II, East Rutherford, NJ). KENNETH DEPAUL, Whittaker, Clark & Daniels, 1000 Coolidge St., S. Plainfield, NJ 07080.

NORTHWESTERN (Tuesday after first Monday—Jax Cafe, Minneapolis, MN). LARRY BRANDENBURGER, Valspar Corp., 1101 Third St. S., Minneapolis, MN 55415.

PACIFIC NORTHWEST (Portland Section—Tuesday following second Wednesday; Seattle Section—the day after Portland; British Columbia Section—the day after Seattle). DENNIS HATFIELD, J.F. Shelton, 1067 Industry Dr., Tukwila, WA 98188.

PHILADELPHIA (Second Thursday—Dugan's Restaurant). DONALD F. DENNY, E.W. Kaufmann Co., P.O. Box 529, Southampton, PA 18966.

PIEDMONT (Third Wednesday—Howard Johnson's, Brentwood exit of I-85, High Point, NC.) STEVE LASINE, McCullough & Benton, P.O. Box 29803, Atlanta, GA 30359.

PITTSBURGH (First Monday—A.J. ISACCO, Puritan Paint & Oil Co., 1 N. Main St., Pittsburgh, PA 15215).

ROCKY MOUNTAIN (Monday following first Wednesday—Bernard's, Arvada, CO). CRAIG HANSEN, George C. Brandt, Inc., 6500 Stapleton Dr. S., Denver, CO 80216.

ST. LOUIS (Third Tuesday—Salad Bowl Restaurant). MERLE D. HELD, Cyrus Industrial Minerals Co., 225 S. Meramec St., St. Louis, MO 63105.

SOUTHERN (Gulf Coast Section—Third Thursday; Central Florida Section—Third Thursday after first Monday; Atlanta Section—Third Thursday; Memphis Section—bi-monthly, Second Tuesday; Miami Section—Tuesday prior to Central Florida Section). RONALD R. BROWN, Union Chemicals Div., P.O. Box 26845, Charlotte, NC 28213.

TORONTO (Second Monday—Cambridge Motor Hotel). PHILIP READ, Sico, Inc., 30 Bethridge Rd., Rexdale, Ont., Canada M9W 1N2.

WESTERN NEW YORK (Third Tuesday—The Red Mill, Clarence, NY). MICHAEL DE PIETRO, Spencer-Kellogg Div., Textron, Inc., P.O. Box 210, Buffalo, NY 14225.

Future Society Meetings

Birmingham

(June 12)—SYMPOSIUM—"MIRACLE 85—MANAGEMENT AND INVESTMENT REQUIRED TO ACHIEVE COATINGS LABORATORY EFFICIENCY."

Cleveland

(May 21)—"PAINT EXAMINATION TECHNIQUES USED IN THE F.B.I. LABORATORY"—Jim Corby, Federal Bureau of Investigation.

Golden Gate

(May 20)—"EXTERIOR LATEX PAINT STUDY"—Dan Dixon, Freeport Kaolin Company.

Los Angeles

(May 15)—"EXTERIOR LATEX PAINT STUDY"—Dan Dixon, Freeport Kaolin Company.

(June 12)—ANNUAL MEETING, ELECTION OF OFFICERS.

Montreal

(May 29)—SEMINAR ON "SUBSTRATES AND THEIR COATINGS."

Pacific Northwest

(May 21-23)—"EXTERIOR LATEX PAINT STUDY"—Dan Dixon, Freeport Kaolin Company.

Piedmont

(May 15)—"INFLUENCE OF INACTIVE AND ACTIVE PIGMENTS ON THE CORROSION INHIBITING PROPERTIES OF PAINT FILMS"—Dr. Rolf H. Odenthal, Mobay Chemical Corp.

(June 19)—NOMINATION OF OFFICERS.

St. Louis

(May 21)—MANUFACTURING NIGHT.

Western New York

(May 21)—"ORGANIC PIGMENTS: PAST, PRESENT, AND FUTURE"—Dr. Hugh Smith, Sun Chemical Corp.

Elections

BALTIMORE

Active

MCADAMS, HUGH—Farboil Paint Co., Baltimore, MD.
ROBERTS, JAMES F.—Laykold Corp., Baltimore.
ROSSI, WILLIAM—Laykold Corp., Baltimore.

Associate

HUDDLESTON, MIKE—Callahan Chemical Co., Richmond, VA.
JORDAN, ALFRED F.—W.R. Grace & Co., Baltimore, MD.

BIRMINGHAM

Active

BERRY, STEPHEN J.—M.C.I.F. Ltd., West Bromwich, West Midlands.
BROOKES, PETER R.—M.C.I.F. Ltd., West Bromwich.
COTTON, MALCOLM—Sandoz Products Ltd., West Yorkshire.
HASSALL, P.—M.C.I.F. Ltd., West Bromwich.
RAINE, CLINT—Bayer U.K., Berks.
SIMMONS, GARNETT C.—Becker Paints Ltd., West Midlands.
SINGH-PALL, HARGURTEK—Holden Surface Coatings Ltd., Birmingham.

CHICAGO

Active

FENWICK, MARC B.—Nalco Chemical Co., Naperville, IL.
HASTIE, JOHN F.—The Enterprise Cos., Chicago, IL.
LUKANICH, JOSEPH—DeSoto, Inc., Des Plaines, IL.
MARTIN, JAMES W.—Bradshaw Praeger Co., Chicago.
MILLER, MICHAEL F.—U.S. Gypsum Co., Chicago.
MILLS, FRED B.—The Enterprise Cos., Chicago.
NEWELL, KEVIN A.—DeSoto, Inc., Des Plaines.
SHAH, ASHOK A.—The Enterprise Cos., Chicago.
SHTEYNBERG, VLADIMIR—D.C. Franche & Co., Chicago.
SKERRY, BRIAN S.—Sherwin-Williams Co., Chicago.
STREZO, RICHARD M.—Stepan Chemical Co., Northfield, IL.
TSE, RAYMOND—DeSoto, Inc., Des Plaines.
VAN WINKLE, CHARLES—Elpaco Chemical Coatings, Elkhart, IN.
WILLIS, VICTOR M.—Ace Paint Div., Ace Hardware, Matteson, IL.

Associate

FRITZE, CHARLES B.—UCD Div., Lansing, IL.
MAGETT, ROY L.—S.C. Johnson & Son, Inc. Oakbrook, IL.
SCIMECCA, FRANK—NL Industries, Inc., Downers Grove, IL.
WAREHIME, GARY C.—Spencer-Kellogg, Schaumburg, IL.

LOUISVILLE

Active

KATJE, FRANKLIN G.—Whirlpool Corp., Evansville, IN.
OVERSTREET, DENISE D.—Olympic Home Care Products, Louisville, KY.
WILSON, TERRY—Olympic Home Care Products, Louisville.
ZAMLER, BRIAN K.—Reliance Universal, Inc., Louisville.

Associate

BYRNE, THOMAS J.—ASARCO Inc., Columbus, OH.
KIDWELL, CLARK—Kidwell Associates, Versailles, KY.
KROCK, LAWRENCE M.—BASF Wyandotte Corp., Louisville, KY.
SHUMATE, THOMAS E.—ChemCentral Louisville, Louisville.

NEW YORK

Active

BRODY, DONALD E.—Maas & Waldstein Co., Newark, NJ.
FELLER, SHERMAN—Norton & Son, Inc., Bayonne, NJ.
LEWIS, JOSEPH—Ell-Bee Chemical Co., Inc., East Hanover, NJ.
SHAH, JITENDRA—R&A Specialty Chemical Corp., Brooklyn, NY.
SLATER, WILLIAM W.—International Paint Co., Inc., Union, NJ.

Associate

KRANIS, JEFFREY M.—Degussa Corp., Teterboro, NJ.
RUMER, RAYMOND S.—Thor Chemicals, Inc., Norwalk, CT.

NORTHWESTERN

Active

BOESPFLUG, DONALD W.—Valspar Corp., Moundsview, MN.
COLLINS, STUART—Sierra Corp., Minnetonka, MN.

FERLAUTO, EDWARD C.—Valspar Corp., Minneapolis, MN.
LOPEZ, DAVID—Worum Chemical Co., St. Paul, MN.
TAYLOR, LAURENT—SCM Corp., Minneapolis.
WALGRAVE, SUSAN L.—Cargill, Inc., Wayzata, MN.
WALTER, MARK C.—Cargill, Inc., Wayzata.

Associate

GUNDRY, JEFF—Horton-Earl Co., St. Paul, MN.
KARNOPP, PATRICIA—Ashland Chemical Co., Shakopee, MN.
VAN STONE, ROBERT J.—Horton-Earl Co., St. Paul.

PHILADELPHIA

Active

CALDWELL, RICHARD A.—Reichhold Chemicals, Inc., Dover, DE.
GUTTERIDGE, WILLIAM H.—Lawrence-McFadden Co., Philadelphia, PA.
JACKSON, HAROLD L.—DuPont Co., Wilmington, DE.
LICCIARDELLO, ROSARIO—Wilmington Chem. Co., Wilmington.
MILLER, MICHAEL W.—Whittaker Corp., North Brunswick, NJ.
NGUYEN, TRACH DANG—M.A. Bruder & Sons Inc., Philadelphia.
SALMON, HOWARD J.—Clement Coverall Co., Camden, NJ.
SCHILLER, ROBERT M.—Reichhold Chemicals, Inc., Dover.
WILLS, PAUL E.—DuPont Co., Philadelphia.

Associate

LAUBLE, HAL—HL Industries, Ottsville, PA.
SOLOMON, JANICE D.—Sannor Industries, Plainsboro, NJ.
VAN DER POL, PAUL—Whitco Chemical Corp., Yardley, PA.

PIEDMONT

Active

BEANE, BOBBY E.—Lilly Co., High Point, NC.
BOYLAN, WILLIAM G.—Blue Ridge Talc Co., Henry, VA.
BRIGHT, JOHN I.—Reliance Universal, Inc., Roanoke, VA.
GATLIN, KATHY G.—Ashland Chemical Co., Charlotte, NC.
KECK, FRANCIS D.—Reichhold Chemicals Inc., Charlotte.
PEAKE, THOMAS H.—Reliance Universal, Inc., High Point.

WINKLER, SAMUEL N.—Reliance Universal, Inc., Roanoke.

Associate

EDELMAN, RALPH E.—Heubach, Inc., Charlotte, NC.

ELIOT, PAUL H.—Alchemy South Ltd., Doraville, GA.

FAUST, RON A.—NL Chemicals, Greensboro, NC.

LOGUE, DON H.—AZS Chemical Co., Greer, SC.

MARTIN, EDWARD L.—Hercules Incorporated, Norcross, GA.

WEST, RICHARD O. JR.—Filter Specialists, Charlotte.

PITTSBURGH

Active

SIERADZKI, RAYMOND—PPG Industries, Inc., Allison Park, PA.

Associate

HOOVER, RICHARD M.—Neville Chemical Co., Pittsburgh, PA.

KRESS, MICHAEL A.—Mobay Chemical Co., Pittsburgh.

SOUTHERN

Active

COLBY, JOANN M.—Coronado Paint Co., Edgewater, FL.

GUSTAVO, GUERRA—Pintex Chemicals Corp., Hialeah, FL.

HARDCASTLE, RUSSELL R.—Anvil Paints & Coatings, St. Petersburg, FL.

MCDOWELL, SCOTT—Spectrum Paints Inc., Decatur, GA.

RECTOR, FRANKLIN D. JR.—AMP, Inc., Winston-Salem, NC.

WEISS, ROWLETTE Q.—Weatherproofing Products Co., Inc., Hialeah.

WENTINK, STEVEN G.—AMP, Inc., Winston-Salem.

WONDERLING, M.B.—GTW Coatings, Inc., Fayetteville, TN.

Associate

DALTON, DENNIS—Buckman Labs, Inc., Memphis, TN.

EULER, MARYBETH—Union Chemicals Div., Tarpon Springs, FL.

HISLOP, ROBERT—McWhorter, Inc., Carpentersville, IL.

MARSH, BRADLEY K.—Union Chemicals Div., Tampa, FL.

MCLAURIN, MICHAEL C.—Buckman Labs, Inc., Memphis.

RAMPEY, JOSEPH F. JR.—Union Chemicals Div., Charlotte, NC.

SKAGGS, PAMELA J.—P/S Chemical Inc., Ft. Lauderdale, FL.

SPITZER, RONALD G.—Cosan Chemical Corp., Carlstadt, NJ.

WILSON, DENNY A.—Manville Corp., Norcross, GA.

TORONTO

Active

BOONE, PEGGY—K-G Packaging Ltd., Concord, Ont.

GREY, JAMES—London, Ont.

QURESHI, ASLAM NIZAM—Niagara Paint & Chemical Co., Ltd., Hamilton, Ont.

Associate

RANA, VIK—Reichhold Ltd., Toronto, Ont.

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Richard M. Gallas has been named Market Manager, Industrial Coatings Polymers, U.S. Specialty Chemicals, Johnson Wax, Racine, WI. He is a member of the Southern Society.

In addition, the firm has named **Gordon S. Wolfe** an Industry Specialist, Industrial Coatings. Mr. Wolfe, a member of the Louisville Society, will be working on technical service activities for the company's industrial coating polymer intermediate customers and field sales force. He will report to **M.K. (Hal) Yousuf**, Senior Industry Specialist. Mr. Yousuf is a member of the Chicago Society.

Mobay Chemical Corp., Pittsburgh, PA, has announced that **Sheila I. McCarthy**, Sales Representative for the Pigments Dept. of the company's Dyes and Pigments Div. has been transferred to St. Louis, MO. This move is in line with the department's efforts to expand sales coverage to the plastics, ink, and coatings industries.

Spencer Kellogg Division of Textron, Inc., Buffalo, NY, has announced the appointment of new accounts representatives: **John J. Falsone** has been transferred and assigned to the New York sales area with headquarters in Newark, NJ and **Robert C. Jakosh** will be the accounts representative in the southern California area with headquarters in Long Beach.

The Gilbert Spruance Co., Bryn Mawr, PA, has promoted **Philip Erwin Payne** to Executive Vice-President of the firm's Southern Division of Winston-Salem, NC. Prior to his promotion, Mr. Payne was Technical Director of the Southern Div.

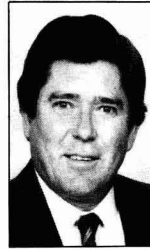
Myron O. Beatty, Vice-President and Technical Director of C.M. Athey Co., was the recent recipient of the Herman Shuger Memorial Award of the Baltimore Society. The award was presented in recognition of Mr. Beatty's service to the Baltimore coatings industry.



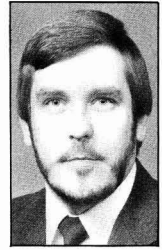
R.M. Gallas



S.I. McCarthy



J.D. Boggess



D.J. Subach

At a recent meeting of the Materials Marketing Associates, **Art Benton**, of McCullough & Benton, Inc. and **Eugene Daigle**, of Mehaffey & Daigle, Inc. were elected to serve on the MMA Board of Directors. Both men are members of the Southern Society.

Serving the second year of the two-year term of office on the Board are **James D. Boggess**, of Wm. B. Tabler Co., Inc., and **James A. Grierson**, of APCO Industries, Ltd. Mr. Boggess is a member of the Louisville Society.

In addition, **John F. Boorman**, of Van Horn, Metz & Co., Inc., was elected Chairman of the MMA Awards Committee. The MMA Awards are presented annually at the Federation Annual Meeting in recognition of Society achievements in education, manufacturing, and training procedures, technology, public service, and other achievements deemed proper and desirable. Mr. Boorman is a member of the Philadelphia Society.

As part of its major marketing reorganization, NYCO, Willsboro, NY, has appointed **Joseph Copeland** to the position of Division Vice-President, Marketing. **Ron Bauer** has been named to the position of Vice-President, Manufacturing. Both men recently were named Joint Managers of NYCO's Business Development Group, created to expand the scope of the company's products line.

The Midland Division, The Dexter Corp., Waukegan, IL, has promoted **Araclai Q. Dahan** to the position of Senior Development Chemist in the Industrial Products Laboratory. Ms. Dahan, who has been with Midland since 1979, has been involved in the development of military camouflage products and release coatings.

NL Chemicals/NL Industries, Inc., Hightstown, NJ, has appointed **Daniel J. Subach** to the position of Manager, New Business Development. Dr. Subach will be responsible for developing and implementing programs to promote the growth of the specialty chemicals business of NL Chemicals.

Michael W. Huber, President of the J.M. Huber Corp., Edison, NJ, since 1957 has been elected Chairman and Chief Executive Officer. **George Schenk**, who has been named President and Chief Operating Officer succeeds Mr. Huber.

Kraft Chemical Co., Melrose Park, IL, has named **Wilfred P. Brandes** to the position of Vice-President and General Manager. Mr. Brandes has served the company for over 35 years.

In addition, Kraft has appointed **Marianne Lerch** a Sales Representative serving the coatings field. A member of the Chicago Society, Ms. Lerch is based at corporate headquarters in Melrose Park.

Roy Ingleston, **Frank Suddaby**, and **Brian Addenbrooke**, of the Birmingham Paint, Varnish, and Lacquer Club were awarded the Club's Distinguished Service Certificate at the December meeting.

Mr. Ingleston, of Drynamels Ltd., joined the Club in 1973 and has been a member of the Technical Committee since 1976. He was Treasurer from 1977-79 and President in 1980-81.

Mr. Suddaby, retired from Blundell Permoglaze Ltd., has been a member since 1957, was Secretary from 1963-70, and President in 1970-71.

Mr. Addenbrooke, of Croda Paints Ltd., joined the Club in 1960 and has served the Technical Committee since 1972. He was President in 1976-77.

John R. Krajcech has been promoted to Director, Management Information Systems at McCloskey Varnish Co., Philadelphia, PA. Mr. Krajcech is responsible for all corporate information processing operations, including the plants in Los Angeles and Portland, as well as in Philadelphia.

Sadolin & Holmblad, Ltd., Denmark, has named **Dr. Jesper Nielsen** as President of its three companies located in North Carolina: Sadolin of America, Inc., Sadolin Technology, and Sadolin Paint Products.

Andrew Doroskin has been appointed to the position of Field Sales Manager of CasChem, Inc., Bayonne, NJ. Mr. Doroskin will be headquartered in Chicago.

The Process Chemicals Div. of Diamond Shamrock Corp., Morristown, NJ, has appointed **Dr. Thomas M. Cawthon** as Director, Research and Commercial Development. In this position, Dr. Cawthon will be responsible for business planning and future growth of the division through the development of new products, business ventures, and acquisitions.

Gerald T. Noel has been named a Research Leader in coatings and electronic materials research at Battelle Memorial Institute's Columbus Laboratories. In his new position, he will provide technical direction and management to photovoltaic programs aimed at implementing solar-powered systems. He continues to serve as a Group Leader in physical deposition research on the development of thin film coatings and coating techniques using physical vapor deposition.

Obituary

Lyman P. Hunter, Past-President of the Federation, died on March 5 at the age of 86.

Mr. Hunter entered the paint industry as a Paint Chemist for Bennett's in Salt Lake City in 1928. He was an instrumental figure in the development of the firm's Colorizer Paint Tinting System. At the time of his retirement from Bennett's in 1968, he was Vice-President and Technical Director.

One of the organizers of the Rocky Mountain Society, Mr. Hunter served as its Society Representative to the Federation for many years. He was President of the Society from 1962-63 and was elected to Federation Honorary Membership in 1970.

Charles H. Parker, retired member of the New England Society, died on January 24. He was 78 years old.

A veteran of the coatings industry, "Charlie" Parker joined the American Cyanamid Co. after his graduation from Purdue University. There, he performed research on alkyds and aminoplast resins. He was employed by Monsanto Co. in 1950, managing surface coatings resins technical service. Following his retirement in 1962, Mr. Parker served as a Consultant to paint companies, and then to Springborn Laboratories. He was the author of papers on melamine and urea formaldehyde resins, and more recently, on waste management and environmental issues.

Frederick O. Volgenitz, retired Technical Manager of The Valspar Corp., died on December 22. He was 75.

Mr. Volgenitz joined Valspar in 1956 as Assistant Technical Director after being employed by Sears, Roebuck and Co. in Chicago as a Chemist in charge of trade sales.

He was President of the Chicago Paint and Coatings Association in 1970-71.

Bead Mills With A Brain



The "state of the art" micro-processor in Netzsch's new computerized Bead Mills makes it possible to reduce solvent loss, operating cost, down time, explosion hazard, environmental hazard and labor cost while stabilizing product quality and assuring repeatability. In addition, it allows the safe, accurate processing of temperature sensitive products.

The microprocessor can control the cooling water temperature and flow rate, ball charge, pump speed, and washdown cycle. It also can automatically start-up and shut-down the mill. When raw material feed is reduced or ceases it acts as an emergency shut off. Computerizing all these functions results in greater control of product temperature, throughput rate, fineness of grind and longer media and machine life. It also reduces the chance of operator error.

By addition of a monitoring and recording system it is possible to both supervise and record in units or in total the agitation speed, pump speed, throughput rate, product density, viscosity, cooling water temperature, product back pressure, amperage of main drive and product temperature. The result is greater overall supervision of the process and machine performance including production totals and down times.

Netzsch's computerized Bead Mill can act as a single processing system or can be interfaced with higher level plant computers.

For more information on how Netzsch's new Bead Mills "with a brain" can work for you write or call today.

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Record Attendance and Exhibits Set At 1985 West Coast Symposium & Show

New attendance and exhibit records were established at the 17th Western Coatings Societies' Symposium and Show (WCSSS) in Anaheim, CA, February 26-March 1. This biennial event is sponsored by the Federation's four West Coast Societies (Los Angeles, Golden Gate, Rocky Mountain, and Pacific Northwest). The Los Angeles and Golden Gate Societies alternate as hosts/managers at a California site chosen by them.

Richard C. Sutherland II, of the E.T. Horn Co., was General Chairman of the 1985 WCSSS. Co-Chairman was Earl B. Smith, of Spencer Kellogg Div., and President of the LA Society.

Mr. Sutherland reported a registration of about 3,000—a new record for the WCSSS.

Exhibits

There were a record-breaking 109 exhibitors and 171 exhibit spaces in the show, managed by Robert M. Abrams, of Major Paint Co. The show ran for four days. Winners of the plaques for the best exhibits were: EM Chemicals, Lorama Chemicals, Inc., Morehouse Industries, Inc., McCloskey Varnish Co., and Norton Containers.

Program Sessions

The Technical Program Sessions were under the direction of Philip C. Bremenstuhel, of Fredericks-Hansen Co. The presentations were:

"French Process Zinc Oxide in Primers for Hand Cleaned Structural Steel"—W.C. Johnson, Consultant.

"High Performance From Lead- and Chrome-Free Anticorrosive Paints"—A. Smith, of NL Chemicals.

"Application for Thick-Walled Ceramic Microspheres in Coatings"—T.G. Brown, of Zeelan Industries.

"Polyurethanes—State of the Art"—H.A. Kasprzak, of Spencer Kellogg Div.

"Polyols for High Solids Novel Vinyl Coatings"—G.D. Shields, of Union Carbide Corp.

"Directions for Coatings Technology"—A. Banov, of the *American Paint Journal*.

"Chlorinated Polyolefins—New Developments in Coatings Plastics"—T.E. Parsons and S.B. Miller, of Eastman Chemical Products, Inc.

"Formulation of Solvent-Based Paints Pigmented with Titanium Dioxide"—J.E. McNutt, of the DuPont Co.

"Polyester and Polyurethane Wood Finishes—High Solids Alternatives"—S. Siranovich, of Mobay Chemical Corp.

"New Coating Systems for Wood and Metal Based on Modification of Urethane Finishes With Urethane Grade Nitrocellulose"—E.W. Gryger, of Hercules Incorporated.

"Mixed Ether of Melamine Resins in High Solids Coatings"—J.W. Santer, of Monsanto Co.

"New Generation Acrylics for Elastomeric Roof Mastic"—W.A. Kirn, of Rohm and Haas Co.

"Formulating Acrylic Water Borne Coatings for Plastics"—J.E. Fitzwater, Jr., of Polyvinyl Chemicals.

"Fundamental and Practical Aspects of Adhesion in Water-Borne Coatings"—K.C. Sehgal and M.A. Sherwin, of Union Carbide Corp.

"The Role of Paint Additives in the 80's"—B.M. Gan and E.M. Antonucci, of Drew Chemical Corp.

"Corrosion Resistant Water-Borne Coatings Through Resin Selection, Formulation, and Use of Additives"—A. Heitkamp, of Cargill, Inc.

"Biocide Resistance Bacteria Fermenting and Causing Gassing Paint"—C.C. Versfeldt, W.E. Macheimer, and W. Singer, of Troy Chemical Corp.

"Latex Testing for Coating Applications"—R.D. Athey, Jr., of Athey Technologies.

"High Solids Epoxy/Polyamide Coatings"—V. Brytous, of Ciba-Geigy Corp.

"A Unique Extender Pigment for Low VOC Industrial Coatings"—C.J. Stoneback, of Engelhard Corp.

A Hazardous Materials Handling Panel Discussion was moderated by Al Aronow, Consultant. Panel members were: M.D. Sands, of McKesson Environmental Services; H.H. Kim, of Major Paint Co.; M. Uziel, of Enviropro, Inc.; A. Probiżanski, of Ampro Technologies; and S.S. Sherrill, Assistant Chief of the Los Angeles County Fire Dept.

Other Events/Information

The featured speaker at the WCSSS Luncheon was Willie L. Brown, Jr., Speaker of the California Assembly.

Other Chairmen of Symposium Committees were: Publicity—Lee W. Foster, of Mobay Chemical Corp.; Entertainment—Andrew R. Ellis, of NL Chemicals; Registration—James A. Dye, of Transwestern Chemicals, Inc.; Advisor—Tony Rumfola, of TCR Industries; and Secretary-Treasurer—Geneva H. Wells, of H.M. Royal, Inc.

1987 WCSSS

The 18th WCSSS will be held at the Monterrey Convention Center, Monterrey, CA, February 23-25, 1987. For information contact: Barry Adler, of Royell, Inc., 1150 Hamilton Court, Menlo Park, CA 94025 or Ted Favata, of TLT, Inc., 318 Pendleton Way, Oakland, CA 94621.



Recipients of plaques for best exhibits were (left to right): Bill Moore, of Norton Containers; Don Arntfield, of Lorama Chemicals; Doug Melton, of Morehouse Industries; Bob Buwall, of McCloskey Varnish Co.; and Joseph Feldman, of EM Chemicals

"Polymers" and "Coatings and Films" Among Topics Explored At 1985 Gordon Research Conferences in New Hampshire

The 1985 Gordon Research Conferences, designed to foster and promote education and science by organizing meetings of research scientists with common interests in the fields of chemistry and related sciences, have been scheduled in various locations in New Hampshire from June 10 to August 30. Among the many topics scheduled are "Coatings and Films" and "Polymers."

On July 1-5, Colby-Sawyer College (N) in New London, NH, will present "Polymers." Norbert M. Bikales will serve as Chairman for the following discussions:

July 1

"Metal-Catalyzed Polymerization and Routes to Metal-Containing Polymers"—T. Katz.

"Model Copolymerization Reactions"—D.A. Tirrell.

"New Developments in the Field of Tailor-Made Macromolecules"—P. Rempp.

July 2

"Mechanism of Alternating Copolymerizations in the Presence of Complexing Agents"—P. Sigwale.

"Miscible Polymer Blends: Recent Infrared Spectroscopic Studies"—M.M. Coleman.

"Molecular Motions in Bulk Polymers by Solid-State NMR"—L.W. Jelinski.

July 3

"Electronic Excitation Transport and Excimer Formation as Probes of Poly-

mer Structure and Dynamics"—C.W. Frank.

"Surface Forces in Polymer Solutions"—J. Klein.

"Influence of the Molecular Structure on the Macroscopic Properties of Glassy Vinyl Polymers"—U.W. Suter.

"Recent Studies on the Composition Heterogeneity of Copolymers"—P. Kratochvil.

July 4

"Quasi-Elastic Light Scattering for Network Characterization"—S.J. Candau.

"Intra- and Intermolecular Scattering from Polymer Solutions as a Function of Concentration"—R. Ullman.

Round Table Presentation on "Where Is Polymer Science Headed"—B.M. Culbertson, Discussion Leader.

July 5

"Formation and Properties of Polymer Networks"—R.F.T. Stepto.

"Single-Molecule Gas-Phase Polymerization Kinetics"—H.M. Reiss.



From August 5-9, the Conference program at Plymouth State College (S), in Plymouth, will focus on "Coatings and Films." Chaired by Loren W. Hill, of Monsanto Co., the following presentations have been scheduled:

August 5

"Latent Catalysts for Thermoset Coatings"—S.P. Pappas.

"Reaction Mechanisms in High Solids Coatings"—E.W. Meijer.

"Chemistry and Characterization of Cure in Blocked Isocyanate Coating"—G.M. Carlson, C.M. Neag, and T. Provder.

"Benzoxazine Crosslinkers for Coatings"—H.P. Higginbottom.

August 6

"Formation and Properties of Thermosetting Polymers"—J.B. Enns.

"Transport in and Physical Aging of Polymeric Glasses"—H.B. Hopfenberg.

"Synthesis and Characterization of Functionally Reactive Polymers"—J.E. McGrath.

"Photodegradation of Aromatic Diisocyanate-Based Polyurethanes"—C.E. Hoyle.

August 7

"Characterization of Core-Shell Emulsion Polymers"—J.W. Vanderhoff.

"New Developments in Water-Borne Coatings"—Y. Sasaki.

"Separating Solubility Parameters of Polymers into Their Components"—K.L. Hoy.

"Recent Investigations on IPN Coating"—K.C. Frisch.

August 8

"Use of Acoustic Emission in Characterizing Degradation of Coatings"—T.A. Strivens.

"Fundamentals of Impact Phenomena in Coatings Systems"—M. Oosterbrok.

"Single Crystal Coatings: High Technology Applied to Coatings and Coating Processes"—S.E. Rickert.

August 9

"Cationic Electrodeposition of Primers Over Zinc Coated Steel"—C. Schoff.

"Correlation of Application and Appearance with Rheological Measurements"—R.J. Barsotti and C. Scopazzi.

For more information on these and other topics to be presented, contact Dr. Alexander M. Cruickshank, Director, Gordon Research Conferences, Gordon Research Center, University of Rhode Island, Kingston, RI 02881.

Georgia Institute of Technology to Sponsor Emulsion Polymers Course in Switzerland

The eighth annual short course on emulsion polymers will be presented by the Georgia Institute of Technology in Davos, Switzerland, on August 19-23. Entitled "Advances in Emulsion Polymerization and Latex Technology," the course will offer an in-depth study of the synthesis, characterization, and properties of high polymer latexes.

The subject matter includes a balance of theory and practical problems. Designed for engineers and scientists who are actively involved in emulsion work as well as for those who wish to develop expertise in the area, lectures will begin with introductory material and reviews and will progress through recent research results. Lectures will be given in English. A basic background in chemistry will be assumed.

Course organizers are Dr. Gary W. Poehlein, Professor of Chemical Engineering, Georgia Institute of Technology; and Dr. John W. Vanderhoff and Dr. Mohamed S. ElAasser, Co-Directors of the Emulsion Polymers Institute, Lehigh University.

Registration fee for the course is \$575 for five days or \$175 per day for any portion of the course attended. This fee covers course attendance and a set of course notes. Registration will be limited to 50 participants.

For further information, write to Dr. Gary W. Poehlein, School of Chemical Engineering, Georgia Institute of Technology, Atlanta, GA 30332.

Paints and Coatings Technology Collection Available at Redwood City Library

The following index has been submitted by members of the Golden Gate Society for Coatings Technology as a reader service. It lists available publications from the paints and coatings technology collection of the Redwood City Public Library, located in Redwood City, CA. Additional information may be obtained by contacting the Library at (415) 369-3737 or 369-3738.

Procedures for Borrowing Books

Any Society member residing in San Mateo County, CA, who holds a library card issued by any of the public libraries in the county can come to the Redwood City Public Library and borrow books.

Should non-San Mateo County residents be in Redwood City and desire to borrow a book, they may do so by identifying themselves through Society membership cards. Books will be loaned under a library card issued to the Society.

Borrowers are responsible for the return of the books. Society members residing in San Mateo County may return the books to any of the public libraries in the County. Those members who reside outside of San Mateo County who borrow books on the Society card must return the books directly to the Redwood City Public Library.

The preferred method of borrowing for non-residents is through interlibrary loan. Go to your nearest public library and have that library borrow the book for you. Also, if your company has a library, have your company librarian relay the request to Redwood City Public Library. Redwood City Public Library will honor all interlibrary loan requests.

Interlibrary loan is the preferred method for loaning books to Society members who do not have library cards from any of the public libraries in San Mateo County. Through this method all transactions, including the return of books, are handled by the requesting library. There is a further advantage since the loan period of a book is one month. A direct borrowing loan period is three weeks.

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Two Spring Short Courses Scheduled by University of Missouri—Rolla

As part of its series of spring short courses, the University of Missouri-Rolla will offer "Physical Testing of Paints and Coatings" and "BASIC Microcomputer Programming for Coatings" at its Rolla, MO, campus.

"Physical Testing of Paints and Coatings: Get in the Swing to Higher Quality," will be presented from May 13-17. The course is designed to improve testing techniques for quality assurance of paints and coatings. It is intended to benefit those working in quality assurance for coatings or raw materials; newcomers to the paint industry in a quality control lab; and quality control lab supervisors.

The intensive course will show participants how to better measure the quality of paint from the standpoint of the coatings manufacturer.

Morning lectures will concentrate on the purpose, theory, and techniques of quality assurance. Afternoon laboratory workshops will include tests on equipment discussed in lectures, and demonstrations on how to use the equipment and techniques in the lab. In addition, a tour of a paint company in St. Louis will be arranged.

Prerequisites for the course are: experi-

ence in a quality assurance laboratory, the equivalent of one year of college chemistry, or completion of the UMR Introductory Short Course on the Composition of Paints and Coatings or similar education or experience.

The course fee of \$499 includes all classroom materials and instruction.

"BASIC Microcomputer Programming for Coatings," scheduled for May 20-23, is designed for laboratory, purchasing, and marketing people who have a desire to use the computer as a tool to make jobs faster, more efficient, and productive. No prior programming experience is required.

Attendees of this course will learn how to write custom-designed software for use on a microcomputer costing less than \$2000. From basic design to final working programs using the BASIC programming language, "hands-on" experience in programming will be provided. The programs will be useful in formulation, information retrieval, purchasing, costing/pricing, sales analysis, and inventory control.

Stanley W. Harshfield, Technical Director of United Paint Co., Memphis, TN, and James Stoffer, Professor of Chemis-

try at the University of Missouri-Rolla, will serve as instructors for the courses.

Fee for the course is \$610.

For further information, contact Coatings Continuing Education, Dept. of Chemistry, University of Missouri-Rolla, Rolla, MO 65401.

Montreal Society Holds Substrates Seminar, May 29

The Montreal Society for Coatings Technology will sponsor a one day seminar on "Substrates and Their Coatings," at Bill Wong's Restaurant in Montreal on May 29.

Morning sessions will concentrate on resin systems for coatings. Representatives from industry will discuss alkyds, epoxies, urethanes, and PVA's. Substrates, such as metal, wood, cement, and polymeric will be the topics of the afternoon session. The moderator of the seminar is Barry Kay, of *Coatings Magazine*.

For additional information, contact B. Papenburg, Canada Colors & Chemicals, 155 Montee de Liesse, St. Laurant, Que., Canada H4T 1T9.

Fire Retardant Coating

A recently released technical bulletin details the properties of a new type of fire retardant coating. Main applications of the coating include the thermal protection of structural steel in high rise building construction, petroleum storage tanks, and uses where thermal protection of capital equipment is a major concern. For additional information, contact William A. MacKeil, Fiber Materials, Inc., Biddeford Industrial Park, Biddeford, ME 04005.

Urethane Coatings

Water-borne urethane coatings are the subject of a recently published brochure. These coatings offer outstanding cold flex, abrasion resistance and adhesion properties, and are suitable for industrial applications including textile binders, saturants, coatings for wound dressings, and automotive interiors. Inquiries for further details should be sent to Permuthane, P.O. Box 3039, Corwin St., Peabody, MA 01960.

Spectrometer

A modular spectrometer system designed to measure colors and color differences has been described in a brochure. This instrument is suited for use in stationary or traveling paper machine control systems, pass/fail analysis in process control applications, color measurement of various media, and general color specifications and quality control. Inquiries should be sent to Karl Mahler, Carl Zeiss Canada Ltd., 45 Valleybrook Dr., Don Mills, Ontario, Canada, M3B 2S6.

Associative Thickeners

A new rheology modifier is the subject of a recently published product bulletin. The thickener is designed for improved efficiency and hiding in acrylic and vinyl acrylic latex paints. This thickener modifies rheology through an associative mechanism that provides a unique viscosity-shear profile, improving paint application properties and appearance. Further information on the thickener SCT-270 can be obtained from Union Carbide Corp., Specialty Chemicals Div., Dept. K3444, Danbury, CT 06817.

Horizontal Grinder

A bench top, explosion-proof horizontal grinder has been featured in a new brochure. The mill is reported to process water-based suspensions, high-solids mill bases, magnetic iron oxide slurries, dye dispersions, pigments dispersed in oils, and nearly any solvent-based slurry. For additional information on the model HML-0.25 VSD Supermill, contact Premier Mill Corp., 220 E. 23rd St., New York, NY 10010.

Coupling Agents

A 230-page technical reference manual discussing titanate and zirconate coupling agents has recently been published. The volume contains 257 tables, 128 illustrations, and details advantages, applications, primary effects, and production improvements. A free copy of the Ken-React® Reference Manual can be obtained from Kenrich Petrochemicals, Inc., P.O. Box 32, Bayonne, NJ 07002.

Conference Proceedings

A publication containing the proceedings of the Tenth International Conference in Organic Coatings Science and Technology is now available. The price per book, including air mail postage and handling, is \$100 in USA and \$150 in Europe. For further details, write to Dr. Angelos V. Patsis, CSB, Rm. 209, State University of New York, New Paltz, NY 12561.

Instrument Product Catalog

A new product catalog highlights a complete line of electronic analytical and precision balances, electronic scales, weight-related peripherals, and analytical instruments. For a free copy of the 1985 Product Catalog, write to Mettler Instrument Corp., P.O. Box 71, Hightstown, NJ 08520.

Filter Bags

A new line of mesh filter bags is introduced in literature. The bags are reported to be suitable for critical applications and are offered in all standard sizes. For copies on the Metraflow line, contact American Felt and Filter Co., New Windsor, NY 12550.

Nitrocellulose

Detailed information on toluene-wet nitrocellulose is now available. When joined with urethane polymers, it produces a coating with an excellent gloss, claimed to be fast-drying, durable, and stain-resistant. To obtain free trial formulations for wood and metal nitrocellulose urethane finishes, contact Product Inquiry, Hercules Incorporated, Hercules Plaza, Wilmington, DE 19894.

Chemical Products

Literature describing the performance features of four new chemical products has been released. Triethylene glycol dichloride (TEG-DC) and bis(2-hydroxyethyl)-5-(sodiosulfo)isophthalic acid—40%(BEG-5-SSIPA) are available for sampling, while 5-(lithiosulfo)isophthalic acid (5-LISIPA) and 5-(sodiosulfo)isophthalic acid (5-SSIPA) are available in commercial quantities. Further information can be obtained from Brenda Hyatt, New Products Div., Eastman Chemical Products Inc., P.O. Box 431, Kingsport, TN 37662.

Safety Manuals

Two manuals providing authoritative information and continuous reference sources on the subject of safety practices are now available. "The Safety Management Planning Manual," by USC's Dr. Ted Ferry, provides key guides for integrating safety and productivity from the management point of view.

The "OSHA Reference Manual" serves as an aid to managers responsible for OSHA-regulated worker safety. Both manuals come with periodic updates and monthly newsletters. Write to The Merritt Co., Dept. 43701, P.O. Box 955, Santa Monica, CA 90406 for more details.

Color Dispersions

Literature detailing color dispersions for polyether polyurethanes has been published. The colors are dispersed in a polyether vehicle which is claimed to be totally reactive with all polyether polyurethane systems. For information on the Series 4000, contact Pigment Dispersions Inc., 54 Kellogg Court, P.O. Box 412, Edison, NJ 08818.

Antifoams

Performance specifications of two liquid antifoams are discussed in a product bulletin. The antifoams are reported to prevent foaming of emulsion coatings based on acrylic, latex, polyvinyl acetate, and others. For copies of the bulletin and samples, contact Hodag Chemical Corp., 7247 N. Central Park Ave., Skokie, IL 60076.

Bead Mill

Detailed in a recently released product bulletin are performance specifications of a new bead mill. The mill is designed for continuous wet grinding and dispersion of a wide variety of materials. For more information on the Rotomill, contact Union Process, Inc. 1925 Akron-Penninsula Rd., Akron, OH 44313.

Crosslinker

Butyl etherified phenol formaldehyde resin, a new crosslinker designed as a coreactant for hydroxy functional vehicles, has been introduced in a booklet. For copies on EP-3560, write to Monsanto Polymer Products Co., 800 N. Lindbergh Blvd., St. Louis, MO 36167.

Cartridge Filters

Literature discussing a new line of cartridge filters has been published. The filters are available in a bleached cotton media as well as polypropylene and polyester media. For detailed product information, contact the Sales Department, Filter Specialists, Inc., 100 Anchor Rd., Michigan City, IN 46360.

Resin Catalog

A recently published resin catalog describing over 150 products can now be obtained. The catalog offers pertinent technical information in a "user-friendly" format. Inquiries for copies should be sent to Robert Costin, McWhorter, Inc., 400 E. Cottage Pl., Carpentersville, IL 60110.

Organoclays

A new organoclay which offers cost savings and higher efficiency in the manufacturing of paints is featured in literature. The organoclay is designed to improve particulate suspension and eliminate the need for polar activators and pre-gels. For further details on Claytone AF, write to Ken Westray, Southern Clay Products, P.O. Box 44, Gonzales, TX 78629.

Coatings Thickness Gauge

A waterproof coating thickness gauge is detailed in a product bulletin. The fully sealed instrument is suitable for use at depths down to 443 meters and is pressure tested to 600 psi. The bulletin is available from Sheen Instruments Ltd., Sheendale Rd., Richmond, Surrey, TW9 2JL, England.

Electric Infrared Oven

A new conveyerized electric infrared oven has been introduced in a brochure. The oven delivers a closely controlled pattern of radiant energy for many of the drying, curing, and heating applications required to make printed circuit boards, hybrid circuits, and ceramic parts. Further details can be obtained from Glenro Inc., 39 McBride Ave. Extension, Paterson, NJ 07501.

Coupling Agents

A new 12-page, full-color booklet has been published which highlights the invention and production of a new line of organometallic coupling agents. For copies, contact Kenrich Petrochemicals, Inc., 140 E. 22nd St., P.O. Box 32, Bayonne, NJ 07002.



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Nitrocellulose

Newly developed toluene-wet nitrocellulose containing reduced moisture levels is highlighted in literature. When joined with urethane prepolymers, it produces coatings that combine the fast-dry properties and application ease of nitrocellulose lacquers with the durability, gloss and stain resistance of urethane coatings for metal and wood finishes. For more information and free trial formulations, contact Product Inquiry, Hercules Incorporated, Hercules Plaza, Wilmington, DE 19894.

Surface Coatings Volumes

Surface Coatings, Volumes I and II, published by the Oil and Color Chemists Association of Australia, have recently been released. *Volume I* serves as an introduction to polymer science, pigments, solvents, and additives. *Volume II* discusses basic manufacturing, application, and technology of coverage, as well as lacquers, powder coatings, and UV-cured coatings, and decorative paint selection. For further information, contact Methuen, Inc., 733 Third Ave., New York, NY 10017.

Filter Bags

A brochure describing a new line of high efficiency liquid filter bags for use in liquid processing systems is available. The bags are applicable in a variety of industries, including reagent and bulk chemicals, oil and gas extractions, adhesives, nuclear power, and many others. Contact Christine Mailed, 220-7W, 3M Center, St. Paul, MN 55144, for copies.

Warning Labels

The National Paint and Coatings Association has released a health bulletin detailing its suggested labeling language for warning consumers and professional painters about alleged hazards associated with solvent overexposure. For more information, write to Marilyn E. Ludwig, NPCA, 1500 Rhode Island Ave., N.W., Washington, D.C. 20005.

Acrylic Polymers

Complete information on a new waterborne acrylic polymer has been published. In addition to raw materials savings, reported advantages of coatings based on this polymer are easy stain removal, low maintenance costs, and high gloss. For more details on Maincote TL-5, contact the Marketing Services Dept., Rohm and Haas Co., Independence Mall West, Philadelphia, PA 19105.

Mini-Bulk Tanks

Performance specifications and features of a portable tank for storing liquids are discussed in a bulletin. The tanks feature special steel channels on the bottom to permit forklifting from any side. For more details, contact Certified Equipment & Manufacturing Co., P.O. Box 298, Springfield, IL 62705.

Buyer's Guides

Two new buyer's guides have been published. The fourth annual edition of *High Solids Coatings® Buyer's Guide* offers a comprehensive listing of applications, testing, processing and formulator suppliers and consultants covering such categories as additives, pigments, resins, and solvents.

The seventh annual edition of the *Radiation Curing® Buyer's Guide* contains a vendor selection directory with the following supplier categories: chemical, equipment, light source, product formulators, and surface preparation, as well as consultants. For more information on either guide, contact Technology Marketing Corp., 17 Park St., Norwalk, CT 06851.



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Thickener

A new and extensive line of organoclay thickeners has been introduced in a product bulletin. The line includes two low-cost thickeners, a self-activating product, a low viscosity product, and a thickener for water-based systems. Performance specifications are available from Ed Davis, Chemical Specialties Div., Henkel Corp., 255 West Spring Valley Ave., Maywood, NJ 07067.

Grinding Media

A new six-page, color brochure containing useful information to aid in the selection of grinding media has been released. The publication contains charts, tables, selection rules, and descriptive data for large and small nonferrous and ferrous media and various types of milling equipment. For copies, write to Epworth Manufacturing Co., Inc., 1400 Kalamazoo St., South Haven, MI 49090.

MSDS Safety Software

A Material Safety Data Sheet (MSDS) module is described in a product bulletin. The new module is designed to assist companies in the compliance with recent state and federal statutes requiring the disclosure of all hazardous materials used in production. For details on the capabilities of the module, contact DataLogix Formula Systems, 1561 NE 47 St., Ft. Lauderdale, FL 33334.

Acrylate for UV/EB Coatings

The benefits of a functional caprolactone acrylate for radiation-curable coatings are featured in a publication. The acrylate is recommended as a diluent or a comonomer for producing tough and flexible coatings by UV or EB radiation. For further details on the monomer M-100, contact Union Carbide Corp., Specialty Polymers & Composites Div., Dept. M1553, Danbury, CT 06817.

Polyisoimide Resins

Two high temperature acetylenic capped polyisoimide resins have been introduced in literature. Both provide continuous use at temperatures in excess of 500° F, are soluble in low boiling solvents, and are curable at 400° F. For additional information, write to National Starch and Chemical Corp., Thermal Materials Dept., Finderne Ave., Bridgewater, NJ 08807.

Aluminum Pigments

A brochure has been released detailing the performance specifications, test methods, and formulating conditions of leafing aluminum pigments. The pigments are claimed to aid in attaining increased brightness, total reflectivity, and excellent chemical and corrosion resistance. Contact E. Glenn Kleppinger, Silberline Mfg. Co., Inc., Lansford, PA 18232 for copies.

Macromonomers

Two new high molecular weight products based on macromonomer technology for high energy cure systems have been described in literature. The products are polystyryls capped with methacrylate groups designed to perform similarly to reactive resins and oligomers in UV/EB cure coatings, inks, and adhesives. Technical data on formulations and evaluations can be obtained from Sartomer Co., West Chester Plaza, West Chester, PA 19380.

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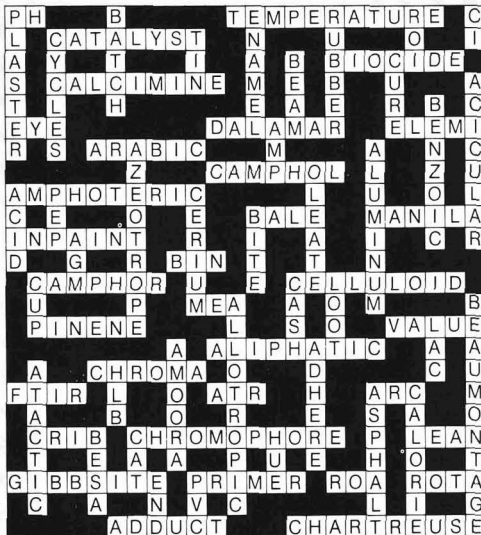
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Coming Events

FEDERATION MEETINGS

For information on FSCT meetings, contact FSCT, 1315 Walnut St., Philadelphia, PA 19107 (215-545-1506).

(Oct. 7-9)—63rd Annual Meeting and 50th Paint Industries' Show. Convention Center, St. Louis, MO.

1986

(May 13-16)—Federation "Spring Week." Seminar on 13th and 14th; Society Officers on 15th; and Board of Directors on 16th.

(Nov. 5-7)—64th Annual Meeting and 51st Paint Industries' Show. World Congress Center, Atlanta, GA.

SPECIAL SOCIETY MEETINGS

(June 14-15)—Joint Meeting of St. Louis and Kansas City Societies for Coatings Technology. Lake of Ozarks, MO.

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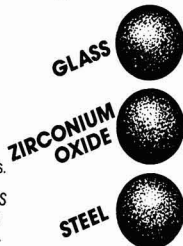
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(June 17)—"Packaging, Labeling, and Warehousing" Conference. Sponsored by the Golden Gate Society Manufacturing Committee. A. Sabella's Restaurant, San Francisco, CA. (Louis Sanguinetti, Chairman, Jasco Chemical Corp., P.O. Drawer J, Mountain View, CA 94042).

(Nov. 5-6)—Symco '85. 15th Annual Chicago Society Coatings Symposium, "The Right Stuff." Knickers Restaurant, Des Plaines, IL. (Lonnie U. Haynes, Chairman, Hercules, Incorporated, 300 E. Schuman Blvd., One Energy Center, Suite 260, Naperville, IL 60540).

1986

(Apr. 2-4)—Southern Society. Annual Meeting. Hilton Hotel, Savannah, GA. (Ronald R. Brown, Union Chemicals Div., P.O. Box 26845, Charlotte, NC 28213).

(Apr. 9-11)—Southwestern Paint Convention of Dallas and Houston Societies. Houston, TX. (Mike Winters, Ribelin Distributors, Inc., 7766 Blankenship, Houston, TX 77055).

1987

(Feb. 23-25)—Western Coatings Societies' Symposium and Show. Monterey Convention Center, Monterey, CA. (Barry Adler, Royell, Inc., 1150 Hamilton Ct., Menlo Park, CA 94025).

OTHER ORGANIZATIONS

(May 20-23)—Steel Structures Painting Council Annual Meeting and Symposium. Netherlands Plaza Hotel, Cincinnati, OH. (Harold Hower, SSPC, 4400 Fifth Ave., Pittsburgh, PA 15213).

(May 20-23)—"Colorimetry—An Intensive Short Course for Industry." Munsell Color Science Laboratory, Rochester Institute of Technology campus, Rochester, NY. (Martha Pschirrer, Munsell Color Science Laboratory, RIT, P.O. Box 9887, Rochester, NY 14623).

(May 20-24)—"Adhesion Principles and Practice for Coatings and Polymer Scientists" Short Course. Kent State University, Kent, OH. (Carl J. Knauss, Chemistry Dept., Kent State University, Kent, OH 44242).

(May 20-24)—"Colloids and Interfaces" Short Course, Carnegie-Mellon University, Pittsburgh, PA. (Frank E. Nowak, Director of Post College Professional Education, Carnegie-Mellon University, Pittsburgh, PA 15213).

(May 28-June 2)—International Surface Finishing and Printed Circuit Board Making Exhibition. Beijing, People's Republic of China. (Sino Trade Promotions, Tak Cheung Building, 22-24 Wing Lok St., Central, Hong Kong).

(June 3-6)—"Colorimetry: An Intensive Short Course for Industry." Munsell Color Science Laboratory, Rochester Institute of Technology campus, Rochester, NY (Martha Pschirrer, Munsell Color Science Laboratory, RIT, P.O. Box 9887, Rochester, NY 14623).

(June 3-7)—"Advances in Emulsion Polymerization and Latex Technology" Short Course. Lehigh University, Bethlehem, PA. (Dr. Mohamed S. El-Aasser, Dept. of Chemical Engineering, Sinclair Lab #7, Lehigh University, Bethlehem, PA 18015).

(June 3-7)—"Applied Rheology for Industrial Chemists" Short Course. Kent State University, Kent, OH. (Carl J. Knauss, Chemistry Dept., Kent State University, Kent, OH 44242).

(June 10-12)—International Conference on Biologically Influenced Corrosion, sponsored by the National Association of Corrosion Engineers, Washington, DC. (Meetings Manager, NACE Headquarters, P.O. Box 218340, Houston, TX 77218).

(June 11-13)—Eastern Plant Engineering & Maintenance Show and Conference. Georgia World Congress Center, Atlanta, GA. (Show Manager, Plant Engineering & Maintenance Shows, 999 Summer St., Stamford, CT 06905).

(June 16-19)—Dry Color Manufacturers' Association. Annual Meeting. The Greenbriar, White Sulphur Springs, WV. (DCMA, 206 N. Washington St., Ste. 202, P.O. Box 931, Alexandria, VA 22313).

(June 26-29)—Oil & Colour Chemists' Association's Biennial Conference. Edinburgh, Scotland. (R.H. Hamblin, OCCA, Priory House, 967 Harrow Rd., Wembley, Middlesex, HA0 2SF England).

(July 4-7)—Oil and Colour Chemists Association Australia. 27th Convention. Hunter Valley, NSW, Australia. (Ted Saultry, 46 Tamarisk Ave., Glen Waverly VK.3150, Australia).

(July 8-12)—11th International Conference on Organic Coatings Science and Technology. Athens, Greece. (Dr. A.V. Patsis, Institute in Materials Science, S.U.N.Y., New Paltz, NY 12561).

(July 15-19)—Short Course on "Corrosion and Its Control by Protective Coatings." Lehigh University, Bethlehem, PA. (Prof. H. Leidheiser, Jr., Sinclair Lab. #7, Lehigh University, Bethlehem, PA 18015).

(Aug. 26-28)—Advanced Colorimetry Course. Munsell Color Science Laboratory, Rochester Institute of Technology campus, Rochester, NY. (Martha Pschirrer, Munsell Color Science Laboratory, RIT, P.O. Box 9887, Rochester, NY 14623).

(Sept. 2-4)—Federation of Scandinavian Paint and Varnish Technologists. 11th Congress. SAS Hotel Scandinavia, Oslo, Norway. (Paal Ivan, Nodest Industries A/S, Boks 500, N-3001 Drammen, Norway).

(Sept. 2-6)—Short Course on "Films and Coatings for Technology." Davos Congress Center, Switzerland. (Continuing Education Institute—Europe, Rörtorpövägen 5, S-612 00 Finspang, Sweden).

(Sept. 9-13)—Short Course on "Nitride and Carbide Coatings." LSRH Research Center, Neuchatel, Switzerland. (Continuing Education Institute—Europe, Rörtorpövägen 5, S-612 00 Finspang, Sweden).

(Sept. 16-19)—Fifth Finishing Conference and Exposition of the Association for Finishing Processes of the Society of Manufacturing Engineers. Cobo Hall, Detroit, MI. (Public Relations Dept., AFP/SME, One SME Dr., P.O. Box 930, Dearborn, MI 48121).

(Sept. 17-19)—FINISHING '85. Cobo Hall, Detroit, MI. (AFP/SME, P.O. Box 930, Dearborn, MI 48128).

(Sept. 21-24)—Canadian Paint and Coatings Assn. 73rd Annual Convention. Cleavelands House, Minnett, Ont. (CPCA, 515 St. Catherine St. W., Montreal, Que., Canada H3B 1B4).

(Oct. 8-11)—XVIIth Congress of AFTPV (French Assn. of Paint and Varnish Technicians), Strasbourg, France. (Congress Secretary, B.P. 1036, 68050 Mulhouse Cedex, France).

(Oct. 14-18)—European Conference on Applications of Surface and Interface Analysis. Veldhoven, The Netherlands. (ECASIA Conference Bureau: QLT Convention Services, Keizersgracht 792, 1017 EC Amsterdam, The Netherlands).

(Nov. 4-6)—National Paint and Coatings Association. 98th Annual Meeting. Hilton Hotel, New Orleans, LA. (Karen Bradley, NPCA, 1500 Rhode Island Ave. N.W., Washington, DC 20005).

(Nov. 6-8)—National Coil Coaters Association Fall Technical Meeting. Hyatt Regency Dearborn, Dearborn, MI. (Tony Carroll, NCCA, 1900 Arch St., Philadelphia, PA 19103).

(Nov. 15-17)—38th National Decorating Products Association Show. McCormick Place, Chicago, IL. (Lillian Smysor, NDPA, 1050 N. Lindbergh Blvd., St. Louis, MO 63132).

(Apr. 14-15)—ASTM Symposium on "Testing of Metallic and Inorganic Coatings," Chicago, IL. (Teri Carroll, ASTM Standards Development Div., 1916 Race St., Philadelphia, PA 19103).

(Sept. 8-13)—190th National Meeting. American Chemical Society. Chicago, IL. (ACS, A.T. Winstead, 1155 16th St., N.W., Washington, D.C. 20036).

(Sept. 9-11)—RadCure '86—Association for Finishing Processes of the Society of Manufacturing Engineers Conference and Exposition. Baltimore Convention Center, Baltimore, MD. (AFP/SME Public Relations, Society of Manufacturing Engineers, One SME Dr., Dearborn, MI 48121).

(Sept. 21-26)—XVIIIth Congress of FATIPEC. (Federation of Associations of Technicians in the Paint, Varnish, and Printing Ink Industries of Continental Europe). Venice, Italy. (C. Bourgerie, Secretary General of FATIPEC, 76 Blvd. Pereire, 75017 Paris, France - or - Amleto Poluzzi, AITIVA, Piazzale R. Morandi 2, 20121 Milano, Italy).

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'Humbug' from Hillman

From "Datamation" magazine, Maureen Lein sends us several resumé goofs prepared by Robert Half, who should know whereof he speaks. Half claims that these are from his voluminous office files. They give me a better insight as to why there is so much unemployment.

- Please call me after 5:30 P.M. because I am self-employed and my employer does not know I am looking for another job."
- From an anxious job seeking bookkeeper, "I am very conscientious and accurate."
- I was proud to win the Gregg Typing Award."
- From a frank financial analyst, "I am impatient with quibbling over minor minor details. I am stubborn on matters of principle and major objectives. I dislike routine thinking, unnecessary jobs, inefficient systems, and Republicans."—How come he had to look for a job?
- "Will locate anywhere—except Russia, Red China, Vietnam, or New York City."
—Would you call this person a liberal?
- Reason for leaving last job.—"No special reason."
- "I am also a notary republic."

• • •

Speaking of jobs, we've heard from Joe Boatwright's sister, Betty, recently, who waxes poetic about HER job:

My Job

I'm not allowed to run the train
The whistle I can't blow
I'm not allowed to say how fast
The railroad train can go
I'm not allowed to shoot off steam
Nor even clang the bell
But let the damned train jump the track
And see who catches Hell!

Joe and Betty also sent us a clip from the Rockford, IL Register. Here are some of the quotes from, "It was so cold that—"

- I let my dog out and I had to break him loose from the tree.
- You could freeze an egg on the sidewalk.
- We opened the refrigerator to heat the house.
- I saw a 32nd degree Mason and he was down to 15.

• • •

When Dick Kiefer graduated from good old Drexel U, his engineering prof gave him a copy of the ten commandments, listed below, which were prepared by Paul Entrikin of Esso Standard in 1948. Since Dick has often been seen wandering around with a lantern in his hand, I wonder if he ever got past the first.

Ten Commandments for Technical Men

- I. Thou shalt not follow in the dust of progressing operations but shalt run ahead with a lantern in thy hand to reveal the way.
- II. Thou shalt seek and respect the opinions of operators, even unto the third helpers, for theirs is a wisdom unknown to technocrats.
- III. Thou shalt determine what should be done and do it without the necessity of others holding thy hand.
- IV. Thou shalt not be too dignified to shoot the bull; neither shalt thou shoot it entirely, for so is its productivity destroyed.
- V. Thou shalt not forsake the ways of thy technical training so that to thee CH₂O cease to be formaldehyde and become sea water.
- VI. Thou shalt not take thy grievances and ideas first to the top, lest the bottom remove its support from under thee, saying, "We knew nothing of it."
- VII. Thou shalt remember that refining processes change not because of reasoning and meditation, however profound, but only by the turning of valve.
- VIII. Thou shalt study thy conclusions from all sides through many viewpoints, for verily, undiscovered claws may rip thy rear.
- IX. Thou shalt strive to make thy judgment as good as any man's by experimenting, observing, recording, calculating, studying, and thinking; and having done so,
- X. Thou shalt use it.

• • •

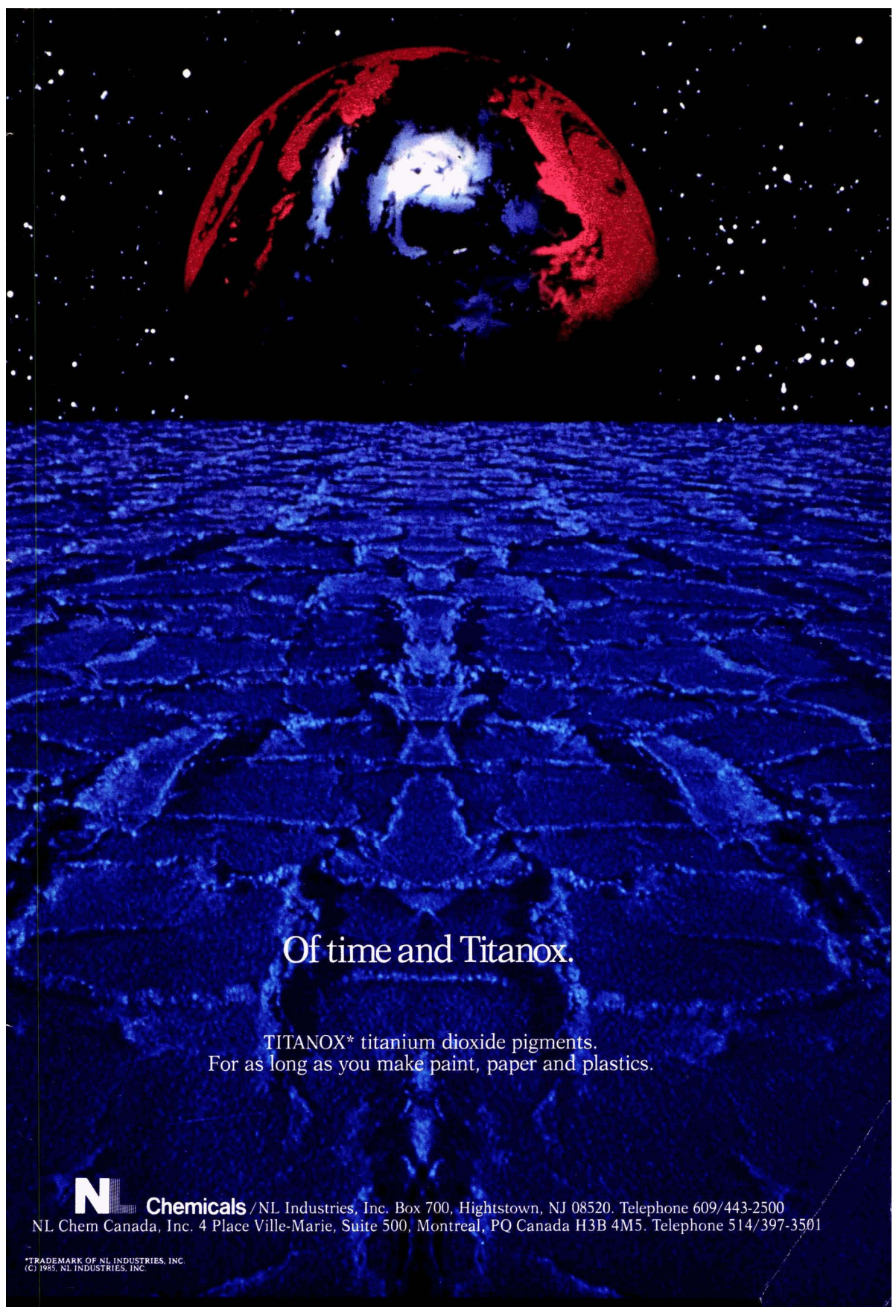
When the floor nurse at the hospital answered the phone, a voice at the other end asked, "Can you tell me how Mr. Donovan is getting along?"

"He's doing splendidly," she answered enthusiastically. "I believe he'll be going home tomorrow. Who shall I say called?"

"This is Donovan. No one tells me a thing around here."

The Lion

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*from the Greek TRIBEIN - 'to rub or wear'

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