

November 1991


ict JOURNAL OF
COATINGS
TECHNOLOGY

***Electrochemical Methods for
Appraising Corrosion Protective Coatings***

***1990 Joseph J. Mattiello
Memorial Lecture***



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THE JOURNAL OF COATINGS TECHNOLOGY (ISSN 0361-8773) is published monthly by the Federation of Societies for Coatings Technology, 492 Norristown Rd., Blue Bell, PA 19422. Phone: (215) 940-0777. Second class postage paid at Blue Bell, PA and at additional mailing offices. POSTMASTER: Send address changes to JOURNAL OF COATINGS TECHNOLOGY, 492 Norristown Rd., Blue Bell, PA 19422. Subscriptions: U.S. and Canada—1 year, \$30; 2 years, \$57; 3 years, \$82. Europe (Air Mail)—1 year, \$60; 2 years, \$117; 3 years \$172. Other Countries—1 year, \$45; 2 years, \$87; 3 years, \$127.

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The JOURNAL OF COATINGS TECHNOLOGY is published monthly by the Federation of Societies for Coatings Technology for its membership of approximately 7,300 in 26 Constituent Societies in the United States, Canada, Great Britain, and Mexico. The JOURNAL is devoted to the advancement of knowledge in the science and technology of surface coatings, the materials comprising such coatings, and their use and performance.

The Editors invite submission of original research papers, review papers, and papers under the special headings *Open Forum* and *Back to Basics*, as well as *Letters to the Editor*. All manuscripts will be assumed to be previously unpublished writing of the authors, not under consideration for publication elsewhere. When review papers contain tables or graphs from copyrighted articles, the authors will be required to obtain permission for use from the copyright holders. When the organization with which the authors are affiliated requires clearance of publications, authors are expected to obtain such clearance before submission of the manuscript. Papers presented to associations other than the Federation must be released by written communication before they can be considered for publication in the JOURNAL OF COATINGS TECHNOLOGY. Authors are obligated to reveal any exceptions to these conditions at the time a manuscript is submitted.

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Papers in which proprietary products or processes are promoted for commercial purposes are specifically nonacceptable for publication.

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Four complete copies should be sent to the Editor, JOURNAL OF COATINGS TECHNOLOGY, 492 Norristown Rd., Blue Bell, PA 19422-2350. The cover letter should address copyright, clearance, and release issues discussed above and should specify paper category: *Original Research*, *Reviews*, *Open Forum*, or *Back to Basics*.

Letters to the Editor: The JOURNAL will consider for publication all correspondence relevant to the coatings industry and to the contents of the JOURNAL. When a letter concerns an article appearing in the JOURNAL, the original author is usually given an opportunity to reply.

... by Constituent Societies For Annual Meeting Presentation

Ten complete copies of the manuscript are required for committee review. The set of copies should be addressed to the Editor at the address listed previously.

... for Roon Foundation Award Competition

Ten complete copies of the manuscript are required, and should be submitted to the Chairman of the 1991 Roon Awards Committee, George R. Pilcher, Akzo Coatings, Inc., P.O. Box 147, Columbus, OH 43216. (For complete details, see "Roon Awards" section of the JOURNAL in January 1991 issue.)

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In general, authors are advised to use the "Handbook for Authors" published by the American Chemical Society as a guide to the preparation of manuscripts (ACS, 1155 Sixteenth St., Washington, D.C. 20036). Another excellent reference work is "How to Write and Publish a Scientific Paper," by Robert A. Day (ISI Press, 3501 Market St., University City Science Center, Philadelphia, PA 19104).

Authors are encouraged to consider submissions in several categories and to prepare their manuscripts accordingly. The categories are:

Original Research Papers: The main technical content of the JOURNAL OF COATINGS TECHNOLOGY will continue to be original research papers. Editors support the trend in scientific writing to a direct, less formal style that permits limited use of personal pronouns to avoid repetitious or awkward use of passive voice.

Review Papers: Papers that organize and compare data from numerous sources to provide new insights and unified concepts are solicited. Reviews that show how advances from other fields can beneficially be applied to coatings are also desired. Reviews that consist mainly of computer searches with little attempt to integrate or critically evaluate are not solicited.

Open Forum: Topics for this category may be nontechnical in nature, dealing with any aspect of the coatings industry. The subject may be approached informally. Editors encourage submission of manuscripts that constructively address industry problems and their solutions.

Back to Basics: Papers that provide useful guides to Federation members in carrying out their work are solicited. Topics in this category are technical but focus on the "how to" of coatings technology. Useful calculations for coatings formulation and procedures that make a paint test more reproducible are examples of suitable topics. Process and production topics, i.e., paint manufacture, will also be reviewed in the *Back to Basics* category.

If a submitted paper consists of the text of a presentation made previously to a monthly or special meeting of a Society for Coatings Technology, or to another technical group, the name of the organization and the date of the presentation should be given. If someone other than the author of the paper made the presentation, this information, too, should be noted. Papers originally composed for oral presentation will have to be revised or rewritten by the author to conform to the style described in this guide.

Manuscripts should be typed with double spacing on one side of 8 1/2 x 11 inch (22 x 28 cm) paper, with at least one-inch (2.5 cm) margins on all four sides. All paragraphs should be indented five spaces, and all pages should be numbered at the top center, or upper right corner.

Title

The title should be as brief and informative as possible. Selection of titles that are key word-indexable is a helpful and recommended practice.

Authors' Biographies and Photographs

Give complete names, company or institutional affiliations, and brief biographical sketches of all authors. If available, submit a 5 x 7 inch (13 x 18 cm) black-and-white photograph with glossy or smooth high sheen surface, for each author. See later section on photographs for further details.

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A 75-100 word abstract must be part of the manuscript, and should be a concise description of the key findings or teachings of the work described in the paper. The abstract should not repeat the title or include reference numbers, nor should it duplicate the Conclusion or Summary.

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Main headings and sub-headings should be used to improve readability, and to break up typographical monotony. The text should *not* be presented as an alphanumeric outline.

The main headings usually should be INTRODUCTION, EXPERIMENTAL, RESULTS AND DISCUSSION, and SUMMARY or CONCLUSIONS. Sub-headings will be specific to the subject.

Only as much review as is necessary should be given to provide an introduction to the subject; the main burden for extensive background should be placed on the list of references.

Standard scientific and technical terminology should be used to convey clear and unambiguous meaning, but the use of technical jargon or slang should be avoided. Authors should bear in mind that the JOURNAL has an international audience, for many of whom English is a second, not native, language. Use of regional idioms or colloquialisms should be avoided. The use of obscure abbreviations is also discouraged. When appropriate, abbreviations should be made in parenthesis immediately following first mention of the term in the text, and then used alone whenever necessary.

Recent issues of the JOURNAL should be consulted for desired style and technical level.

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Metric system units should be used wherever applicable with the equivalent English units shown afterwards in parentheses. The ASTM Metric Practice Guide, E 380-72 (American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103) is a convenient reference.

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Equations must be typed, or written clearly, with equations numbered sequentially in parentheses to the right. If Greek letters are used, write out their names in the manuscript margin at the first point of use. Place superscripts^a and subscripts_b accurately. Avoid the use of superscripts in a manner that can lead to their interpretation as exponents.

Summary

The paper should be concluded with a summary which is intelligible without reference to the main text. The summary may be more complete than the abstract, listing conclusions drawn from the text. A well written summary can serve to inspire the busy reader to turn back to the paper, to read it thoroughly.

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If used, it should follow the summary.

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These should be listed in the numerical order in which they are cited in the text, and should be placed at the end of the manuscript. Names of authors may or may not be shown in the text with reference numbers. If possible, include titles of articles referenced in the literature. The following are examples of acceptable reference citations for periodicals,^{1,2,3} books,⁴ and patents.⁵

- (1) Pascal, R.H. and Reig, F.L., "Pigment Colors and Surfactant Selection," *Official DIGEST*, 36, No. 475 (Part 1), 839 (1964).
- (2) Davidson, H.R., "Use and Misuse of Computers in Color Control," *JOURNAL OF COATINGS TECHNOLOGY*, 54, No. 691, 55 (1982).
- (3) Stephen, H.G., "Hydrogen Bonding—Key to Dispersion?," *J. Oil & Colour Chemists' Assoc.*, 65, No. 5, 191 (1982).
- (4) Patton, T. (Ed.), "Pigment Handbook," Vol. 1, John Wiley & Sons, Inc., New York, 1973.
- (5) Henderson, W.A. Jr. and Singh, B. (to American Cyanamid Co.), U.S. Patent 4,361,518 (Nov. 30, 1982).

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Annual dues for Active and Associate Members of the Federation of Societies for Coatings Technology is \$20.00. Of this amount, \$13.50 is allocated to a membership subscription to this publication. Membership in the Federation is obtained through prior affiliation with, and payment of dues to, one of its 26 Constituent Societies. Non-member subscription rates are:

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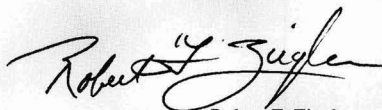
For Future Reference

The recent Annual Meetings of FSCT, in Toronto, and NPCA, in San Francisco, indicate that both technical and management personnel are dealing head on with the concerns facing the industry. The programs presented at the events spanned more than the continent; they addressed the increasingly international nature of the industry and the obvious challenges of today's business climate and the opportunities available in tomorrow's global market.

Formulation alternatives, management and marketing strategies, and the push to produce quality, environmentally acceptable coatings are topics which affect every aspect of the industry. Coatings manufacturers, from the largest to the smallest, both international and regional, as well as suppliers of raw materials, production equipment and instruments, found the meetings informative and their attendance critical to their success.

Although recessionary pressures have taken their toll on budgets, companies which passed up attending these meetings in order to save a few dollars may have done themselves a disservice. The knowledge gained by personally attending the meetings, interacting with peers and colleagues, and visiting with supplier companies is an asset of inestimable potential value, and irreproducible beyond those three days in Toronto and San Francisco.

The industry's trade associations, FSCT and NPCA, provide critical services in both technical education and legislative representation. For those who missed the 1991 events, please take note—the 1992 annual conventions of the groups will take place in Chicago, October 19-21 (NPCA) and 21-23 (FSCT). It may be wise to circle these dates on your calendar now.



Robert F. Ziegler
Executive Vice President

Abstracts of Papers in This Issue

ELECTROCHEMICAL METHODS FOR APPRAISING CORROSION PROTECTIVE COATINGS—H. Leidheiser, Jr.

Journal of Coatings Technology, 63, No. 802, 20 (Nov. 1991)

The author's experience with the application of eight electrochemical techniques for the study of corrosion protective polymeric coatings is summarized. The techniques include: corrosion potential, DC resistance, AC impedance at room temperature, AC impedance as a function of temperature, current flowing through the coating at high potential, repetitive cathodic polarization, cathodic delamination, and current/time measurements.

CHANGES IN HIDING DURING LATEX FILM FORMATION: PART II. PARTICLE SIZE AND PIGMENT PACKING EFFECTS—Cleveland Society for Coatings Technology Technical Committee

Journal of Coatings Technology, 63, No. 802, 35 (Nov. 1991)

Several latex paints were prepared to study pigment particle size and packing effects. Each paint contained varying ratios of fine to coarse particle size extenders at different pigment volume concentrations (PVC). Using a technique previously reported, changes in hiding were monitored during the drying process and reflectance data acquired for these paints. The reflectance (Y) of each paint, drawn down over a black substrate, was measured as a function of drying time using the long-term drift test of a computer-interfaced spectrophotometer. Using blends containing varying ratios of large to fine extender pigments at constant PVC, changes in hiding due to extender dilution effects could be determined and compared to proposed models offered by other researchers. Additionally, critical pigment volume concentration (CPVC) information for each PVC ladder could be obtained by inspection, with accuracy exceeding that of other classical methods; the presence or absence of a minimum in the drying curves indicating whether a paint is above or below CPVC. In earlier work, correlations of CPVC determined by this method compared to methods using standard dry film properties (contrast ratio, porosity, rewet with mineral oil, etc.) were very good and actually demonstrated the greater sensitivity of this technique. Changes in the reduced PVC, Λ (where $\Lambda = \text{PVC}/\text{CPVC}$), which occur as the ratio of course to fine extender varies from blend to blend, were also apparent.

COUPLING SOLVENT EFFECTS ON WATER-REDUCIBLE ALKYD RESINS—R.G. Vance, N.H. Morris, and C.M. Olson

Journal of Coatings Technology, 63, No. 802, 47 (Nov. 1991)

This research examined the coupling ability of various solvents, primarily glycol ethers, and the effect of glycol ether solvents on the stability of water-reducible alkyd resins. Perceived toxicity concerns with ethylene glycol *n*-butyl ether, EB, an ethylene-based (referred to as E-Series) glycol ether, have resulted in requests for propylene-based (P-Series) glycol ether alternatives.

This study characterized the effects of alternative solvents to EB on two alkyd resin systems. An accelerated aging study was employed to determine solvent performance in these alkyd systems.

It was determined that coupling performance data can be used as a predictive tool for determining initial viscosity of these alkyd systems. Data from the aging study demonstrated that P-Series glycol ethers and blends of P-Series and C4 alcohols exhibit equivalent behavior to EB with respect to stability of the resin system.

VISCOELASTIC AND ADHESION PROPERTIES OF AIR-DRYING COATING FILMS—K. Horiuchi and K. Sato

Journal of Coatings Technology, 63, No. 802, 55 (Nov. 1991)

Temperature dependencies of dynamic viscoelasticity and peel strength of commercial air-drying coating films and experimental nitrocellulose (NC)/alkyd lacquers were measured. Moreover, the correlations between the surface tension of a plastic substrate, on which a coating film was brushed, and the adhesion of the coating film to the plastic substrate, were also studied. All the results are summarized as follows:

(1) The dynamic viscoelasticity of a commercial air-drying coating film at temperatures above the glass transition temperature (T_g) showed a plateau elastic modulus ranging from 10^9 dyne/cm² to 10^7 dyne/cm², which corresponds from highly-crosslinked to low-crosslinked structures, respectively. Noncrosslinked type coating films, like NC lacquers, flow at a higher temperature than their T_g .

(2) Temperature dependencies of the peel strengths of air-drying type coating films showed bell-shape curves, independent of the structures of the coating films. The temperature where the peel strength is maximum is characteristic to the coating film.

(3) Correlations between the surface tensions of plastic substrates and peel strengths of the coating films showed bell-shape curves having a maximum peel strength at a certain surface tension.

Resúmenes de Artículos en este Número

MÉTODOS ELECTROQUÍMICOS PARA LA EVALUACION DE LA CALIDAD EN LOS RECUBRIMIENTOS ANTI-CORROSIVOS—H. Leidheiser, Jr.

Journal of Coatings Technology, 63, No. 802, 20 (Nov. 1991)

Se menciona la experiencia del autor al aplicar ocho técnicas electroquímicas para el estudio de recubrimientos poliméricos anticorrosivos. Las técnicas incluyen: potencial de corrosión, resistencia DC, impedancia AC a la temperatura ambiente, impedancia AC como una función de la temperatura, flujo de corriente a través del recubrimiento a un potencial alto, polarización catódica respectiva, delaminación catódica y mediciones corriente/tiempo.

CAMBIOS EN EL PODER CUBRIENTE DURANTE LA FORMACION DE UNA PELICULA DE LATEX: PARTE II. EFECTOS DEL TAMAÑO DE PARTICULA Y EMPAQUETAMIENTO DEL PIGMENTO—Cleveland Society for Coatings Technology Technical Committee

Journal of Coatings Technology, 63, No. 802, 35 (Nov. 1991)

Se prepararon algunas pinturas base latex para estudiar los efectos del tamaño de partícula y empaquetamiento del pigmento. Cada pintura contenía varias relaciones de extendedores de tamaños de partícula fino y gruesos a diferentes concentraciones de pigmento en volumen (PVC). Utilizando una técnica previamente reportada, se monitorearon los cambios en el poder cubriente durante el proceso de secado a la vez de obtener los datos de reflectancia para estas pinturas. La reflectancia (Y) de cada pintura, aplicada sobre un sustrato negro, se midió como una función del tiempo de secado usando una prueba de larga exposición en un espectrofotómetro conectado a una computadora. De esta forma, los cambios en el poder cubriente debidos a una delución por el extendedor se pudieron determinar y comparar con modelos propuestos y ofrecidos por otros investigadores. Este método también proporcionó información para valores críticos de PVC (CPVC) en toda la escala de valores del PVC. La presencia o ausencia de un mínimo en las curvas de secado indican, en el caso de que así sea, que una pintura esta por arriba o abajo del CPVC. Las correlaciones de CPVC determinadas por este método comparado con otros métodos que usaron propiedades estandar de película seca (relación de contraste, porosidad, rehumectación con aceite mineral, etc.) fueron muy buenas demostrando la alta sensibilidad de la técnica. Los cambios en el CPVC reducido (D), donde $D = \text{PVC}/\text{CPVC}$, ocurren cuando la relación de extendedor fino a grueso varía de mezcla a mezcla, siendo esto también aparente.

EFECTOS DE LOS SOLVENTES DE ACOPLA EN RESINAS ALQUIDALICAS REDUCIBLES CON AGUA—R.G. Vance, N.H. Morris, and C.M. Olson

Journal of Coatings Technology, 63, No. 802, 47 (Nov. 1991)

Esta investigación examina la habilidad de acoplamiento de varios solventes, principalmente glicoleteres, y el efecto de estos solventes sobre la estabilidad de resinas alquidálicas

reducibles con agua. La toxicidad concerniente al Eter n-butílico del etilen glicol, EB, y a los glicoleteres del etilen glicol (referido a la serie E), han generado un requerimiento de búsqueda de alternativas de sustitución por glicoleteres del propilen glicol (serie P).

Este estudio caracterizó los efectos de los solventes alternos del EB en dos sistemas de resina alquidálica. Se empleo un estudio de envejecimiento acelerado para determinar el comportamiento del solvente en estos sistemas alquidálicos.

Se determinó que los datos del comportamiento de acoplamiento pueden ser usados como una herramienta de predicción para determinar la viscosidad inicial de estos sistemas alquidálicos.

Los datos proporcionados por el estudio de envejecimiento demostraron que los glicoleteres de la serie-P y las mezclas de la serie P con alcoholes C4 muestran un comportamiento equivalente al EB con respecto a la estabilidad del sistema resinoso.

PROPIEDADES VISCOELASTICAS Y DE ADHESION EN PELICULAS DE RECUBRIMIENTO DE SECADO AL AIRE—K. Horiuchi and S. Sato

Journal of Coatings Technology, 63, No. 802, 55 (Nov. 1991)

Se midió la dependencia de la temperatura con respecto a la viscoelasticidad dinámica y la resistencia al pelado en películas de recubrimientos comerciales de secado al aire y lacas de nitrocelulosa/alquidálica. Más aún, se estudio también la correlación entre la tensión superficial del sustrato plástico en donde la película de recubrimiento fue aplicada y la adhesión de la misma al sustrato descrito. Todos los resultados se resumen como sigue:

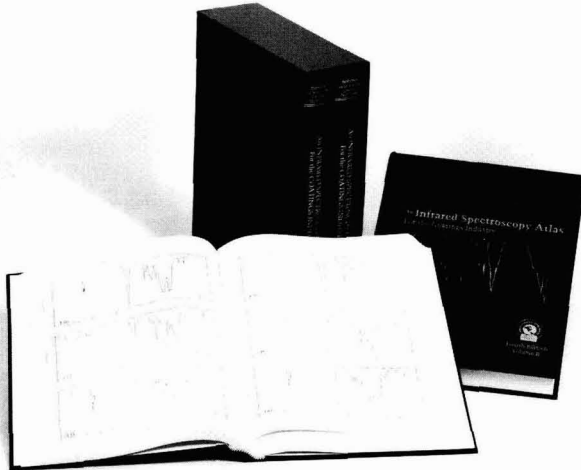
(1) La viscoelasticidad dinámica de una película secada al aire de un recubrimiento comercial a temperaturas por arriba de la temperatura de transición vítrea, mostró una variación en los rangos del modulo de elasticidad de 10^9 dinas/cm² a 10^7 dinas/cm² que corresponden a estructuras que tienen una alta reticulación y a las que tienen baja reticulación respectivamente. Las películas de recubrimiento del tipo no reticuladas como las lacas de nitrocelulosa, fluyen a una temperatura más alta que su temperatura de transición vítrea.

(2) La dependencia de la temperatura con respecto a la resistencia al pelado de las películas de recubrimiento secadas al aire, es un parámetro independiente de las estructuras de las películas. La temperatura a la cual la resistencia al pelado es un máximo, es un característica de la película de recubrimiento.

(3) Las correlaciones entre la tensión superficial del sustrato plástico y la resistencia al pelado de la película de recubrimiento muestran curvas en forma de campana, teniendo la resistencia a máxima al pelado a una cierta tensión superficial.

Translations made by Ing. Carlos Urbina V., of Instituto Mexicano de Técnicos en Pinturas y Tintas, Mexico

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Committee Activities



Baltimore Hosts FSCT Educational Steering Committee Meeting with Society Educational Committee Chairmen

Representatives of Society Educational Committees met recently with members of the Federation's Educational Steering Committee in Baltimore, MD. Topics of discussion included: Society-sponsored educational activities; the Federation educational structure; scholarship programs of the Federation and individual Societies; what is important to Society educational programs, and how the Federation can help; and a session on brainstorming recommendations.

The meeting was chaired by Don Boyd, of the Pittsburgh Society, Chairman of the FSCT Educational Steering Committee.

In addition to the Chairman, the following Steering Committee members attended: Ted Fuhs (Chicago); John Gordon (Los Angeles); Carl Knauss (Cleveland); Sid Lauren (New England); Gerry Mattson (Southern); and John Oates (New York).

The following Society Educational Committee representatives attended: Albert Holder (Baltimore); DeVilla Moncrief (Cleveland); Dan Melnyk (Detroit); William Porter (Kansas City); Eduardo Villegas (Mexico); Bruce Bridges (Montreal); Don Brody (New York); Mustapha Bacchus (Northwestern); Dave Pasin (Pacific Northwest); Jim Bohannon (Piedmont); Mark Harley (Pittsburgh); Jim Lindsley (St. Louis); Robert Wayne West (Southern); and A. Clarke Boyce (Toronto).

Guests attending were: FSCT Secretary-Treasurer Colin Penny (Baltimore); and Gary Morgereth, President of the Baltimore Society.

Also attending were the following FSCT staff members: Pat Viola, Editor of JOURNAL OF COATINGS TECHNOLOGY; Mike Bell, Director of Educational Services; and Tom Kocis, Director of Field Services.

Society Reports on Activities

Society representatives had been requested to prepare brief summaries of their educational activities for presentation at the meeting. The following summarizes the written and/or verbal reports submitted and discussed.

Baltimore

Continuing scholarship program; awarded grants to two children of Society

members . . . Distributed notices to six institutions of higher learning in the Baltimore area, promoting A. L. Hendry Award competition . . . Arranged a speaker for the Society monthly meeting in February . . . Presented the Federation videotape, "The Choice," at two area high schools on their respective Career Days; also presented the videotape at U.S. Navy's David Taylor Research Center, so that personnel there could inform summer co-op students of career opportunities in the coatings industry . . . Continued sponsorship of basic and intermediate paint and coatings technology course at Catonsville Community College; planning to present again this fall.

CDIC

Primary activity continues to be arranging for post-dinner speakers at Society monthly meetings, which feature two speakers; pre-dinner presentation deals with technical aspect of coatings; after-dinner speaker focuses on topics of general interest. Recent meetings have included presentations on: whole house inspections; regulations concerning hazardous waste disposal; investment and tax strategies for the 90s; and technology transfer . . . Established educational grant, to fund tuition expense of selected member to attend coatings short course.

Chicago

Educational activities jointly sponsored with local Paint and Coatings Association . . . Held one-day management development seminar, "Increasing Productivity Through Employee Development and Motivation." . . . Continuing scholarships/grants-in-aid to students enrolled in polymer and coatings technology programs at selected colleges; have increased both amount and number awarded . . . Planning SYMCO seminar in early '92; this is two-day event: first day deals with trade sales, second day with industrials . . . Coatings Advisory Council assists Elmhurst College in student/teacher recruiting efforts, acquisition of equipment, and providing industry liaison.

Cleveland

Again participated in Northeast Ohio Science Fair, awarding cash prizes to top

projects related to coatings . . . Made presentations at two area high schools, with lectures on coatings careers supplemented by Federation videotape, "The Choice" . . . Assisted in local Explorer Scout program, which is designed to inform high school students of career opportunities; program consisted of five monthly meetings, each held at a coatings-related facility . . . Primary activity continues to be development of annual Advances in Coatings Technology Conference. This year's event, held June 6 at the B. F. Goodrich Research Center, focused on advances in additive technology for water-base, high-solids, and powder coatings.

Detroit

Continuing sponsorship of evening coatings courses at University of Detroit. Offerings expanded to include newly introduced course on environmental chemistry; CEU certificates issued to those successfully completing courses . . . In conjunction with Technical Committee, jointly sponsored a coatings technology workshop as part of Materials Week, as well as programming for a conference on advanced coatings technology for the automotive and durable goods manufacturing industries . . . Held annual FOCUS conference in April; theme of this year's event was "Complying with the DNR While Remaining Solvent," and featured presentations on compliant solvents, reactive diluents, waterborne coatings, powder coatings, and transfer efficiency . . . Continuing to maintain close liaison with Eastern Michigan University, Wayne State University, and University of Detroit; discussing expansion of curriculum at University of Detroit which would lead to degree program there . . . Pursuing discussions on proposed establishment of Society student chapter at Eastern Michigan University . . . Continuing funding for scholarship program.

Houston

Efforts concentrated on administering and broadening scholarship program, which this year provided funds for six students . . . Assisting Technical Committee in preparation of paper for presentation at Annual Meeting in Toronto . . . Arranged for speaker at first Society meeting this fall—a young-

ster who won first prize in Houston Science Fair for development of a new varnish.

Kansas City

Principal activity continues to be participation in local Science Fair, judging entries, and awarding prizes. Each of three winning students receive savings bonds (their high school science department receives check in matching amount); presentations are made at Society monthly meeting, at which winning exhibits are displayed (parents and teachers also attend) . . . Scholarship funding again contributed to University of Missouri-Rolla.

Los Angeles

Scholarship program provided funds for 21 students. Four of the recipients are students enrolled in the newly established polymers and coatings program at California Polytechnic State University (Cal Poly) at San Luis Obispo . . . Assisted in establishment of foundation to raise funds, materials, and equipment for the Cal Poly program; also hosted Cal Poly students and professors at West Coast Coatings Societies' Symposium and Show in San Francisco, and placed 14 students in summer internship programs . . . Sponsorship of evening

coatings course continues; students receive certificates for successful completion of course . . . Several programs being considered: (1) Expansion of polymers and coatings concentration to include another university (e.g., Cal Poly Pomona); (2) Offer course for store personnel and sales people to better acquaint them with coatings; (3) Develop for presentation a summer survey course on the South Coast Air Quality Management District paint emission regulations, environmental impact the rules have had over a 25-year period, and an assessment of the regulations benefit/cost ratio.

Louisville

Sponsorship of coatings courses at University of Louisville continues. The fundamentals of coatings are covered in four semesters; current year offered modules II and III, on non-resinous raw materials and end-uses and formulation; courses are designed to be complementary, but can be taken independently . . . Topic of annual symposium was "Hazardous Waste Reduction."

Mexico

Presented two-day seminar on "Leadership for the 90s Decade" in February . . . Sponsored course on "Resins for Coatings,"

presented by Steering Committee member Paul Baukema, which attracted 60 attendees . . . Annual technical symposium will be held August 22-24; program to include international speakers . . . Presented FSCT videotape, "The Choice," to students enrolled in the polymers program at the University of Guadalajara, and invited their participation in the A.L. Hendry Award competition.

Montreal

Sponsorship of introductory course on coatings technology continues; students are awarded certificates for successful course completion . . . Participated in regional science fair, awarding certificates of merit and cash awards to students with best coatings-related exhibits; presentations made at Society monthly meeting.

New England

Close liaison continues to be maintained with University of Lowell, in support of the coatings and adhesives program. Society member will present a new course there on color science and technology; Society will also advise on selection of equipment for setting up coatings lab . . . Scholarship

Problems.

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From inadequately dispersed antifoam.

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From surface tension variations during drying.

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From a contaminated surface.

CREEPING AND CRAWLING

From too high a coating surface tension.

funding was provided to five college students enrolled in coatings-related programs.

New York

Continuing joint sponsorship (with local Paint and Coatings Association) of coatings technology curriculum, consisting of four courses given in successive semesters over a two-year period. Held at Fairleigh Dickinson University, each one-year (two semester) module of the program is a complete course in itself and may be taken independently; each semester qualifies for three CEU's of credit . . . Assisted in developing schedule of presentations on various regulatory and quality control topics at sessions held prior to Society monthly meetings . . . Continuing scholarship funding program . . . Teaching outline being developed for a formal coatings curriculum, as part of efforts to establish a Coatings Center at local university . . . Planning production of A/V material on lab procedures and test methods to supplement lecture course; also, might be basis for development of a laboratory course.

Northwestern

Annual Spring Symposium had as its theme, "Coatings—A Global Perspective," and featured presentations on waste man-

agement, growth trends for industrial coatings, and changes in polyurethane technology . . . Education Night was highlighted by attendance of 20 students and coordinators from area colleges; speaker was Dr. Gordon Bierwagen, Polymers and Coatings Dept., North Dakota State University . . . Continuing to maintain close relationship with NDSU, and funding scholarship program there . . . Among plans for expanding current activities are developing summer internships with local coatings firms, and exploring potential for joint research projects with local academia.

Pacific Northwest

Continuing scholarship program . . . Annual symposium held this year in Vancouver; theme was "Environmentally Friendly Coatings Options" . . . Portland Section sponsored new introductory course, which is to be offered in alternating years; considering development of advanced course, which would feature guest speakers and "hands-on" lab work . . . Vancouver Section sponsored high school Career Day program, attended by area students. Continued sponsorship of introductory coatings course; updating curriculum of advanced course . . . Planning development of a career

promotion video, augmented by literature and display materials to assist in presentation to student groups . . . Seattle Section reorganizing activities; hope to reinstate introductory coatings course within the next year.

Piedmont

Continuing to maintain close relationship with University of North Carolina at Greensboro; participated in Career Day there, informing students of opportunities in the coatings industry . . . Scholarship program, now in its second year, continues.

Pittsburgh

Participated in area high school Science Fair, judging the competition and funding a cash award . . . Visited several high schools to present the videotape, "The Choice," supplemented by a lecture, products display, and open forum . . . Planning financial aid program to assist prospective students wishing to pursue studies in coatings technology.

St. Louis

Close relationship with University of Missouri-Rolla continues to be maintained.

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Awarded grants to five employees of local companies to attend short courses at University of Missouri-Rolla. Recipients were chosen on basis of brief essays describing how they would benefit by attending course of their selection . . . Sponsored annual Education Night in March, with 29 high school teachers and students attending; local high school chemistry teacher was featured speaker, and described cooperative program between his school and local industry . . . Donated funds to University of Missouri-Rolla Chemistry Department to support research in flash rusting . . . Continuing funding of scholarship program at University of Missouri-Rolla . . . Planning to participate in area Science Fair by sponsoring projects and providing funds for awards . . . At next Education Night, plan to have tabletop displays featuring products manufactured and/or coated by area firms.

Southern

Continuing sponsorship of A. L. Hendry Award for best undergraduate student-authored paper on some aspect of coatings technology . . . Continuing to offer one-day technical seminars on various topics at Society Sections . . . Offering matching funds to each Section that contributes funds to scholarship program . . . Developed program for Society Annual Meeting; theme was "Surviving and Prospering in the 90s," and featured special seminars on trade sales coatings and industrial coatings . . . Continuing close relationship with University of Southern Mississippi through funding scholarship program and jointly sponsoring annual Waterborne, Higher Solids and Powder Coatings Symposium; also donated proceeds from Annual Meeting to USM's Polymer Science Department.

Toronto

Close liaison maintained with George Brown College, where sponsorship of basic and advanced coatings course continues. Industry Advisory Committee provides course notes, lecturers, and other aids; currently revising and updating course material . . . Spring symposium had as its theme, "Coatings and the Environment in the 90s. Progress or Perish" . . . Offering subsidized registration to area university students wishing to attend 1991 FSCT Annual Meeting and Paint Industries' Show.

Discussion of FSCT Educational Structure

Chairman Boyd noted that the Federation has reaffirmed its commitment to education, focusing efforts to insure that adequate resources are available, and invited FSCT Secretary-Treasurer Colin Penny to comment on developments in this regard.

Mr. Penny expressed his pleasure at being able to participate in the meeting. He

commended the representatives for their educational activities, and urged them to continue their efforts.

He observed that times are changing and the Federation is initiating adjustments to deal with the changes. He cited the addition to staff of Mike Bell as Director of Educational Services, a new position, as recognition of the need to upgrade educational efforts.

These efforts include support for activities at the local level. The Federation is amenable, he said, to appropriate funds for joint ventures with Societies, provided it is deemed worthwhile and detailed documentation accompanies requests for appropriations.

Chairman Boyd then explained the new FSCT educational structure and the roles of the Educational Committee, Coatings Industry Education Fund (CIEF), and Professional Development Committee, in the evolving educational policy.

The Educational Steering Committee, which was initiated in an informal arrangement and never accommodated in the By-Laws, has been operating as an Ad Hoc Committee. Proposals have been approved by the Executive Committee and submitted to the By-Laws Committee to draft appropriate language to formally incorporate the Steering Committee as a Standing Committee.

In its new form the Steering Committee will become the Educational *Coordinating* Committee.

It will have as its objective to promote the educational programs of the Constituent Societies and the Federation, and to guide them into the most productive and useful channels by: coordinating activities of the Educational Committee; studying/evaluating stated needs of the Society Educational Chairs; focusing on the issues and resources required to further the overall educational programs of Constituent Societies; developing proposals and obtaining funds for meeting those needs; and providing continuity to the overall educational programs of the Federation.

The Professional Development Committee will continue to direct its efforts to developing programs for the benefit of those in the coatings industry, that is, continuing education.

The Coordinating Committee plans to cede administration of the Federation scholarship program to the Coatings Industry Education Fund, which will continue to administer the Vasta Memorial Scholarship Fund, as well as fellowship grants.

Chairman Boyd reported that the Federation scholarship funding will total \$50,000 for the 1991-92 academic year for undergraduate grants at seven schools: University of Detroit; Eastern Michigan University; Kent State University; University of Missouri-Rolla; North Dakota State University; University of Southern Missis-

sippi; and California Polytechnic State University at San Luis Obispo.

The funding, which is increased from \$43,000 appropriated for 1990-91, reflects the recommendations of the Steering Committee.

The funds are to be used as grants-in-aid for the coatings technology programs at each school, with preference given to qualified scholarship applicants who are children of Federation members.

Society scholarship programs continue to provide substantial funding (last year topping \$50,000), and a tabulation of these monies is again being compiled. The request for this information has yielded a goodly number of responses, and Chairman Boyd urged the representatives who have not yet submitted this data to do so as early as possible, so that the tabulation can again be published in an early issue of the *JCT*.

What is Important to Society Educational Programs? How Can Federation Help?

To aid in determining the role the Federation can play in assisting Society educational activities, Chairman Boyd asked each attendee to respond to the question, "What Is Important to Your Society's Educational Program?"

The list of responses was reviewed and discussed, and four topics were selected as the focus for discussions: Technical/Management Link; General Education; Monthly Meeting Programs; and Continuing Education.

Chairman Boyd then asked attendees to assemble in four groups for a 30-minute "brainstorming" session, each group to pursue discussions on one of the four topics, then report recommendations for developing an action plan.

Brainstorming Session Ideas

TECHNICAL/MANAGEMENT LINK

Need to inform management of Society/Federation achievements and encourage support of employee membership and participation.

—Have members identify key management contact

—Develop informational packet advising management of member employee's participation and acknowledging support

—Produce quality-type brochure which describes activities and benefits of membership

—Solicit management input via questionnaire regarding programming needs/commitment/perceptions

MEETING PROGRAMS

The heart and soul of Society activities are the monthly meetings. What is Society

response to the question: "As part of an effort to upgrade programs, would you let FSCT take responsibility to give program at a Society monthly meeting?"

—Form subcommittee to identify kinds of speakers/subjects to qualify for quality programming

—Identify people who can, and are willing, to make commitment. To have effective program committee, there is need for wide diversity of areas of interest.

—Federation should be prepared to pay transportation costs, honorarium, etc., to provide good programs, including resources for slide reproduction.

GENERAL EDUCATION

Develop an awareness program to create an image of the coatings industry as a contributing, responsible member of the community.

—Produce coatings awareness brochure (what coatings can do; special techniques/uses; safe uses and disposal; impact on environment). Could be useful for display at home shows. Project could be started at local level and worked through FSCT to refinement; develop a Federation database.

—Promote career opportunities, to interest students in joining industry. Effort could include videotape, literature, and on-site presentation by members to student groups (including physical Show and Tell) and success stories. Also, foster participation in Career Days, as well as interacting with teachers. Form Career Guidance Task Force to develop/coordinate strategy.

CONTINUING EDUCATION

Structure program for addressing ongoing need to further educational and professional growth of members.

—Offer training seminars (including those aimed at educating consumers, contractors, and industrial finishers — OEM)

—Develop short courses, featuring "experts," to present at outlying locations, as well as in-house (could include video and teleconferencing)

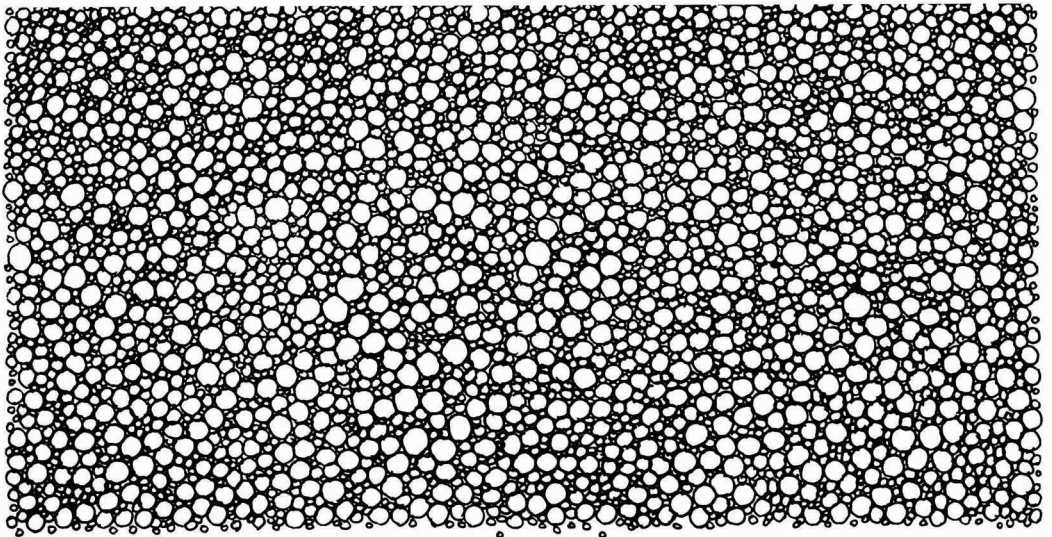
—Establish tie-in with local school system

—Upgrade publicity and communications efforts

—Develop teaching outline/syllabus for presentation of coatings courses

—Federation subsidy for less affluent Societies.

The recommendations will be addressed by the Coordinating Committee, and appropriate action taken to implement selected projects as soon as possible.



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GENSTAR

New Multi-Client Study on Radiation Curing Completed

"Radiation Curing, III," a multi-client techno-economic marketing study, has been completed recently by Skeist Incorporated, Whippany, NJ.

The study is an examination of coatings, inks, and adhesives cured by ultraviolet, electron beam, and visible light. The report analyzes the technical developments and commercial opportunities of this business. Technologies, raw materials, applications, consumption, projections, prices, suppliers, and end users are investigated.

The report states that consumption of radiation-curable coatings, inks, and adhesives was 51 MM lb (5.1 MM gal) worth \$275 MM in 1990. This volume is more

than two times what it was six years ago, and more than 25 times higher than 20 years ago.

According to the study, in the future the demand is projected to reach 80 MM lb (8.7 MM gal) by 1995. This increase corresponds to an average annual compounded growth rate of 9%.

UV systems accounted for about 80% of the poundage and 75% of the dollars. The balance is split between EB and VL formulations almost evenly in dollars; however, the bulk of the volume consists of EB.

The industry analysis includes a competitive analysis of raw material producers as well as compounders of RC systems.

Profiles of the leading 21 raw material producers and 36 compounders are given. A section on new developments of radiation curing technology is provided in the study. The equipment section discusses technology, economics, producers, types, and safety considerations.

For a free brochure and table of contents of the report, write Skeist Inc., 375 Route 10, Whippany, NJ 07981.

Betz MetChem Completes Expansion of Coatings Labs

Betz MetChem, Horsham, PA, a division of Betz Laboratories, Trevoise, PA, has just completed a \$3 million expansion of its coatings laboratory.

The expansion has added approximately 12,000 sq ft of laboratory space and new equipment, including pilot coil and foil lines and paint spray booth simulation capabilities. According to officials at MetChem, the new laboratories are designed with a closed-air system.

Wacker to Construct Process Control Lab

Wacker Silicones Corporation, Adrian, MI, has broken ground for the construction of a Process Control Laboratory at their manufacturing complex in Adrian.

Costs for the new 9,000 sq ft facility are projected at over \$1 million. The plant, which is scheduled for completion in the spring of 1992, will house Wacker's Process Control Department.

Construction of the company's new Training Center was completed at the Adrian complex in June.

Amoco Chemical Belgium Plant To Produce Terephthalic Acid

Amoco Chemical Belgium N.V.'s new purified terephthalic acid plant in Geel, Belgium is fully operational. Construction of the plant began in late 1989.

The world-scale unit, with an annual capacity of 250,000 tons, incorporates the latest Amoco production improvements.

In other news, Amoco Chemical has announced further investment at the Geel plant to expand and improve its worldwide production of isophthalic acid.

Amoco Chemical Belgium N.V. is a wholly owned subsidiary of Amoco Chemical Company, the manufacturing and marketing subsidiary of Amoco Corporation.

Mergers & Acquisitions...

Harcros Chemical Group Forms New Organics Company

Harcros Chemical Group, London, England, has announced the formation of Harcros Organics Inc., a U.S. organics manufacturing company. The new company will be headquartered in Kansas City, KS, with combined sales of approximately \$68 million.

Harcros Organics is comprised of Hardman, Inc., Belleville, NJ, and the Specialty Chemical Division of Harcros Chemicals Inc., Kansas City, KS. Both locations are existing Harcros manufacturing units.

Hardman, Inc. is over one century old and is a manufacturer and formulator of epoxy and urethane adhesives, elastomers, and specialty coatings. It will retain its current name under the umbrella of Harcros Organics Inc. The Specialty Chemical Division of Harcros Chemicals Inc. manufactures surfactants, emulsifiers, and antifoam agents. Its identity will be changed to Harcros Organics Inc.

Robert V. Mann, formerly Vice President and General Manager of the Specialty Chemical Division of Harcros Chemicals Inc., has been named President of the new company.

KTA-Tator Opens Consulting Firm in Argentina

KTA-Tator, Inc., Pittsburgh, PA, has formed KTA-Tator, SudAmericana S.A. (KTA-SUD), headquartered in Buenos Aires, Argentina. The KTA-SUD office and laboratory opened on September 1.

KTA-SUD will offer corrosion protection services throughout South America, including consulting regarding the surface preparation and application of paints and coatings, testing and qualification, specification preparation, coating application inspection services, instrument sales and service, and failure analysis.

The company also will have associate consultants specializing in other areas of corrosion protection, such as safety, cathodic protection, and materials selection.

The consulting firm has a fully equipped physical testing laboratory which includes blast cleaning and coating application facilities, and an analytical laboratory for paint testing and failure analysis.

Remo Rocca, an engineer with 12 years' experience in the protective coatings industry, has been named Operations Manager of the new company.

KTA-SUD currently has 15 employees in Argentina, and employs two technicians/inspectors at a subsidiary office in Montevideo, Uruguay.



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Henry Leidheiser, Jr.

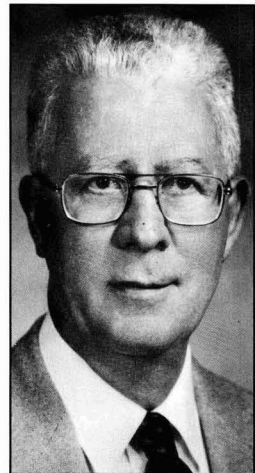
Dr. Leidheiser, formerly Director of the Center for Surface and Coatings Research, at Lehigh University, Bethlehem, PA, received the Ph.D. Degree from the University of Virginia in 1946. He remained at the University of Virginia as a Research Associate working with Prof. Allan Gwathmey until 1949, at which time he became the first employee of the Virginia Institute for Scientific Research. Dr. Leidheiser rose to the position of Director and Chief Executive Officer in 1960 and served in this capacity until he joined the Lehigh University faculty in 1968.

A Lehigh, Dr. Leidheiser served as Professor of Chemistry as well as Director of the Center for Surface and Coatings Research. He also served one term as Chairman of the Chemistry Department. He held the Alcoa Foundation Chair from 1983 until his retirement on January 1, 1990.

Best known for his work on the surface properties of single crystals of metals, Dr. Leidheiser is recognized for his electrochemical studies of protective metallic and organic coatings. His research has been honored by awards from such organizations as the Electrochemical Society, the Virginia Academy of Science, the Oak Ridge Institute of Nuclear Studies, the Society of Automotive Engineers, the Humboldt Foundation, and the National Society of Corrosion Engineers.

Dr. Leidheiser's extensive publishing credits include serving as the author or editor of seven books and over 260 publications in the technical literature. The organizer of many technical conferences, he has presented papers at conferences in this country and abroad. His short course on "Corrosion Protections by Coatings," was taught annually at Lehigh for 16 years and many members of the coatings industry have benefited from attendance at this course.

Dr. Leidheiser's most recent research activities have been concerned with corrosion under organic coatings; the nature of ions within a coating; the chemistry of the metal/organic coating interface; the applications of Moessbauer Spectroscopy and Positron Annihilation Spectroscopy to organic coating; and the application of electrochemical techniques to appraising organic coatings.



Electrochemical Methods for Appraising Corrosion Protective Coatings

Henry Leidheiser, Jr.

The author's experience with the application of eight electrochemical techniques for the study of corrosion protective polymeric coatings is summarized. The techniques include: corrosion potential, DC resistance, AC impedance at room temperature, AC impedance as a function of temperature, current flowing through the coating at high potential, repetitive cathodic polarization, cathodic delamination, and current/time measurements.

INTRODUCTION

Remarkable advances in corrosion protective coatings have occurred over the past two decades. Painted metal siding for buildings is guaranteed for 40 years; perforation of the superstructure of automobiles by corrosion is rare in automobiles manufactured in the 1980s; coatings for metallic food containers can be severely deformed during manufacture and yet provide superb corrosion protection; paints for coil-coated metals provide protection against corrosion in aggressive atmospheres after shaping; and coated components in electronic devices have long lifetimes. These fine developments have resulted from painstaking advances spread over many years. Long-term attention to service experience has been especially helpful. The products referred to previously are made in production facilities where careful attention is paid to the raw materials, the production conditions, and the final product. Quality control is very high.

There is, however, another side of the coin. Coatings applied in the field sometimes show poor protective properties and some coatings lose their adherence when exposed to water. The cliches usually given in explanation

are that the surface was inadequately prepared, the humidity was too high during application, the temperature was inappropriate, or the application was poorly done. These latter facts may be partially true, but the bottom line is that the protective properties of the coating were not up to expectations. Nevertheless, it should be possible to develop coating systems that compensate, or partially compensate, for the incompetence of the applicator.

The major difficulty in designing a coating system that will provide long-term protection to a metallic substrate against known environments is the ability to test a formulation rapidly in a manner that replicates the service environment. That is, an accelerated test is required that allows one to test a range of formulations so that the optimum one may be selected. For example, suppliers and users almost unanimously agree that the salt spray scribe test is inadequate as an appraisal method. However, they generally must fall back on this test because there is no substitute that is universally accepted. The problem is that the salt spray scribe test largely measures the ability of a scribed coating to resist deterioration under the coating in the vicinity of the scribe. If this is the mechanism of deterioration of the system in service in a chloride environment, the relative ranking of systems may provide a guide in selection. However, if the deterioration mechanism in service is entirely different, the salt spray scribe test does not provide useful rankings of coatings.

There is much evidence to support the view that the rate-limiting step in the deterioration of many coated metals is the rate of passage of ionic charge through the coating. Ions are required for coupling the anodic and cathodic sites necessary for the corrosion process and for developing a conductive electrolyte under the coating that permits the electrochemical reaction to occur. Bacon, Smith, and Rugg¹ in a classic paper showed that high ionic resistance of coatings correlated with good behavior on exposure to an aggressive environment, and low ionic resistance that developed during exposure correlated with

Presented at the 68th Annual Meeting of the Federation of Societies for Coatings Technology, in Washington, D.C., on October 31, 1990.
Dr. Leidheiser can be contacted at: 822 Carnoustie Dr., Venice, FL 34293.

Table 1—DC Resistance Behavior of Polybutadiene Films

Thickness (μm)	Cured at ($^{\circ}\text{C}$)	No. Pieces Examined	% D Type	Average Log R_i (ohms)	Average Log R_o (ohms)	Solution
12-14	240-250	15	53	11.3	7.7 ± 1.0	NaCl/KCl
8-10	200	11	91	—	6.3	NaCl
11-12	190-200	16	87	11.3	6.9 ± 0.8	NaCl
20-22	200	17	37	11.3	7.08	NaCl
38	200	8	62	11.5	6.6	NaCl
24-26	240-250	16	25	11.8 ± 0.3	7.8 ± 1.0	NaCl/KCl
22-24	190-200	20	45	11.5	7.4 ± 1.0	NaCl
35	240-250	16	25	11.5	7.2	KCl
20-22	200 ^a	8	75	11.3	8.0 ± 1.0	NaCl

(a) Two 11 μm coats. The top coat was cured in the normal way; the lower coat was cured for a total of 40 min.

poor behavior. A summary of the available literature in 1979² indicated that coatings showing a resistance of less than 10^7 ohms for 1 cm^2 of measured surface area were not protective, whereas those showing resistances much higher than this were protective. More recently, Tait and Maier³ have used impedance measurements to appraise coatings for use in contact with fluids inside spray cans. They observed that low frequency impedances less than 10^7 ohms/cm² of measured area resulted in containers with short service lifetimes. Other coatings that had low frequency impedances greater than 10^9 ohms/cm² of measured surface area had container lifetimes in service of greater than two years.

The correlation between the performance of coatings and their electrical properties encouraged us to explore various types of electrochemical methods as a means for understanding better the protective nature of coatings. This paper represents a progress report and summary of published and unpublished information on eight different types of electrochemical measurements used in our laboratory to understand better the protective nature of polymeric coatings. The types of measurements to be discussed include: corrosion potential, DC resistance, AC impedance at room temperature, AC impedance as a function of temperature, current flowing through coating at high potential, repetitive cathodic polarization, cathodic delamination, and current/time measurements.

CORROSION POTENTIAL

The electrochemical potential of a metal exposed to an electrolyte is that potential at which the anodic (electron-generating) and cathodic (electron-consuming) half reactions occur at the same rate. The rate determining reaction, the relative areas on which the anodic and cathodic reactions occur, and the ability of reactants and products to diffuse to or away from the reaction site, determine the value of the corrosion potential. The value may change with time as different factors become potential determining.

Most polymer-coated metals exhibit a corrosion potential when immersed in an electrolyte. In some cases, the corrosion potential is measurable immediately upon immersion. In other cases, many days are required before a steady-state value is obtained. Our studies indicate that

water permeation into the coating must occur to a significant degree before a meaningful potential is obtained: the metal substrate must be in electrical contact with the electrolyte through the coating. Acrylic, alkyd, epoxy, polybutadiene, and polyurethane coatings, 10-50 μm in thickness, for example, develop a corrosion potential within a short time after immersion in an electrolyte, whereas some vinyl and vinyl ester coatings may require as much as a month to develop a corrosion potential.⁴ Thus, the ability to measure a corrosion potential is an indication that the coating has sufficient permeability to permit ionic charge motion through the coating. The existence of a corrosion potential also suggests that aqueous phase water is present at the metal/coating interface. Unfortunately, the area of the metal substrate in contact with aqueous phase water cannot be determined from the corrosion potential.

A review of the corrosion potential of painted metals covering the literature to 1970 has been prepared by Wolstenholme.⁵ The results of this survey, and experimental data since 1970, indicate that there is no direct relationship between corrosion rate and the magnitude of the corrosion potential. White and Mills⁴ observed a wide range of potentials for a single coating on steel exposed to hot sulfuric acid and the potential range for different types of coatings overlapped. In the case of thick coatings, a corrosion potential much more positive than that of the bare substrate often indicated a low corrosion rate, but, unfortunately, this generalization did not apply in all cases.

One of the mysteries associated with corrosion potential is the fact that a coated steel panel immersed in sodium chloride solution is cathodic to an uncoated steel panel immersed in the same electrolyte. The situation is the same with respect to a scribed panel in the salt spray test in which the area adjoining the scribe is cathodic to the bare steel within the scribe. It is generally true that the cathode is that portion of the metal that has the maximum oxygen concentration since the cathodic reaction requires oxygen in neutral environments. The mystery is why is the coated metal the cathode when the oxygen concentration beneath the coating is presumably low. The most likely explanation is based on the fact that the steel surface is covered with porous solid corrosion product and that additional corrosion occurs beneath the corrosion

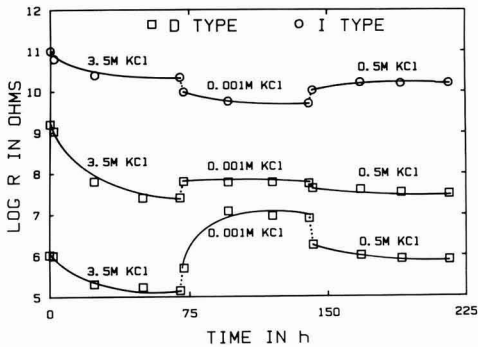


Figure 1—Data showing the different behavior as a function of electrolyte concentration for high resistance and low resistance 1 cm² sections of a polybutadiene coating. See reference (7) for more details

product with the formation of ferrous ions at the metal surface. The ferrous ions diffuse through the corrosion product and are converted at a distance from the metal surface by oxygen to ferric ions with subsequent precipitation as ferric solid corrosion product. This additional reaction removes the oxygen in the immediate vicinity, and thus, negligible amounts of oxygen are present directly at the metal surface at the scribe mark. The small amount of oxygen under the coating forces the metal under the coating to serve as the cathodic site.

DC RESISTANCE

The classic work of Bacon, Smith, and Rugg¹ has already been referred to and has formed the basis for much succeeding research. It appears firmly established that the coating provides superb barrier protection when the resistance is greater than 10⁹ ohms/cm² of measured area. Coatings approximately 50 μ m in thickness often exhibit cm² areas where the resistance is of the order of 10¹³ ohms.^{6,7} Many coatings exhibit DC resistances of 10¹⁰ ohms/cm² measured area when first immersed in the electrolyte, and this resistance decreases with time of exposure. If it is assumed that 10¹² ohms/cm² measured area represents a superbly protective coating, and that the resistivity of any penetrating electrolyte is of the order of 10 ohm-cm, a coating thickness of 100 μ m will have a maximum pore diameter for penetrated electrolyte of the order of 3.4 nm if all the charge is carried through a single pore. As corrosion occurs and additional water penetrates into the coating, the single pore (or multiple pores) increase(s) in diameter and the resistance of the coating decreases. The corrosion process, by either chemical or physical means, apparently causes localized deterioration of the coating, with a consequent increase in the cross-sectional area for charge transport through the coating.

Although the resistance of the coating upon exposure to a corrosive environment is an excellent measure of the protective nature of the coating, it is not an infallible measure of the absence or presence of corrosion. Some years ago, we were involved in a study supported by the

American Iron and Steel Institute in which an appraisal method was being developed for qualification of coatings for application to galvanized steel culvert pipe. An asphaltic coating on galvanized steel maintained a very high resistance during exposure to a sodium chloride electrolyte in excess of a year. When the coating was stripped from the surface, pit-like corrosion was observed. Analysis indicated that particles of calcium chloride were present at the zinc/coating interface. Sufficient water and oxygen apparently penetrated the coating and a highly localized corrosive environment was developed around each calcium chloride particle. The corrosion occurred under the coating without the need for charge transport through the coating.

DC resistance measurements have also been useful in appraising the heterogeneity of coatings. The first work was done on detached pentaerythritol alkyd coatings⁵ and more recent work was done on polybutadiene.⁷ When large sections of detached coatings were cut into 1 cm² sections and each measured separately, it was noted that some sections had resistances in the range of 10⁶ - 10⁸ ohms and other sections had resistances greater than 10¹¹ ohms. Data summarized in Table I illustrate this fact. Other characteristics of these two types of coatings also differed. For example, the low resistance sections (so-called D-type) of the coating had resistances that changed directly with concentration of the electrolyte, as in the lower two curves drawn in Figure 1. The high resistance sections (so-called I-type), however, exhibited the reverse behavior: the resistance of the coating varied inversely as the resistance of the electrolyte. This behavior is illustrated in the upper curve in Figure 1. The electrical behavior as a function of electrolyte concentration is explained as follows. The high resistance section has no large defects, and the resistance is largely determined by the amount of water that penetrates into the coating. Osmotic forces dominate, and less water enters the coating when the electrolyte concentration is high; thus, the resistance increases as the electrolyte concentration in-

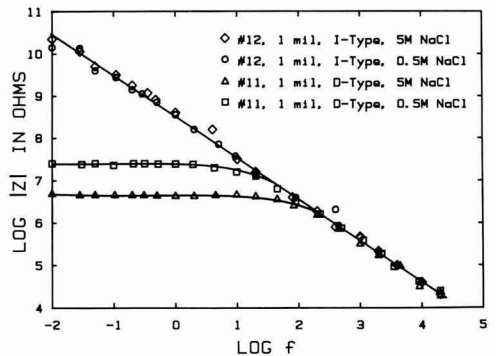


Figure 2—AC impedance data showing the great difference between two 1 cm² sections of the polybutadiene film shown in Figure 1. The high resistance section (#12) exhibits capacitive behavior over the entire range of frequencies covered, whereas the low resistance section (#11) exhibits resistive behavior at low frequencies

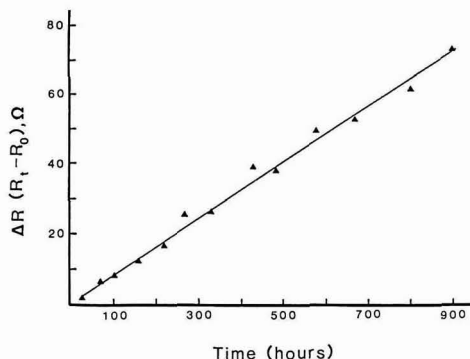


Figure 3—The change in resistance of a thin film of nickel coated with 13 μm of polybutadiene as a function of time of exposure to 3% NaCl solution. The increase in resistance is a consequence of corrosion of the nickel film. See reference (10) for more details

creases. The low resistance sections of the coating have defects into which the electrolyte can penetrate. The resistance of the coating is determined by the resistance of the penetrating electrolyte; thus, the resistance varies directly with the resistance of the electrolyte.

AC IMPEDANCE AT ROOM TEMPERATURE

Electrochemical studies using impedance measurements over a frequency range of 10⁻³ to 10⁵ Hz have become very common as commercial equipment became available at an economic price. An international conference on electrochemical impedance spectroscopy was held in September 1988.⁸ Laboratories concerned with developing or using polymeric coatings have been quick to adapt this technique to their studies and such equipment is common in coatings laboratories. Data representation has not yet been standardized, but the Bode plot (log frequency vs log impedance) is more commonly used for coatings than the Nyquist plot (real vs imaginary impedance). AC impedance measurements have advantages over DC measurements in that more information can be obtained. Since the AC impedance value at 10⁻³ Hz is approximately the same, for the majority of coatings, as the resistance of the coating using a DC measurement, it substitutes for DC measurements. If the slope of the Bode plot over a considerable frequency range is -1, the capacitance of the coating can readily be determined. The shape of the Bode plot also indicates the appropriate electrical model for the metal/coating/electrolyte system. The method is nondestructive since a perturbing voltage of several mV is often sufficient. Complete analysis of the Bode plot is difficult when one is dealing with a very defective coating under which corrosion is occurring at a significant rate. Unfortunately, many corrosion scientists have devoted their efforts to the study of very inferior protective coatings.

Figure 2 shows impedance data for two sections of a coating of polybutadiene on steel. Section #12 illustrates the behavior of an excellent barrier coating: the imped-

ance plot is that of a pure capacitor over the entire frequency range studied. Section #11, on the other hand, exhibits resistive behavior over the frequency range of 10⁻² to 10 Hz and capacitive behavior at higher frequencies. We can conclude from these measurements that Section #12 of the coating has no major conductive paths through the coating and that Section #11 has conductive paths such that its resistance at low frequencies is of the order of 10⁷ ohms. Corrosion beneath Section #11 would be expected to occur.

An important use of AC impedance is the ability to follow in a nondestructive way the change in properties of a coating exposed to a corrosive environment over a period of time. Coatings that retain the same impedance spectrum over long periods of time represent high quality protective coatings, and those whose impedance spectrum changes with time are of lower quality. The degree of change with time can be used to rank coatings in specific environments.

Good correlations have been found between impedance measurements and the corrosion of substrate metals such as iron, cobalt, and nickel.⁹⁻¹¹ The method utilized involved a thin film of metal with an appropriate coating and measuring the change in resistance of the metal with time to determine the loss of metal by corrosion. Concurrently, the impedance was determined normal to the surface of the coating. Figure 3 shows the change in resistance of a nickel film coated with 13 μm thick polybutadiene during exposure to a 3% NaCl solution. Figure 4 shows the concurrent measurements of the AC impedance. As corrosion occurs and the resistance of the thin film of nickel increases, the impedance spectrum reflects this fact by changes in the impedance at low frequencies. Although the data from the two measurements were not quantitatively correlatable, a sufficient number of experiments was performed to give adequate assurance that the impedance spectrum does indeed determine when corrosion is occurring.

Impedance measurements have also been used to detect electrical inhomogeneities in a coating.¹² An AC probe with a potential of 0.1 V applied between the probe and the substrate is rastered across the surface while the electrical signal is monitored. An example of the output of

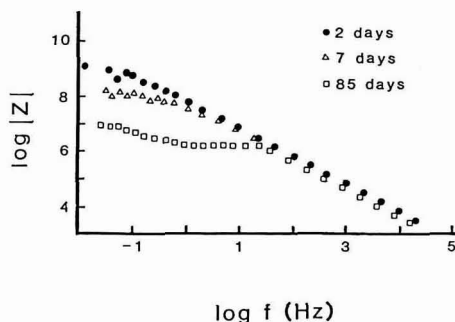


Figure 4—AC impedance measurements perpendicular to the surface of a nickel film coated with 13 μm of polybutadiene. Data were taken concurrently with those shown in Figure 3

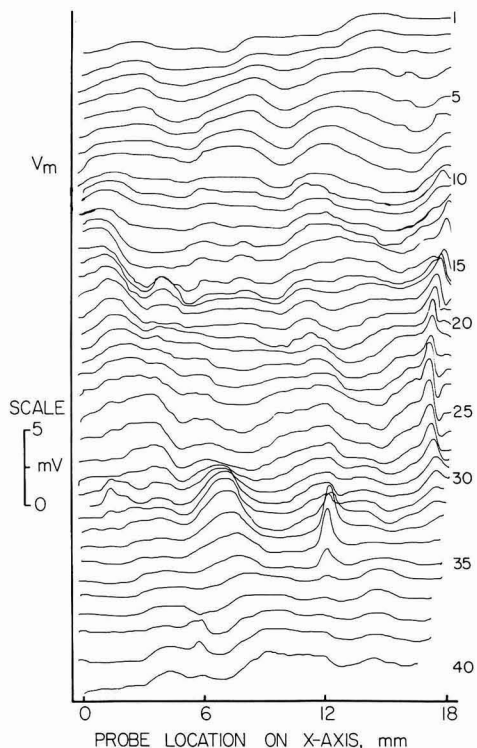


Figure 5—Electrical contour map of a 70 μm thick coating of epoxy on galvanized steel when exposed to 3% KF solution. Spikes in V_m (higher values represent lower impedance) represent regions of the coating that exhibit poor protective properties. See reference (12) for details

such a system is shown in Figure 5. The peaks represent regions of lower impedance.

AC IMPEDANCE AS A FUNCTION OF TEMPERATURE

Corrosion processes that cause degraded barrier properties of the coating result in increasing passage of ionic charges through the coating. These charges may be transmitted through pores large enough to support an aqueous phase or through the free volumes within the polymer framework. The large pores may be detected, as shown previously, by DC resistance measurements or by AC impedance measurements, but it is difficult to arrive at conclusions relative to characteristics of the free volume from these types of measurements.

A technique that appears promising for determining the size of the free volume in a polymer coating utilizes the lifetime of positrons injected into the coating. Jean, Sandreczki, and Ames¹³ have been able to calculate the size of the free volume in a series of epoxy coatings using positron annihilation spectroscopy (PAS). They observed that the free volume size increased with increase in tem-

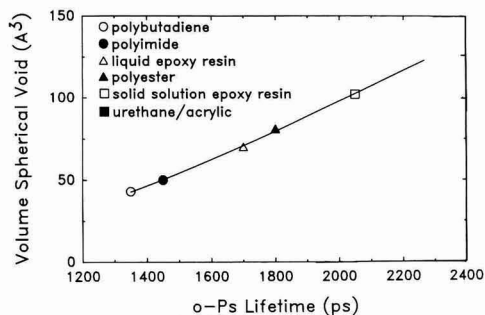


Figure 6—The relationship between the free volume in six coatings and the lifetime of the long-lived ortho-positronium when positrons are injected into the coating

perature. MacQueen¹⁴ has carried out a similar set of experiments with several coatings on steel. His data for the positron lifetime and the free volume size as determined by Jean et al. are given in Figure 6.

PAS measurements, thus, look very promising as a means for studying the free volume of coatings, but they are time consuming, require the use of a radiotracer (Na-22), and demand equipment not readily available in most coatings laboratories.

An interest also exists in determining free volume as a function of temperature since many protective coatings are exposed to aqueous media at temperatures above room temperature. PAS measurements are very difficult

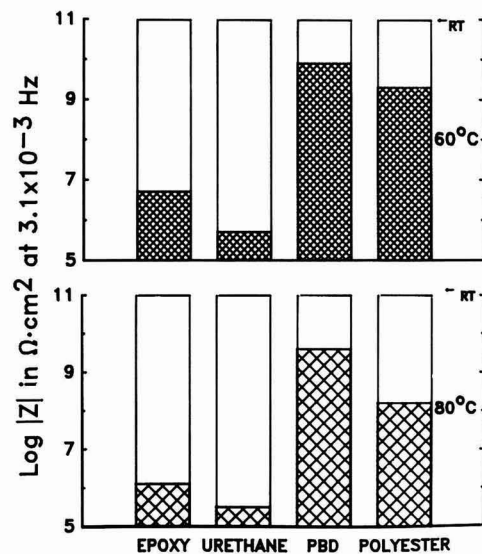


Figure 7—The low frequency impedance of samples of epoxy, urethane, polybutadiene, and polyester coatings at room temperature, 60° and 80°C. Note the widely different behaviors at the elevated temperatures even though all four coatings have approximately the same impedance at room temperature

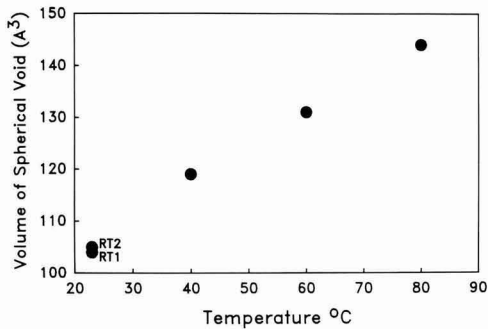


Figure 8—The free volume of an epoxy coating on steel as a function of temperature. The free volume was determined from the lifetime of the long-lived positron component after injection of positrons into the coating

to do at temperatures above room temperature and we thus sought to correlate another candidate technique, impedance measurements at elevated temperatures, with PAS measurements. The technique for determining the impedance as a function of temperature is very simple. The coated metal is immersed in distilled water and the impedance spectrum is determined at room temperature; the temperature is raised to 40°C, the system equilibrated for 1 hr, and the spectrum again determined. The same procedure is followed at 60° and 80°C, allowing 1 hr equilibration at temperature before the measurement is made. After the 80°C measurement, a second measurement is made at room temperature and a third measurement is made at room temperature after one week of immersion in water. Different coatings subjected to such a thermal cycling test show a range of behaviors. Some coatings exhibit only a small change in low frequency impedance as the temperature is increased and other coatings exhibit a change between room temperature and 80°C of several orders of magnitude. Data for four coating systems are shown in *Figure 7* in the form of bar

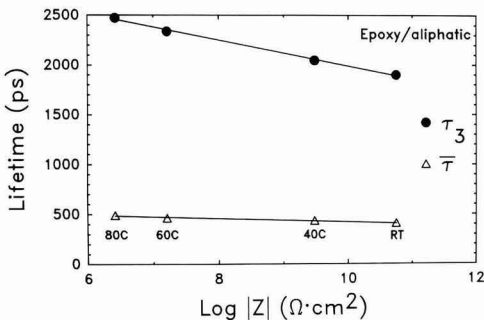


Figure 9—Data showing the relationship between impedance values at 3×10^{-3} Hz and the positron lifetime over a temperature range for an epoxy/aliphatic coating on steel. The top curve represents data for the long-lived component and the bottom curve represents data for the mean lifetime of injected positrons

charts of the impedance at 3×10^{-3} Hz on a logarithmic scale.

Our first efforts to correlate the two types of measurements are shown in two figures. *Figure 8* is a plot of the free volume values obtained at 20, 40, 60, and 80°C using PAS measurements and the data of Jean et al.¹³ to correlate the PAS measurements with the free volume. These data were then compared in *Figure 9* with the values of the impedance at the same temperatures at a frequency of 3×10^{-3} Hz. It will be noted that there is a good linear relationship between the PAS lifetime values and the impedance. The measurements to date do not prove a 1:1 relationship between the two types of measurements, but the initial data encourage us to continue such studies.

Important information about a coating may also be obtained by making impedance measurements as a function of temperature over the range of -100 to +100°C without immersing the coating in an electrolyte during the data accumulation. A simple means for carrying out such a study is shown in *Figure 10*. The electrode assembly is immersed in liquid nitrogen and then is placed in an insulated box equipped with electrical heating. Measurements are made continuously while the sample increases in temperature.¹⁵

The dielectric properties of the coating are strongly a function of the amount of water in the coating, as shown by the data in *Figure 11* above room temperature and the

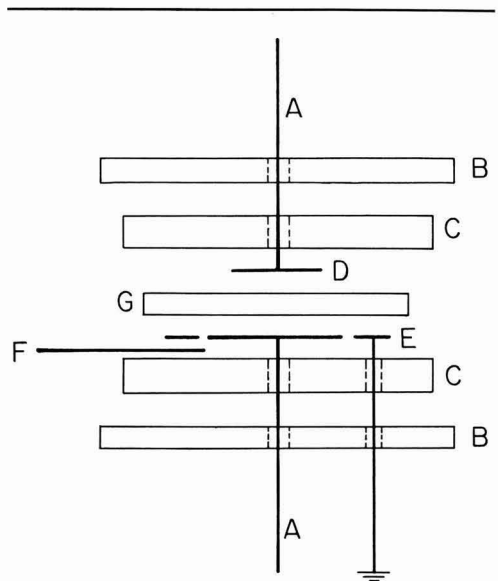


Figure 10—Schematic diagram of a method utilized to make dielectric measurements as a function of temperature. A—electrode leads; B—insulated metal plates; C—rubber gasket; D—electrode; E—grounded guard ring; F—thermocouple; and G—sample. Entire system is placed in a thermally insulated box that can be cooled and heated. See reference (15) for more details

data in *Figure 12* below room temperature. The dielectric properties are also strongly influenced by the crosslink density as shown, for example, in *Figure 13*, for an epoxy-polyamide coating cured at room temperature and at 100°C.

Impedance measurements as a function of temperature remain a largely unexploited field for coatings scientists.

CURRENT FLOWING THROUGH COATING AT HIGH POTENTIAL

Many people have advocated over the years that coatings should be tested with applied potentials of up to 100 V. The Japanese coatings industry is presently considering a qualification test for marine coatings that requires the application of a significant potential. It does not appear appropriate to test coatings under conditions that do not reflect service conditions or do not reflect the mechanism by which the protective coating degrades. The actual test itself may develop defects in the coating that would not occur under milder conditions of service. An example of the effect of an applied potential of -4 V across a thin, electrostatically-applied coating on copper is shown in *Figure 14*. It will be noted that the impedance in the frequency range of 10^{-2} to 10 Hz, where the resistive nature of the coating is dominant, that the polarization caused a decrease of approximately one order of magnitude in the impedance. These data suggest that the polarization process itself resulted either in the development of pores or an enlargement of pores already extant.

The technique, however, does have merit for some specific applications where a clear question can be posed. We have utilized the technique to determine the thickness to which an electrostatic powder coating must be applied to obtain a pore-free coating. *Figure 15* is a plot of the current flowing when coated copper is immersed in 3% NaCl and a potential of -4 V is applied. It will be noted that a 20 μm thick coating appeared to be essentially pore-free when applied to copper sheet, but that a coating thickness of 40 μm had to be applied when the substrate metal had 1.2 mm diameter holes. The reason for this difference is the fact that the specimen containing holes had burrs on the hole edges, and a thicker average coating thickness was required in order to obtain the insulative properties on the burr edges.

REPETITIVE CATHODIC POLARIZATION

A very aggressive test of the integrity of a coating, as well as the ability of the coating to resist enlargement of a defect, is based on repetitive cathodic polarization. We have applied this technique to the study of the ability of an electrostatic powder coating to cover uniformly the burrs on copper panels drilled with an equal number of holes of different diameter.¹⁶

Figures 16-18 show repetitive polarization of coated panels to a maximum potential of -4 V. The coated panels were immersed in 0.5M NaCl and were polarized cathodically to a maximum potential of -4 V vs SCE at a rate of 100 mV/s. This procedure was repeated 50 times after allowing time for the panel to reach a steady state

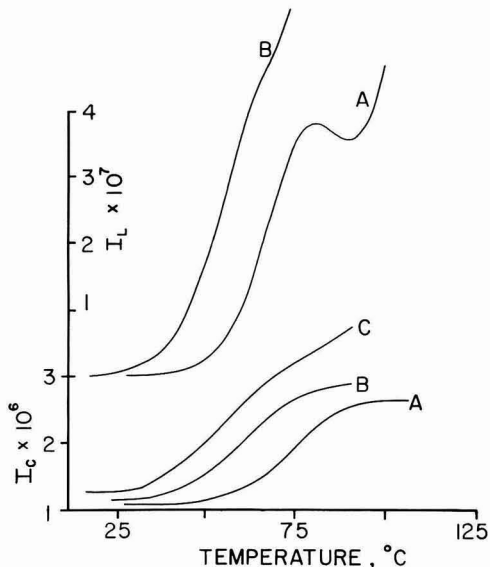


Figure 11—Dielectric measurements made at 1000 Hz for a coating of Epon 1002/Versamid 100 after: A—storage in a desiccator; B—after exposure to 65% relative humidity for one day; and C—after one day immersion in water. Values of I_r are related to the resistive component of the impedance and values of I_c are related to the capacitive component of the impedance. The I_r data for C are very similar to those of B and are not shown [reference (15)]

corrosion potential before the next polarization. The left hand curve in each figure is the first polarization and the right hand curve is the 50th polarization. Intermediate polarizations lie between the extremes. Several features of the curves warrant comment:

(1) The curves move to the right on successive scans. This behavior is indicative of the fact that the exposed surface area of the substrate metal increases with succes-

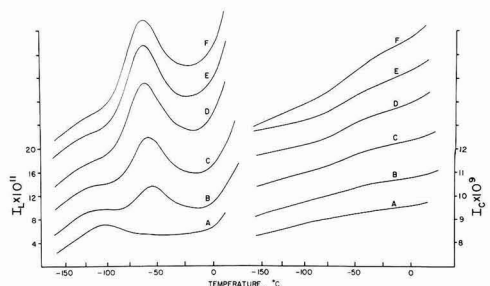


Figure 12—Dielectric results obtained at 10 Hz showing the effect of water content of a film of Epon 1002/Versamid 100. Water contents of film are: A—0%; B—0.47 wt%; C—0.95 wt%; D—1.54 wt%; E—2.02 wt%; and F—2.18 wt%. Values of I_r are related to the resistive component of the impedance and values of I_c are related to the capacitive component of the impedance [reference (15)]

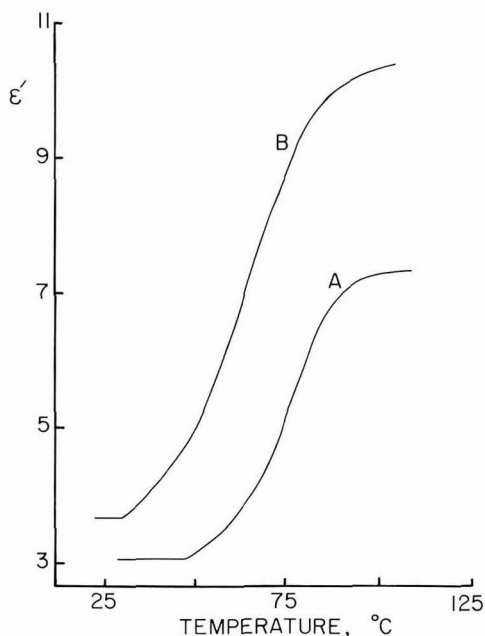


Figure 13—Data showing the effect of cure temperature on the dielectric properties at 1000 Hz for films of Epon 1002/Versamid 100 cured: A—at 100°C; and B—cured at room temperature [reference (15)]

sive polarizations. Thus, the size of the defects or the number of defects in the coating increase with time.

(2) The current density at a fixed potential and at a fixed scan number is greater with increase in hole diameter. Thus, the defects associated with the burrs on the larger holes tend to be larger or more numerous.

(3) The shape of the polarization curve changes with time with the development of a larger current density at voltages more positive than -1.2 V. This behavior is probably associated with the growth in the defect size with successive polarizations and the larger amount of charge necessary to reduce the oxide that forms on the copper surface between each additional polarization.

A more extensive summary of these studies can be found in reference (16).

CATHODIC DELAMINATION

A standard method (ASTM G-8) is often used to appraise coatings that are candidates for use on steel under conditions where the steel is cathodically protected. A hole is drilled through the coating to the substrate, the coated metal is immersed in 3% NaCl, and a potential of 1.5 V is applied. The evaluation criterion is the extent to which the coating delaminates from the substrate laterally from the defect. This test is presumed to judge the ability

of the coating to continue to protect the substrate metal adjoining a site where the coating has been damaged.

We have made an extensive study of the principles underlying the phenomenon of cathodic delamination in the case of coatings 10-100 μm in thickness.¹⁷⁻²⁶ A sufficient number of studies was made with thick epoxy powder coatings to conclude that the same principles apply to thick coatings. The major results of these studies may be summarized as follows:

- (1) Cathodic delamination does not occur in the absence of oxygen nor in strongly acidic solutions.
- (2) The pH of the solution under the delaminated coating is alkaline and in some cases may be close to 14.²⁷
- (3) Cathodic delamination occurs at a significant rate only in solutions of the alkali metals, lithium, sodium, potassium, rubidium, and cesium. The rates of delamination are very low in solutions of the alkaline earth metals, magnesium, calcium, and barium.
- (4) The rate of delamination increases in alkali metal ion solutions in the order, lithium < sodium < potassium < cesium. This relative order is observed with all coating systems studied.
- (5) The rate of delamination is independent of the anion in solution.
- (6) The area delaminated, at a constant potential, is linearly related to the time.
- (7) The rate of delamination increases with increase in the applied cathodic potential.

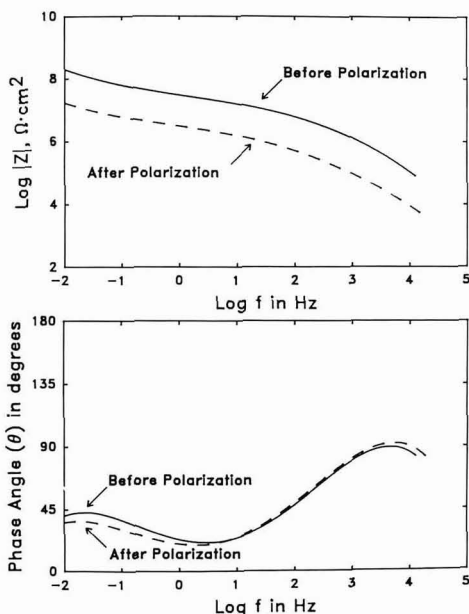


Figure 14—AC impedance data showing the effect of DC polarization at -4 V (vs SCE) of an epoxy powder coating on copper in 0.5M NaCl. Notice that the values of impedance are less after polarization over the entire frequency range studied [reference (16)]

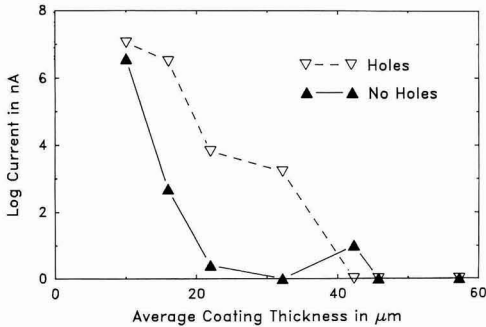


Figure 15—The defect nature of an epoxy powder coating on copper sheet, with and without drilled holes, as determined by the current flowing when polarized cathodically at -4 V vs SCE [reference (16)]

(8) The rate of delamination decreases with increase in film thickness.

(9) The rate of delamination is a function of the composition of the coating. Insufficient work has been done to state conclusions as to the relationship between structure of the polymer and the rate of delamination.

(10) The activation energy for the delamination process in the case of polybutadiene coatings on steel is approximately 10 kcal.

(11) In the case of coatings thicker than approximately 40 μm , there is a delay time before the delamination process begins. This delay time increases with increase in coating thickness.

These observations, as well as other types of measurements, lead to the conclusion that the cathodic delamination process occurs as a consequence of the reaction, $\text{H}_2\text{O} + \frac{1}{2}\text{O}_2 + 2\text{e}^- = 2\text{OH}^-$, on the metal substrate beneath the coating. The high hydroxyl ion concentration leads to the breaking of the bond at the polymer/oxidized metal interface. The mechanism of bond breaking probably varies with the coating/metal system, but the most likely reasons are: dissolution of the metal oxide at the interface, attack of the polymer, and dewetting by the strongly alkaline solution at the interface.

The critical question in the cathodic delamination process is what is the rate controlling step. It is our feeling, based on quantitative studies of several systems, that cation transport through the coating is the rate controlling step.²⁶ This conclusion is consistent with all the experimental observations enumerated previously. If this conclusion is correct, it suggests that cathodic delamination is a valid means for appraising the corrosion protective properties of a coating since the development of charge transport during exposure of the coated metal to an electrolyte is related to the rate of corrosion of the steel substrate.

Since the major charge carrying species through the coating is the cation, and the effects caused by alkali metal cations appear to be most damaging to polymeric coatings,²⁸ the next question we addressed was the nature of the cation within the polymer coating. Moessbauer spectroscopy provided some information,²⁹⁻³¹ but the al-

kali metal ions cannot be studied by this technique. Nuclear magnetic resonance spectroscopy was then resorted to,³²⁻³⁴ since lithium, sodium, and cesium can be readily studied by this technique. The major conclusions resulting from this study are the following:

(1) The alkali metal ions can be injected into epoxy, polybutadiene, and polyimide coatings by means of an applied potential.

(2) When the coating is completely wetted, the alkali metal ion exists in the fully hydrated state within the polymer.

(3) Partial drying of the coating leads to partial loss of waters of hydration by the cesium ion. The waters of hydration are more difficult to remove from the hydrated lithium and sodium ions.

(4) When the coating is completely dried, the alkali metal ions associate selectively with special polar groups within the coating.

These data are consistent with the viewpoint that the cesium ion can more readily diffuse through a coating because its waters of hydration are less tightly held and are more easily deformable. Lithium and sodium ions, on the other hand, bind the waters of hydration more firmly, and this increased effective size of the ion/water complex leads to a lower rate of diffusion through the polymer matrix.

CURRENT-TIME MEASUREMENTS

As discussed previously, it is relatively easy to distinguish between poor and good protective coatings, but it is very difficult to rank good coatings in the laboratory. There is much evidence to support the view that the best protective coatings have DC resistances in the range of $10^9 - 10^{13}$ ohms/cm² measured area. DC measurements that provide the resistance of the coating are relatively easy to carry out with the aid of sensitive electronic

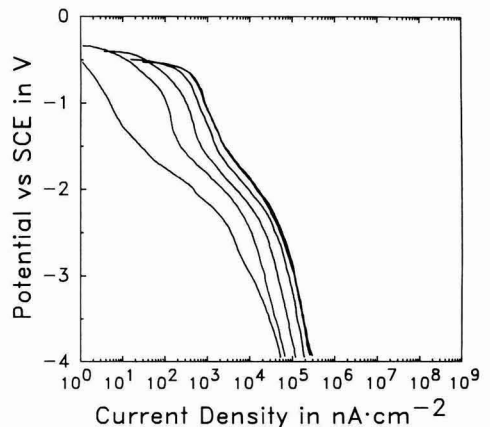


Figure 16—Repetitive cathodic polarization curves obtained in 3% NaCl for an epoxy powder coating on copper containing 0.5 mm diameter drilled holes [reference (16)]

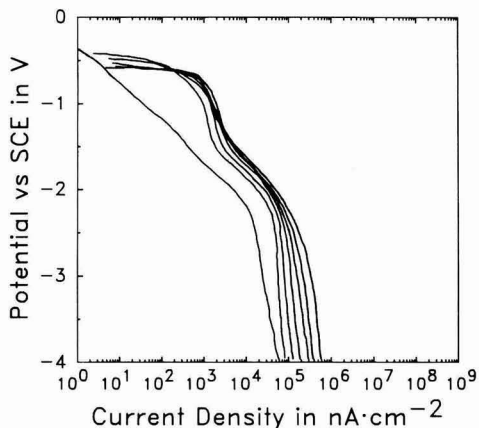


Figure 17—Repetitive cathodic polarization curves obtained in 3% NaCl for an epoxy powder coating on copper containing 0.8 mm diameter drilled holes [reference (16)]

equipment and good shielding. However, if one wishes to measure the capacitance simultaneously with the resistance, such measurements are difficult to make using AC measurements because the electronic equipment is sensitive to noise in the circuits. Also, if one wishes to follow changes in the resistance and capacitance during exposure in time intervals of several minutes, the available impedance equipment is inadequate. Therefore, a method was sought that could be used with coatings having resistances up to 10^{13} ohms/cm² measured area and that could follow rapid changes in the electrical characteristics.

The method adopted is a modification by Granata³³ of one proposed by Sykes, Sharman, and Smith³⁴ who followed potential changes of the coated metal as a function of time after the application of a potential pulse. Granata

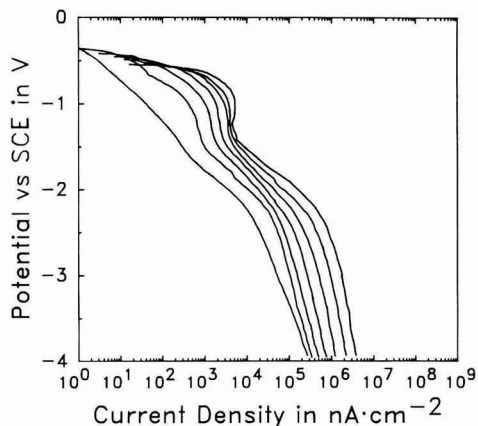


Figure 18—Repetitive cathodic polarization curves obtained in 3% NaCl for an epoxy powder coating on copper containing 1.2 mm diameter drilled holes [reference (16)]

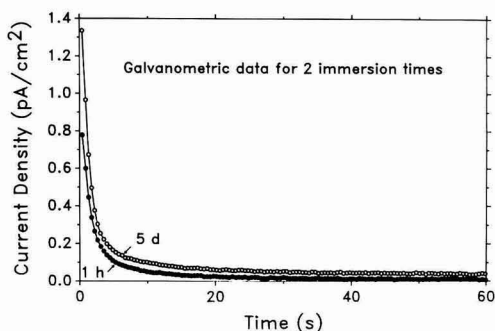


Figure 19—The current/time curve upon the application of an applied potential of 0.5 V for an epoxy powder coating on steel. Data are given after exposure of the coated metal to 0.5M NaCl for 1 hr and for five days. The resistance and the capacitance of the coating may be obtained from these measurements

applies a fixed potential of 0.5 V and follows the current with a sensitive picoammeter for approximately 60 s. An example of such an experiment is shown in Figure 19. The resistance and capacitance of the coating are readily calculated from the decay curve. Good agreement between the values calculated from the decay curve and those calculated from concurrent measurements of the impedance have been obtained in cases where the low frequency resistance of the coating is 10^{10} ohms/cm² measured area of less.

ACKNOWLEDGMENTS

My research on polymeric coatings during the past 18 years was only possible because of the capable senior associates (R.D. Granata, G.W. Simmons, W. Funke, A. Vertes, M.L. White, M. Kendig, D. Mills, J. McIntyre, Wayne Bilder, L. Igetoft, I. Czako-Nagy, and J.C. Galvan) and talented students (M. Atkinson, W. Bilder, J. Catino, S-M. Chou, P. Deck, M. DeCrosta, D. Eadline, K. Koshiichi, K. Kovaleski, R. MacQueen, J. Parks, V. Rodriguez, G. Rommal, P. Santiesteban, A. Sommer, S. Spadafora, J. Standish, R. Touhsaent, R. Turoscy, H. Vedage, and W. Wang) who contributed so much to these efforts. I am especially grateful to the Office of Naval Research for the support provided during the past 11 years. Gratitude is also expressed to others who contributed financial support to the coatings research: The National Science Foundation, the American Iron and Steel Institute, the Lead Zinc Research Association, the International Copper Research Association, the Electric Power Research Institute, the National Coil Coaters Association, Arco Chemicals, IBM, Ford Motor Co., PPG, and Mobil.

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Regulatory UPDATE

NOVEMBER 1991

This digest of current regulatory activity pertinent to the coatings industry is published to inform readers of actions which could affect them and their firms, and is designed to provide sufficient data to enable those interested to seek additional information. Material is supplied by National Paint and Coatings Association, Washington, D.C. and edited by member of the FSCT Environmental Affairs Committee.

**Environmental Protection Agency
September 25, 1991—56 FR 48475
Toxic Chemical Release Reporting: Pollution Prevention Information
Action Proposed rule**

The EPA has proposed a rule requiring companies to indicate measures they've taken to reduce the amount of toxic chemicals they generate. This is in addition to the information they already supply to the EPA as mandated under section 313 of EPCRA. The new information, required by the 1990 Pollution Prevention Act, includes source reduction and recycling procedures, and would be incorporated into the current annual toxic release inventory (TRI) reports. EPA is requesting comments on the revised section of Form R, which is the form used to collect the data.

Beginning with 1991 reporting, all facilities subject to TRI reporting would have to provide "the quantity of the chemical (prior to recycling, treatment, or disposal) entering any waste stream or released to the environment; the quantities of the chemical recycled at the facility; the quantities of the chemical treated at the facility; information on source reduction activities and the methods used to identify those activities; the quantities of the chemical released in one-time events not associated with production processes; the quantities of the chemical expected to enter any waste stream or be recycled in future years; and a product ratio or activity index for the reported chemical."

**Environmental Protection Agency
October 2, 1991—56 FR 49992
Guidance for the Use of the Terms "Recycled" and "Recyclable"
Action: Notice of public meeting and request for comments**

A growing concern in the United States is the lack of a nationwide consensus on the definition and use of environmental terms in marketing and labeling. Environmental marketing is becoming increasingly difficult for both manufacturers and consumers. Manufacturers are producing and attempting to attract consumers with environmentally oriented products, and consumers are seeking to purchase these products, but are skeptical because there is no universal meaning for "environmentally safe."

In an attempt to address the problem, and to respond to petitions from states, the Federal Trade Commission (FTC) is considering voluntary guidance for environmental labeling of recycled and recyclable materials. The U.S. Environmental Protection Agency (EPA) is developing recommendations to the FTC, and has proposed several options for defining the terms "recycled" and "recyclable." Because the agency has no authority to regulate environmental claims, the final definitions will be strictly voluntary.

In an effort to clarify what EPA considers vague terms with regard to the term "recycled," the agency suggests that companies clearly state in the product content the percentage by weight of recycled materials. Another option would be for EPA to set a predetermined percentage of recycled materials in a given product, and then let companies promote the recycled content. With regard to the term "recyclable," EPA would prefer claims: that don't mislead consumers with language that may indicate the product is recyclable everywhere in the U.S.; that provide consumer information on ways to recycle the material; and include the national recycling rate of the material to show the overall rate of recyclability.

Comments will be accepted until December 31, 1992, and must be sent in triplicate to RCRA Docket Information Center, Office of Solid Waste (OS-305), U.S. EPA, 401 M Street, S.W., Washington, D.C. 20460. The docket number, F-91-GPLP-FFFFF, must be included.

**Department of Labor
Occupational Safety and Health Administration
September 20, 1991—56 FR 47892
Occupational Exposure to Indoor Air Pollutants;
Request for Information**

The Occupational Safety and Health Administration (OSHA) is requesting comments and information in order to make a determination as to whether regulations are needed to control the quality of indoor air in the workplace.

OSHA would like the comments to address the following five categories: "(1) definition of health effects pertaining to indoor air quality; (2) monitoring and exposure assessments; (3) controls; (4) local policies and practices; and (5) potential content of regulations." Of particular interest is specific

The Regulatory Update is made available as a service to FSCT members, to assist them in making independent inquiries about matters of particular interest to them. Although all reasonable steps have been taken to ensure the reliability of the Regulatory Update, the FSCT cannot guarantee its completeness or accuracy.

information on the definition of and the health effects attributable to poor indoor air quality; ways to assess indoor air quality; performance of various ventilation systems; and the content of a regulation, should the agency determine that a regulation is necessary. With respect to particular contaminants such as passive tobacco smoke, radon, and bioaerosols, information is requested on how these contaminants contribute to the general degradation of indoor air quality.

Comments, recommendations, data, and information should be postmarked no later than January 21, 1992, and should be sent in quadruplicate to the Docket Office, Docket No. H-122, Room N-2625, U.S. Department of Labor, 200 Constitution Avenue, N.W., Washington, D.C. 20210, (202) 523-7894. For further information, contact James Foster, Office of Public Affairs, OSHA, (202) 523-8151.

**Department of Labor
Occupational Safety and Health Administration
September 18, 1991—56 FR 47348**

Occupational Exposure to Cadmium

Action: Notice of limited reopening of rulemaking record

OSHA has announced a limited reopening of a proposed rulemaking on occupational exposure to cadmium. The record will be open for 45 days to receive comments on two recent experiments on the solubility and carcinogenicity of cadmium pigments.

In February 1990, OSHA proposed to regulate all forms of cadmium because they are believed to be probable carcinogens. The comment period on the proposal closed October 30. However, the Dry Color Manufacturers Association requested further hearings because of new German studies that indicate that pigments do not have the same carcinogenic properties as other forms of cadmium. Despite the denial by an administrative law judge for further hearings, OSHA has decided to reopen the record to consider the new information.

Written comments will be accepted until November 4, and should be sent in quadruplicate to Docket Office, Docket H-057a, Room N-2625, Occupational Safety and Health Administration, U.S. Department of Labor, 200 Constitution Avenue, N.W., Washington, D.C. 20210. For further information, contact James Foster, (202) 523-8151.

Lead Tax—Majority Leader George Mitchell (D-ME), and Senate Finance Committee ranking Republican Bob Packwood (R-OR), have recently expressed an interest in a House bill that would impose a tax on lead.

The House bill, H.R. 2922, sponsored by House Ways and Means Committee member Ben Cardin (D-MD), establishes a 75¢ per pound tax on primary lead and 37¢ per pound tax on secondary lead. The tax would cover all lead removed from U.S. smelters, imported lead, and lead products. The purpose of the tax is to set up a trust fund to support lead paint abatement projects.

Reportedly, a number of Senators have expressed an interest in the legislation, but House sponsors would prefer a Senate sponsor from the Finance Committee where tax legislation is debated. Sen. Packwood's interest would, therefore, be significant.

Because a number of tax exemptions are scheduled to expire at the end of this year, there has been some speculation that a minor tax bill, such as H.R. 2922, may have a chance for passage. However, the Chairman of the House Ways and Means Committee (counterpart to the Senate Finance Com-

mittee) Chairman, Dan Rostenkowski (D-IL), reportedly has stated he has no intention of moving any tax legislation this year.

Product Liability Reform—On October 3, by a vote of 13-7, the Senate Commerce, Science and Transportation Committee approved S. 640, the Product Liability Fairness Act of 1991. The vote was not surprising since identical legislation moved exactly that far last year before dying at the end of the 101st Congress.

Just before the Committee vote, a controversial amendment designed to require insurance companies to report to the government how the legislation would affect product liability insurance was narrowly defeated. The closeness of the vote is significant in that the insurance industry launched a major campaign against the provision. Leading opponents of the bill argue that if product liability reform legislation is needed to enhance U.S. competitiveness, the insurance industry should make the data readily available to Congress.

Major provisions in the bill include: a two-year statute of limitations once it has been determined that a product caused the harm; a 25-year statute of repose for product liability litigation involving capital or producer goods; the prohibition of lawsuits if it is found that the primary cause of harm is a result of the claimants use of alcohol or illegal drugs; the abolishment of joint liability for noneconomic damages, with each defendant being liable for damages proportionate to the defendant's individual fault; "clear and convincing" evidence that a defendant's actions reflected a "conscious, flagrant indifference" to public safety; and the prohibition of punitive damages where a defendant's product has the approval of the FDA before it is marketed.

Congress has been unsuccessful in its attempt to reform the nation's product liability laws since 1980. Although it is true that support has increased during the last two years, because of past history it would be imprudent to suggest the legislation will become law during the 102nd Congress. The bill has been sequentially referred to the Senate Judiciary Committee where Chairman Joseph Biden (D-DE), has been a past opponent. Reportedly, if the Judiciary Committee passes this legislation, it will not be without a significant insurance provision.

Occupational Safety and Health—Hearings on the Comprehensive Occupational Safety and Health Reform Act (S.1622) are scheduled to begin in the Senate late in October. The Senate Labor and Human Resources Committee's Subcommittee on Labor has tentatively scheduled witnesses to testify to the successes and failures of the Occupational Safety and Health Administration (OSHA). Other panels will include testimony on strengthening OSHA enforcement and employer/employee involvement in preventing workplace hazards.

The legislation incorporates several labor-back issues, such as expanded employee rights and employer obligations, and greater authority for OSHA, including the elimination of required cost-benefit analysis in rulemaking authority. The bill also includes criminal sanctions against employers for violations that result in serious bodily injury to workers, and whistleblower provisions to cover employees who refuse to work because of an "apprehension of serious injury." Other provisions include written employer health and safety education and training programs that must provide the means to identify, evaluate, and document as well as remedy safety and health hazards. Provisions from High Risk Notification

legislation, such as medical monitoring costs borne by the employer, are also included in the bill.

The House Health and Safety Subcommittee of the Education and Labor Committee has not scheduled any hearings on the companion legislation, H.R. 3160.

Resource Conservation and Recovery Act—Up until recently, action on Sen. Max Baucus's (D-MT), comprehensive bill to reauthorize the Resource Conservation and Recovery Act (RCRA), has been threatened by a separate controversial bill dealing with the transport of interstate waste. Banning out-of-state waste imports has long been a point of contention between Senators in the East with little or no landfill space and Senators from the Midwest and West who do not want the waste dumped in their states. Frustrated with the lack of consensus on the issue, Sen. Dan Coats (R-IN), has repeatedly tried to attach a waste transport amendment to various pieces of legislation, most recently the EPA Cabinet Status bill (S. 533) which passed the Senate on October 1.

Fearing that RCRA reauthorization would again be preempted or "potentially forestalled," Sen. Baucus worked out an agreement with Sen. Coats whereby Mr. Coats agreed to hold off on his amendment until late April 1992. If the Senate has not passed, or is not close to passing a comprehensive bill by then, Sen. Coats will be free to move his legislation separately. The reauthorization to RCRA is likely to be the environmental priority for Congress in 1992.

Department of the Environment—On October 1, the Senate passed legislation that would elevate the EPA from an agency to a cabinet level Department of the Environment. This would make the EPA the 15th department in the President's Cabinet.

Sen. John Glenn (D-OH), the author of the bill (S. 533), said the purpose of elevating EPA to cabinet level is to "strengthen the agency's management effectiveness and ability to execute national and international environmental policy." Sen. Glenn had introduced similar legislation during the last Congress, but it failed to pass because of objections by the Administration. A primary White House objective was the establishment of a Bureau of Environmental Affairs, which would have acted independently of the Administration. Sen. Glenn apparently resolved the problem by placing the Bureau under the control of the President.

Other provisions in the bill include the establishment of a Presidential Commission on Improving Environmental Protection to study the organization of environmental protection within the new Department; a requirement for an international meeting on energy efficiency and renewable energy resources; and the potential establishment of an office within the United Nations to monitor greenhouse gas emissions on a country-by-country basis.

The bill has been sent to the House, but there has been no indication of when they might act. Supporters of the legislation hope to pass the bill by late November.

States Proposed Legislation and Regulations

California

Household Hazardous Waste—CA. A. 304 (Wright) imposes additional eligibility requirements on small quantity waste generators participating in a household hazardous waste program. Requires compliance with specified federal regulations. Deletes a limitation on acceptance of halogenated organic compounds and revises the definition of small quantity commercial sources.

Packaging—CA S. 235 (Hart) makes a statement of legislative intent and requires every rigid plastic packaging container sold or offered for sale in the state to meet specified criteria, beginning on January 1, 1995, except as specified. Authorizes the California Integrated Waste Management Board to grant waivers upon specified findings. Directs the Board to adopt regulations by July 1, 1994, concerning certification of compliance as stated by the requirements of the bill.

Hazardous Waste—CA A. 1899 (Frizzelle) revises the conditions under which used or spent etchants, stripping solutions, and plating solutions as recyclable materials will be regulated as hazardous waste. Requires the Department of Toxic Substances Control to include in the biannual report the additions or deletions to the listing of recyclable hazardous wastes.

CA A. 1475 (Tanner) requires that a person recycling more than 100 kilograms per month of recyclable materials excluded from the hazardous waste control law, except as specified, to provide specified information to the local health officer or public officer by July 1, 1992, and every two years thereafter, using a format developed by the Department of Toxic Substances Control and to the generator. Imposes a state-mandated local program by creating a new crime.

CA S. 194 (Torres) includes the collection of fees and taxes related to the handling of hazardous waste and sub-

stances within the Hazardous Substances Tax Law; defines the term "feepayer" for purposes of this law and makes various changes concerning statutory references. Declares that it is to take effect immediately as an urgency statute.

Graffiti—CA A. 446 (Boland) provides that any person who writes, sprays, scratches, or otherwise affixes graffiti on any real or personal property not his/her own is guilty of an infraction punishable by a fine not to exceed a specified amount of money if the amount of the defacement, damage, or destruction is less than the specified amount. Authorizes the court to require the defendant to provide the labor necessary to clean up, repair, or replace the damaged property only at the victim's option.

Hazardous Substances—CA A. 1731 (Sher) deletes the provision allowing the granting of categorical variances from provisions prohibiting the ownership or operation of an underground storage tank used for the storage of hazardous substances unless a local agency issues a permit for its operation.

Air Quality—CA A. 158 (Roybal-Allard) extends the air pollution disclosure statement requirement for the operation of hazardous waste facilities until January 1, 1997, and, until that date, prohibits the Department of Toxic Substances Control from issuing a hazardous waste facilities permit on and after July 1, 1992, unless the Department provided notice. Requires the Department to prepare a specified report when it proposes to issue a permit if it makes a certain determination concerning the applicant's past violations.

Lead—CA S. 240 (Torres) requires the State Department of Health Services to establish and maintain an occupational lead poisoning prevention program; authorizes the department to adopt implementing regulations; requires a fee to be paid by those employers involved in industries which present a potential source of occupational lead poisoning; requires the

fee to be paid annually to the State Board of Equalization; provides that the cost of the program shall not exceed the amount of revenue collected.

CA A. 2038 (Connelly) enacts the Childhood Lead Poisoning Prevention Act of 1991. Requires the State Department of Health Services to adopt guidelines by which all children would be required to be evaluated for lead poisoning by health care providers. Requires those children determined to be "at risk" of lead poisoning to be screened. Requires the department, in those instances in which a child is identified with lead poisoning, to ensure appropriate case management. Authorizes the department to impose fees on manufacturers and other formerly and presently responsible for identifiable sources of lead which contribute to environmental lead contamination. Note—The California Paint Council was successful in having the bill amended.

Florida

Air Quality (Regulation)—Implementation of EPA mandated revisions to correct State Implementation plan (SIP) deficiencies: Florida has proposed to revise its clean air SIP to correct certain deficiencies that have been identified by the EPA. The proposed changes include new definitions of what constitute appropriate "capture efficiency" and "removal and destruction efficiency" as well as a revision to requirements for determining compliance with VOC limitations in regulated surface coating operations, for example, in cases of cross line averaging or in the use of add-on controls, calculations are to be based on pounds of VOC per gallon of coating applied.

Illinois

Packaging—IL S. 1296 (Macdonald) bans the sale of certain plastic containers that are not coded for recycling.

Household Hazardous Waste—IL H. 114 (Novak) creates the Local Hazardous Waste Collection Program Act; requires the Environmental Protection Agency to formulate a pilot plan for the collection of small quantities of hazardous waste from households, farmers, and businesses in the state by March 1, 1992; requires the establishment of a statewide plan by March 1994.

Massachusetts

Household Hazardous Waste—MA H. 2881 (Hynes) establishes a plan for local collection of household hazardous waste in the Commonwealth of Massachusetts.

Packaging—MA H. 5202 (Roosevelt et al.) is The Massachusetts Public Interest Research Group (MASS PIRG) bill to promote recycling and environmentally acceptable packaging. Note—The Massachusetts Paint Council is working to develop an alternative to the PIRG bill.

MA H. 6133 (Angelo) promotes recycling, waste reduction, and composting in the Commonwealth. The bill would mandate recycling in Massachusetts within two years after the bill is signed into law, using state funds to help cities and towns set up recycling programs at the municipal level. Beginning in 1996, all rigid packaging between eight ounces

and five gallons would be required to be made of 25% of recycled or recyclable materials. All forms of packaging would be included in the mandate by 2002.

Michigan

Spray Paint—MI H.B. 5146 (Palamara) allows courts to suspend driver's license for up to one year for persons caught spray painting or otherwise defacing property.

Minnesota

Storm Water (Regulation)—Proposed adoption of storm water permit fees: Minnesota has proposed to assess annual storm water permit fees of \$270.00.

New Jersey

Environment (Miscellaneous)—NJ S. 2058 (Ambrosio) Hazardous Elimination Through Local Participation (Help); establishes a system to authorize local community groups and facility-based groups to conduct cooperative environmental and public health-oriented inspections of facilities where hazards may be present or may be released into the environment. Aids in identifying and addressing environmental or public health problems originating at these facilities before they present a serious threat to the environment or the public health. Authorizes the formation of three distinct types of inspection groups. Note—The New Jersey Paint Council is working to defeat this bill.

Pennsylvania

Household Hazardous Waste—PA H. 953 (Wright, D. et al.) provides for labeling of, and information about, household hazardous materials, confers powers and duties upon the Department of Environmental Resources; establishes the Household Hazardous Materials fund and provides for its administration; imposes penalties.

Hazardous Waste (Regulation)—Administration of the storage and spill prevention program: Pennsylvania promulgated regulations that implement a certification program for installers and inspectors of above ground and underground storage tanks. The regulations, effective on promulgation, implement the state's Storage Tank and Spill Prevention Act that permits the installation of above and underground storage tanks only by certified personnel and authorize regulations requiring that inspections of installations be conducted only by certified inspectors.

Texas

Waste Reduction (Regulation)—Proposed regulations to implement Texas Waste Reduction Policy Act of 1991: Texas has proposed regulations to implement the state's waste reduction law that, among other things, would require facility waste source reduction plans and would specify the required elements of the plans. The facilities to which the program would apply are defined broadly enough to include paint and coatings manufacturing facilities.

Changes in Hiding During Latex Film Formation: Part II. Particle Size and Pigment Packing Effects

Freidun Anwari, Ben J. Carlozzo, Kalpesh Chokshi, Mike Chosa, Mark DiLorenzo, Milind Heble, Carl J. Knauss, Joe McCarthy, Phil Rozick, Phillip M. Slifko, Walter Stipkovich, John C. Weaver, and Michael Wolfe

Cleveland Society for Coatings Technology
Technical Committee

Several latex paints were prepared to study pigment particle size and packing effects. Each paint contained varying ratios of fine to coarse particle size extenders at different pigment volume concentrations (PVC). Using a technique previously reported, changes in hiding were monitored during the drying process and reflectance data acquired for these paints. The reflectance (Y) of each paint, drawn down over a black substrate, was measured as a function of drying time using the long-term drift test of a computer-interfaced spectrophotometer. Using blends containing varying ratios of large to fine extender pigments at constant PVC, changes in hiding due to extender dilution effects could be determined and compared to proposed models offered by other

researchers. Additionally, critical pigment volume concentration (CPVC) information for each PVC ladder could be obtained by inspection, with accuracy exceeding that of other classical methods; the presence or absence of a minimum in the drying curves indicating whether a paint is above or below CPVC. In earlier work, correlations of CPVC determined by this method compared to methods using standard dry film properties (contrast ratio, porosity, rewet with mineral oil, etc.) were very good and actually demonstrated the greater sensitivity of this technique. Changes in the reduced PVC, Λ (where $\Lambda = \text{PVC}/\text{CPVC}$), which occur as the ratio of coarse to fine extender varies from blend to blend, were also apparent.

INTRODUCTION AND REVIEW

Since the concept of critical pigment volume concentration (CPVC) was first proposed by Asbeck and VanLoo,¹ it has long been known that pigment packing effects play a large role in determining the optical properties of latex paint. Several researchers have proposed models for the packing process above and below CPVC²⁻⁶ and methods to calculate the best geometries using both experimental and theoretical considerations.⁷⁻⁹ Other researchers have commented on the ability of extenders to act as spacing or

crowding pigments to change the hiding characteristics of a coating.¹⁰⁻¹⁵ Stieg demonstrated how these concepts could be used to improve or manipulate the hiding power of coatings by using extenders more efficiently.^{16,17}

A method to monitor hiding as it occurs during film formation would be helpful in giving practical information on the drying process, helping confirm theory. Through the use of a technique developed by the Cleveland Society for Coatings Technology Technical Committee,¹⁸ it is possible to follow these changes in hiding with the aid of a computer-interfaced spectrophotometer. A short description of the procedure used and results of an earlier study are described in the following paragraphs.

Presented by Ben J. Carlozzo at the 68th Annual Meeting of the Federation of Societies for Coatings Technology, in Washington, D.C., on October 29, 1990.

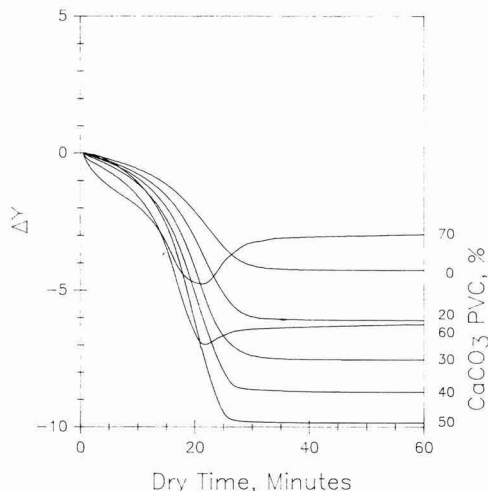


Figure 1—Changes in reflectance as a function of dry time for a calcium carbonate PVC ladder

Briefly, a pigment volume concentration (PVC) ladder of test paint can be prepared; drawdowns of each paint are then made over a black substrate and placed in the viewport of a computer-interfaced spectrophotometer (a Spectro-Sensor II, available from Applied Color Systems, Inc., Princeton, NJ). The “Long-Term Drift Test” option is run for approximately one hour and the spectral included reflectance (Y) measurements recorded during the test are plotted as a function of dry time. The “Long-Term Drift Test” is a diagnostic program normally used to check the stability of the light source or the electronics of the instrument by measuring and printing tristimulus coefficients¹⁹ (X, Y, and Z) of a substrate (normally a green tile) every six seconds. A shim, consisting of a 1/8 in. thick metal washer, is positioned between the drawdown and viewport to prevent wet paint from making contact with the spectrophotometer.

To eliminate variations in shim placement, changes in reflectance (ΔY) relative to the initial reading (Y_i) are calculated for each point measured during the drift test:

$$\Delta Y = Y - Y_i \quad (1)$$

ΔY is then plotted as a function of dry time for each paint. Drying curves similar to those shown in Figure 1, for a calcium carbonate PVC ladder, are generated. The onset of a minimum in the curve is noted as any positive value for the minimum reflectance minus the final reflectance ($\Delta Y_f - \Delta Y_m$).

Using this technique in Part I of “Changes in Hiding During Latex Film Formation,”¹⁸ the Cleveland Society was able to demonstrate the importance of monitoring the drying behavior of a latex film throughout the film forming process. In this earlier study, it was postulated and subsequently shown that the onset of a minimum in the drying curve occurs when PVC of that paint is at CPVC. Therefore, it is the presence or absence of a relative

minimum in these drying curves which is of greatest importance. CPVC determinations obtained from comparing wet and dry film properties alone can give an incomplete picture; one which may, in fact, be incorrect.

In summary, that study demonstrated that three types of behavior occur during the drying process and can be followed through this technique. Below CPVC, a wet film loses hiding steadily until some final minimum value is reached; this agrees well with other studies.²⁰ Above CPVC, however, the reflectance passes through a minimum and one of two things can occur. The change in reflectance can increase to a final value higher than the initial value, or the reflectance can increase to a final value lower than the initial value. Classic spectroscopic methods would be unable to distinguish the first two cases. These three cases, designated as I, II, or III, are:

Case I: The hiding decreases to a final value ($0 > \Delta Y_f = \Delta Y_m$); the paint is below CPVC.

Case II: The hiding decreases to a relative minimum, then increases to a final value smaller than the initial value ($0 > \Delta Y_f > \Delta Y_m$); the paint is above CPVC.

Case III: The hiding decreases to a relative minimum, then increases to a final value greater than the initial value ($\Delta Y_f > 0 > \Delta Y_m$); the paint is above CPVC.

These cases are graphically presented in Figure 2.

Films which dry without a relative minimum are below CPVC (Case I). Films which have a relative minimum are above CPVC, regardless of the final reflectance values (Case II or III). In conjunction with a PVC ladder, this method can easily determine CPVC (Figure 1). For each PVC ladder studied, the onset of the minimum in the drying curves was shown to correspond to CPVC. Correlation to other methods of determining CPVC (K&N Ink staining, 85° sheen, contrast ratio and rewet with mineral oil) were all very good and, in the absence of a PVC

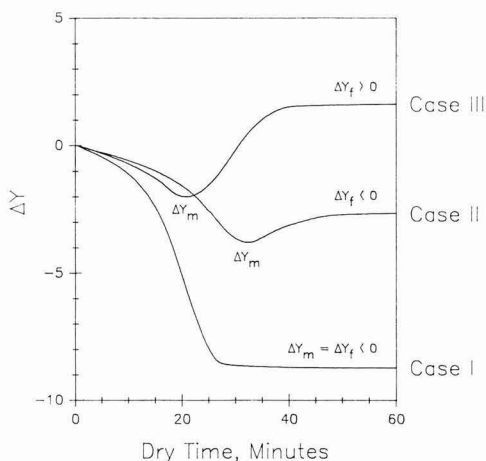


Figure 2—Three types of behavior in the changes in hiding during drying

Table 1—Test Formulas

Formula #1—50% PVC CaCO ₃			Formula #2—70% PVC CaCO ₃		
	Pounds	Gallons		Pounds	Gallons
Water	300.00	35.97	Water	300.00	35.97
Ethylene glycol	25.00	2.69	Ethylene glycol	25.00	2.69
Hydroxyethyl cellulose ^a	5.50	0.48	Hydroxyethyl cellulose	7.50	0.65
Dispersant 35% ^b	9.75	1.06	Dispersant 35%	12.45	1.35
2-Amino-2-methyl-1-propanol ^c	2.00	0.26	2-Amino-2-methyl-1-propanol	2.00	0.26
Package preservative ^d	2.00	0.22	Package preservative	2.00	0.22
Defoamer ^e	2.00	0.27	Defoamer	2.00	0.27
Titanium dioxide, Type II ^f	150.00	4.50	Titanium dioxide, Type II	150.00	4.50
CaCO ₃ ^g	337.40	15.00	CaCO ₃	472.40	21.00
Water	148.94	17.86	Water	196.03	23.51
Nonionic surfactant ^h	2.00	0.23	Nonionic surfactant	2.00	0.23
Defoamer ^e	2.00	0.27	Defoamer	2.00	0.27
Coalescent ⁱ	6.10	0.77	Coalescent	2.61	0.33
PVA latex 55% ^j	184.87	20.43	PVA latex 55%	79.23	8.75
	1177.55	100.00		1255.22	100.00

Disperse first nine items at high speed.
Let down with remaining items in order listed.

Disperse first nine items at high speed.
Let down with remaining items in order listed.

	By Weight	By Volume
Total solids, %	51.46	31.77
Additives as 100% volatile, %	50.03	30.00
Total pigment, %	41.39	19.50
PVC, %	—	65.00
Pigment/Binder	4.79	

	By Weight	By Volume
Total solids, %	54.61	31.99
Additives as 100% volatile, %	53.06	30.00
Total pigment, %	49.58	25.50
PVC, %	—	85.00
Pigment/Binder	14.28	

(a) Cellosize QP-4400H, Union Carbide.

(b) Tamol 731, Rohm and Haas.

(c) AMP-95, ANGUS.

(d) Cosan 145, Hills America.

(e) PA-188, U.S. Movidyn.

(f) Ti-Pure R-900, Du Pont.

(g) Vicron Ground Limestone, Pfizer.

(h) Igepal CTA-639, GAF.

(i) Texanol, Eastman.

(j) Ucar 367, Union Carbide.

ladder, a rapid determination of whether a paint is above or below CPVC was possible.

In order to explore what insights this technique could offer into other PVC/CPVC related phenomena, the Cleveland Society Technical Committee undertook a study to monitor pigment packing effects at constant PVC. A three-component system consisting of titanium dioxide (TiO₂), a fine particle calcium carbonate (CaCO₃) and a coarse particle CaCO₃ was used.

TEST PAINTS

The starting formulation was a 30% nonvolatile by volume (NVV) latex flat enamel containing 15% PVC (approximately 150 lb/100 gal) of ASTM D 476-84 Type II rutile TiO₂. For our investigations, two versions containing 50% PVC (approximately 337 lb/100 gal) of calcium carbonate and 70% PVC (approximately 472 lb/100 gal) of calcium carbonate would be needed. The total PVC of each version would then be 65 and 85%, respectively (Table 1). The volume solids chosen were typical of many interior trade sales latex paint formulations; the TiO₂ level was slightly lower than typical so that changes in hiding could be more easily measured.

To study changes in hiding resulting from various pigment packing arrangements, two commercially available calcium carbonates, whose mean particle size differed by an order of magnitude (2.1 μm vs 11.5 μm), were used. First, a version containing 50% PVC of extender and 70%

PVC of extender for each calcium carbonate was prepared. Then, for each CaCO₃ extender, the 50 and 70% PVC formulations were then blended to give additional PVC levels of 55, 60, and 65%. Finally, paints containing both fine and coarse particle size CaCO₃, at the same PVC, were further blended to give eleven paints containing a ratio of fine to coarse CaCO₃ ranging from 0 to 100% in increments of 10% (expressed as percentage of coarse CaCO₃ of the total extender system).

In all, 55 paints were investigated in this study. Physical properties of the pigments appear in Table 2, and Figure 3 shows the particle size distributions for each pigment as determined by sedigraph.

RESULTS

Pigment packing effects were studied by first running each paint on the spectrophotometer to generate reflectance data. Five PVC ranges were chosen from 65% PVC (15% PVC TiO₂ and 50% PVC CaCO₃) to 85% PVC (15% PVC TiO₂ and 70% PVC CaCO₃). These particular PVCs were chosen to bracket a range where previous experience had shown paints would be produced both above and below the CPVC, depending on the particle size of extender used. In this way, as the ratio of coarse to fine particle extender varied, the transition from above to below CPVC would occur.

For each coating a drying curve was run and changes in hiding (ΔY) were determined (Table 3). The depth of the

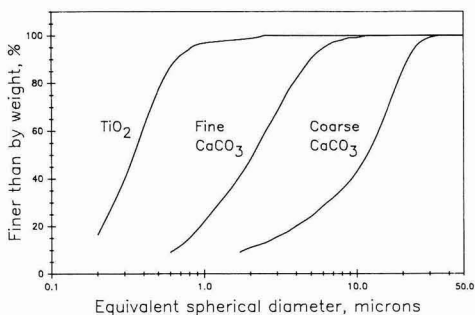


Figure 3—Particle size distribution curves for TiO₂, fine particle CaCO₃, and a coarse particle CaCO₃

Table 2—Pigments

	TiO ₂ ^a	CaCO ₃	
		Coarse part. size ^b	Fine part. size ^c
Density, lb/gal	33.3	22.57	22.57
Refractive index	2.73	1.59	1.59
Oil Absorption			
Rub-out ^d	16.0	15.5	23.0
Mean particle size, microns ^e	0.35	11.5	2.1
Brightness, %	96 ^f	95 ^g	96 ^g
Surface Area, m ² /gm	—	1.4	4.5

- (a) Ti-Pure R900, Du Pont.
- (b) Vicron 41-8, Pfizer.
- (c) Vicron 10-20, Pfizer.
- (d) ASTM D 281-84.
- (e) Edge Moor Sedigraph.
- (f) G.E. Brightness.
- (g) "Rd" Reading—Hunter D25-9.

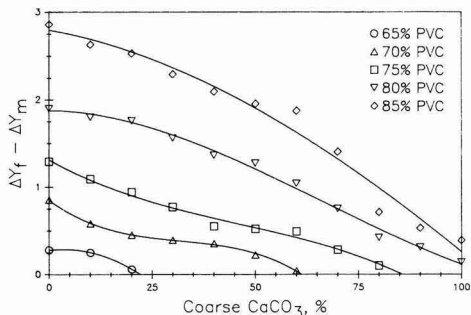


Figure 4A—Changes in reflectance from relative minimum to final value as a function of CaCO₃ ratio (expressed as percent coarse CaCO₃)

relative minimum for each curve ($\Delta Y_f - \Delta Y_m$) was calculated for each blend and these values were then plotted versus the ratio of fine to coarse particle CaCO₃, expressed as percent coarse (Figure 4A). In Figure 4B these values are plotted as a function of PVC for the 0, 30, 50, 70, and 100% coarse CaCO₃ extender systems.

As expected, with a lower oil absorption pigment, $\Delta Y_f - \Delta Y_m$ decreased, as the percentage of coarse CaCO₃ increased. For three of the PVC levels studied, this value was zero, at an extrapolated ratio of 22% coarse CaCO₃ for the ladder containing 50% PVC extender, at 61% for the ladder containing 55% PVC extender, and at 85% for the ladder containing 60% PVC of extender. Since the PVC of the coatings is not changing, this point describes the pigment blend that gives a particle packing such that CPVC of the paint is equal to the PVC of the pigment ratio ladder; that is, where the reduced PVC (Λ) equals 1.²

ADDITIONAL TESTING

Other methods to determine CPVC, both experimental and theoretical, were used to correlate the reflectance data. The experimental methods include the following.

CONTRAST RATIO: Where a drawdown over a black and white sealed chart is used. The reflectance of the film over the black substrate (Y_b) divided by the reflectance of the film over the white substrate (Y_w) is reported. Generally, this quantity decreases with increasing PVC until CPVC is reached, then it increases.²¹

85° SHEEN: Measured on a drawdown over a sealed white chart that was allowed to dry for one week at ambient temperature. Minimum sheen occurs at CPVC.²²

K&N INK: Where the change in reflectance before and after the application of staining medium is measured on a drawdown made over a sealed white chart which is allowed to dry for one week at ambient temperature. The decrease in reflectance ($-\Delta Y_w$) is reported. This quantity increases slowly with increasing PVC until CPVC is reached, then increases rapidly.²³

REWET WITH MINERAL OIL: Where the oil is considered to have the same refractive index as binder. Drawdowns

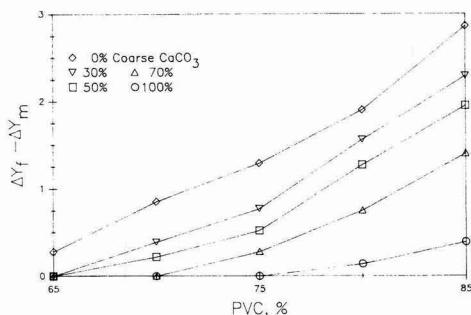


Figure 4B—Changes in reflectance from relative minimum to final value as a function of PVC

Table 3—Reflectance During Drying for a Three Component System at Different PVCs

TiO ₂	PVC, %		Extender blends ^a	Y _i	ΔY _m	ΔY _f	ΔY _f - ΔY _m
	Extender						
15	50		0	92.49	6.53	6.25	0.28
			10	91.96	7.58	7.33	0.25
			20	92.11	8.16	8.10	0.06
			30	92.01	8.75	8.75	0.00
			40	91.73	8.14	8.14	0.00
			50	91.79	9.50	9.50	0.00
			60	91.25	9.65	9.65	0.00
			70	91.15	9.60	9.60	0.00
			80	91.26	10.63	10.63	0.00
			90	91.00	10.05	10.05	0.00
			100	91.12	10.98	10.98	0.00
15	55		0	91.66	5.41	4.56	0.85
			10	92.21	5.54	4.96	0.58
			20	92.02	6.92	6.47	0.45
			30	91.82	7.15	6.76	0.39
			40	91.20	8.00	7.65	0.35
			50	91.58	8.16	7.94	0.22
			60	91.81	8.49	8.45	0.04
			70	91.33	9.56	9.56	0.00
			80	91.04	9.87	9.87	0.00
			90	90.92	10.66	10.66	0.00
			100	91.00	10.07	10.07	0.00
15	60		0	91.93	4.25	2.96	1.29
			10	91.60	4.28	3.19	1.09
			20	91.64	4.81	3.87	0.94
			30	91.90	5.23	4.46	0.77
			40	91.36	6.58	6.03	0.55
			50	91.41	6.30	5.78	0.52
			60	91.49	6.03	5.54	0.49
			70	90.70	7.99	7.71	0.28
			80	91.24	8.14	8.04	0.10
			90	90.87	9.27	9.27	0.00
			100	91.20	9.91	9.91	0.00
15	65		0	92.02	3.71	1.81	1.90
			10	91.47	4.12	2.32	1.80
			20	91.49	4.70	2.94	1.76
			30	91.32	4.88	3.32	1.56
			40	90.82	5.56	4.20	1.36
			50	91.32	5.49	4.22	1.27
			60	91.46	5.87	4.83	1.04
			70	90.71	6.98	6.23	0.75
			80	90.47	6.91	6.49	0.42
			90	90.49	8.08	7.77	0.31
			100	90.68	8.39	8.25	0.14
15	70		0	91.73	3.59	0.73	2.86
			10	91.67	3.68	1.05	2.63
			20	91.65	4.02	1.49	2.53
			30	92.15	3.74	1.45	2.29
			40	91.36	4.50	2.41	2.09
			50	91.54	4.15	2.20	1.95
			60	91.18	4.98	3.11	1.87
			70	90.76	5.60	4.20	1.40
			80	91.21	5.92	5.21	0.71
			90	90.78	6.90	6.37	0.53
			100	90.67	7.30	6.91	0.39

(a) Ratio of fine particle size extender to coarse particle size extender, expressed as percent coarse particle size extender.

over a sealed black chart are allowed to dry for one week of ambient temperature and reflectance measurements are taken before and after rewetting. Decrease in reflectance ($-\Delta Y_b$) is reported. Below CPVC, this value is very small; above CPVC, it increases rapidly with increasing PVC.

ABRASIVE SCRUB RESISTANCE: Where paints are drawn down over a black plastic chart, dried for one week at ambient temperature and scrubbed over a shim with an abrasive media until failure. Cycles to failure are reported. Scrub resistance decreases rapidly with PVC until CPVC is reached. Further PVC increases cause a slow decline in this value.²⁴

The results of these tests are given in Table 4 and represented graphically in Figures 5A-5E and Figures 6A-6E.

DISCUSSION

Earlier work by the Cleveland Society Technical Committee¹⁸ had shown that the presence or absence of a relative minimum in the drying curves can be related to the presence or absence of voids in the paint film. Mathematically:

$$\text{If } \Delta Y_f - \Delta Y_m > 0, \text{ then PVC} > \text{CPVC} \quad (2)$$

It was a straightforward procedure to spectroscopically determine the value of $\Delta Y_f - \Delta Y_m$ and graph it either as a function of PVC, or as a function of percent coarse CaCO_3 for each PVC ladder prepared. In the earlier work, blends which varied PVC of TiO_2 while keeping overall PVC constant, by removal of extender, showed that it is possible to be either above or below CPVC as the ratio of TiO_2 to calcium carbonate was varied. In that experiment, the overall PVC was kept constant at 60%. It was felt that those results could be explained by pigment packing effects.^{4,5,15} The curves generated in the present study are interesting because they graphically show these effects.

Work by Stieg,¹⁶ and others,^{11,24} have shown that extender dilution efficiency, that is, the ability of the extender to space TiO_2 , could be used to explain how coarse particle sized extenders actually crowd TiO_2 together and have a poor dilution efficiency. Fine particle size extenders act more as spacers and enhance hiding. It was also shown that even though fine extenders generally increase the hiding and improve the film integrity, this is true only so far as binder demand (CPVC) is not exceeded.¹⁵

The current results are particularly interesting because they appear to be much more sensitive to the changes involved in the blending of different particle size pigments compared to other experimental methods. Figures 5A-5E are classical renderings of property versus PVC curves for the 0, 30, 50, 70, and 100% coarse CaCO_3 pigment blends. As shown, when only five PVC data points are available, a large degree of intuition is required to obtain an accurate value for CPVC. Also, when graphed in this manner, pigment packing effects are not apparent. $\Delta Y_f - \Delta Y_m$ versus PVC would easily give information to when the ladder was above or below

CPVC (Figure 2) by quick inspection. Although an accurate determination of the CPVC would require several more blends, the estimate available from the onset of a minimum would at most be off by five percent (the range between PVC blends).

Figures 6A-6E are curves graphing the result of additional testing versus the different ratios of extenders at constant PVC. This testing included contrast ratio, 85° sheen, K&N Ink, rewet with mineral oil, and abrasive scrub resistance. Each test will be discussed separately with reference to these graphic results. Superimposed on each graph (except 85° sheen) is a dotted line which separates regions of above and below CPVC as determined by the presence of a relative minimum during drying ($\Delta Y_f - \Delta Y_m > 0$). The experimental data is given in Table 4.

Contrast Ratio

Using the classical format of graphing contrast ratio versus PVC (Figure 5A), one does not see large changes in slope which usually indicate the CPVC. When a dotted line which delineates the areas above and below CPVC, as determined by relative minimums in the drying curves, is added, slight transitions are visible where the different measurements intersect. It is evident that having more PVC data points would not help the determination given the relative smoothness of these curves.

The curves for contrast ratio versus ratio of extenders at constant PVC (Figure 6A) show a general decrease in Y_b/Y_w as the percent of coarse CaCO_3 increases. The major reason for this is due primarily to the poorer dilution efficiency of the coarse CaCO_3 which results in reduced hiding. For example, the effects of extender dilution efficiency can be seen by calculating the hiding power for the 75% PVC paint containing 60% PVC extender at the 0% coarse (100% fine) and 100% coarse CaCO_3 levels:¹⁵

$$\text{Effective TiO}_2 \text{ PVC} = \frac{\text{Vol TiO}_2}{\text{Vol TiO}_2 + (\text{Vol Extender} \times E_d) + \text{Vol Binder}} \quad (3)$$

and,

$$\text{HP} = 370 - 409 (\text{Effective TiO}_2 \text{ PVC})^{1/3} \quad (4)$$

Where: HP = hiding power per lb TiO_2
 E_d = extender dilution efficiency

Typical E_d values for a fine and a coarse particle size calcium carbonate are 0.30 and 0.00, respectively.¹⁶ This would give a hiding power of 92.45 for the paint containing all fine CaCO_3 vs 45.37 for the paint containing all coarse CaCO_3 . This is consistent with the experimental results.

The effect of increasing PVC on hiding can also be seen in Figure 6A. Contrast ratio (hiding) increases as PVC increases, mainly due to dry hiding effects. Because contrast ratio is a nonlinear function (has a maximum value of 1.0) these curves tend to compress as PVC is increased (an incremental increase in PVC results in a much smaller increase in hiding). This tendency is consistent throughout the pigment ratio blends.

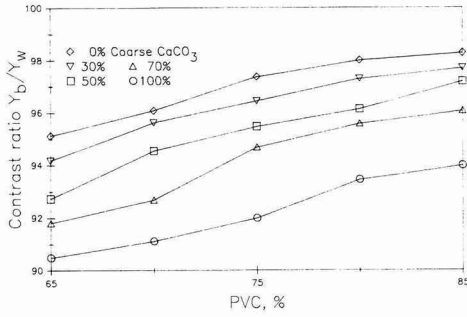


Figure 5A—Contrast ratio as a function of PVC

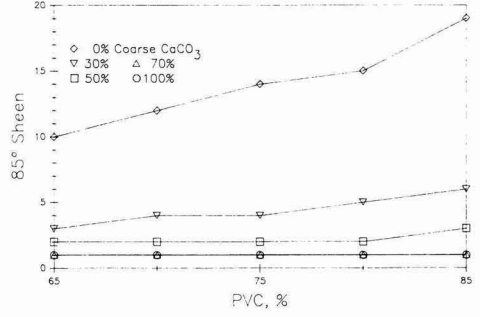


Figure 5B—85° sheen as a function of PVC

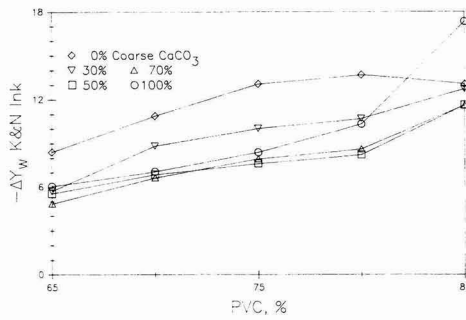


Figure 5C—K&N Ink as a function of PVC

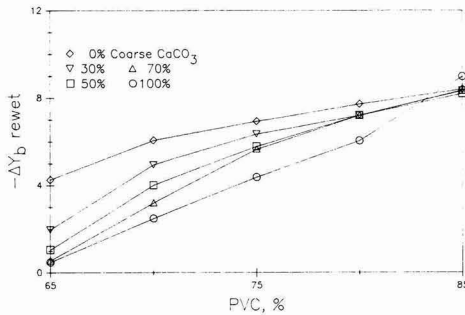


Figure 5D—Rewet with mineral oil as a function of PVC

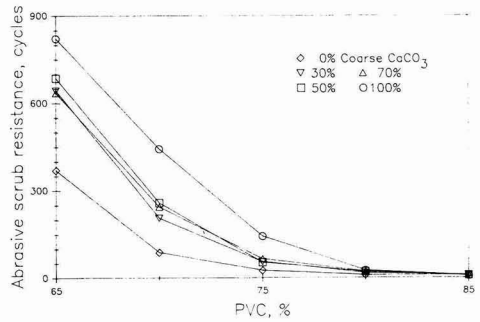


Figure 5E—Abrasive scrub resistance as a function of PVC

**Cleveland Society
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85° Sheen

The 85° sheen is used as a method to determine CPVC by monitoring what are essentially gross morphological differences as PVC of a coating changes (Figure 5B). Usually, the test shows a minimum to signal CPVC. As plotted in (Figure 6B), the curves represent blends of constant PVC paints. As such, if pigment packing were not an issue, the curves would be straight lines. It would then be possible to use that straight line curve to predict the sheen of any particular extender mixture. When packing effects are considered, the curves generated by the data are quite reasonable. In general, at high ratios of fine extender, an increase in PVC increases the sheen. This agrees well with theory.²²

For any given PVC, as coarse extender ratio was increased, the sheen decreased. This was due to two effects. The fine particle CaCO₃ has higher oil absorption producing paints which are substantially above CPVC. As percent coarse CaCO₃ increases, CPVC increases and since PVC does not change, these two values approach each other. The closer they are the better the sheen. Secondly, fine CaCO₃ has fewer surface irregularities giving higher overall sheens. This is predominately why an increase in PVC of paints containing a high loading of coarse CaCO₃ did not increase in sheen.

K&N Ink

The basic premise of this test is that an increase in PVC will eventually lead to an increase in film porosity as CPVC is reached and binder demand of the pigment present is no longer satisfied. At values below CPVC, the film should be essentially nonporous and the K&N Ink does not stain as heavily and changes in reflectance ($-\Delta Y_w$) are not as great. When the results are graphed in this classical way (Figure 5C), the ability to distinguish between coatings which are above and below the CPVC is difficult.

Using changes in reflectance versus pigment ratio (Figure 6C) the results show that as the percent of coarse extender increases, the porosity of the film decreases and reflectance changes decrease. This is primarily due to the difference in oil absorption of the fine versus the coarse

extender. Therefore, the general trends of the curves are consistent with theory.

Increasing PVC causes compression of the curves at the higher levels of fine extender pigment. It is believed that this occurs because Λ at 0% coarse extender is higher than at 100% coarse extender for any given PVC. Therefore, 0% coarse for 85% PVC is close to the limit of porosity which results in poorer film integrity.

Some of the curves have minima which may be due to pigment packing effects. The minima are generally present at higher ratios of coarse to fine extender and at the higher PVCs.

Rewet with Mineral Oil

Rewet with mineral oil is another method which uses the presence of voids, presumably caused by a decrease of available binder, to pinpoint CPVC. Several of the factors governing the K&N Ink test are present here and can be seen in the results graphed in Figures 5D and 6D. For this test, the classical curves (Figure 5D) are somewhat better at discerning where CPVC occurs, but starting at lower PVC would probably have highlighted this transition.

The curves varying the pigment ratios (Figure 6D) tend to compress and level off as PVC is increased and the limit of porosity is reached. Inflection points are more defined in these curves and indicate packing effects. Inflections seem to coincide with the dashed line of CPVC determination.

Abrasive Scrub Resistance

Scrub resistance is one of the more tedious and time consuming of the tests used to determine CPVC from a PVC ladder. The gradual changes in reduced PVC result in very little change in abrasive scrub to indicate where CPVC occurs (Figures 5E and 6E). Compared to the onset of a minimum, this test is very insensitive. Inflections in the curve coincide with the experimentally determined CPVC, but these and other inflections in the curve are more likely due to packing effects.

Compression of the curves at higher PVC is visible as in all of the previously discussed data.

$$\Delta Y_f - \Delta Y_m$$

Unlike the previously discussed methods used to study changes in PVC, determine CPVC and indirectly study pigment packing effects, none has shown the ease and sensitivity of the method developed by the Cleveland Society Technical Committee. The data graphically presented in Figures 4A and 4B clearly show when regions are above or below CPVC. These areas are not obvious from the other data.

The method shows extender dilution effects and hiding variations due to changes in oil absorption and film porosity, as well as packing effects which occur as mean particle size varies. The sensitivity of the method can be shown by considering the transition from 50 to 40% coarse CaCO₃. If no packing effects are assumed, oil absorptions of the blends can be calculated by a simple weighted average of the oil absorption of each extender

Table 4—Dry Film Properties for Extender Blends at Different PVCs

PVC	Extender blends ^a	Contrast ratio ^b	85° Sheen ^c	Reflectance Change		Abrasive scrub ^f
				K&N Ink, - ΔY_w ^d	Rewet - ΔY_e ^e	
65	0	95.13	10	8.41	4.26	369
	10	95.12	7	7.65	3.44	377
	20	94.64	5	5.58	2.64	577
	30	94.18	3	5.72	1.98	644
	40	93.50	2	6.13	1.51	675
	50	92.73	2	5.54	1.06	686
	60	92.05	1	4.83	0.75	657
	70	91.80	1	4.85	0.56	635
	80	91.07	1	4.97	0.58	752
	90	90.42	1	5.26	0.34	836
	100	90.49	1	6.05	0.44	822
70	0	96.08	12	10.88	6.06	87
	10	96.44	8	8.83	5.48	175
	20	96.17	6	8.57	5.38	233
	30	95.62	4	8.83	4.94	205
	40	94.75	3	8.57	4.45	200
	50	94.55	2	6.86	4.01	257
	60	93.97	1	7.35	3.87	283
	70	92.68	1	6.63	3.20	243
	80	92.79	1	5.90	2.74	291
	90	91.60	1	6.64	2.42	445
	100	91.11	1	7.06	2.49	422
75	0	97.37	14	13.06	6.93	25
	10	97.53	9	11.22	6.65	30
	20	97.09	6	11.40	6.50	47
	30	96.45	4	10.02	6.35	55
	40	95.55	2	8.54	6.21	60
	50	95.48	2	7.61	5.78	53
	60	95.72	2	8.69	6.22	40
	70	94.69	1	7.93	5.65	65
	80	93.70	1	8.95	5.73	100
	90	93.14	1	9.38	4.77	106
	100	91.99	1	8.38	4.37	143
80	0	98.00	15	13.68	7.72	9
	10	97.75	11	12.19	7.43	13
	20	97.79	7	11.58	7.20	13
	30	97.29	5	10.70	7.20	16
	40	96.66	3	10.26	7.28	19
	50	96.14	2	8.22	7.20	20
	60	96.36	2	9.77	7.15	22
	70	95.58	1	8.61	7.20	21
	80	94.80	1	9.31	6.81	24
	90	94.30	1	9.82	6.72	25
	100	93.45	1	10.32	6.04	25
85	0	98.27	19	13.03	8.40	9
	10	98.30	13	13.57	8.40	8
	20	97.98	9	13.76	8.37	8
	30	97.70	6	12.72	8.34	9
	40	97.41	4	12.89	8.47	9
	50	97.18	3	11.62	8.19	8
	60	96.80	2	11.32	8.21	8
	70	96.06	1	11.60	8.32	7
	80	95.56	1	12.45	8.43	7
	90	94.74	1	13.50	8.55	7
	100	93.98	1	17.33	8.98	7

(a) Ratio of small particle size extender to large particle size extender expressed as percent coarse particle size extender.
 (b) ASTM D 2805-88.
 (c) ASTM D 523-80.
 (d) ASTM D 3258-80.
 (e) Decrease in reflectance when dry film over black substrate is rewet with mineral oil.
 (f) ASTM D 2486-78.

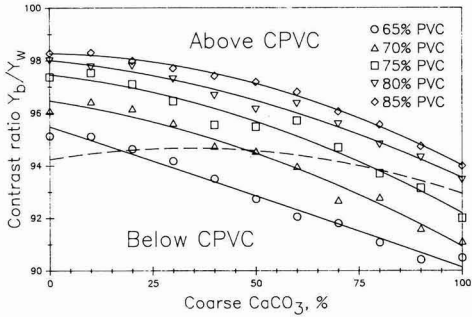


Figure 6A—Contrast ratio as a function of CaCO₃ ratio (expressed as percent coarse CaCO₃)

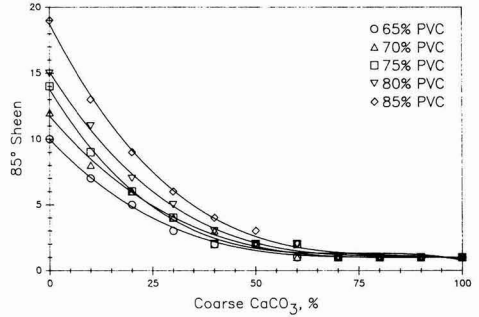


Figure 6B—85° sheen as a function of CaCO₃ ratio (expressed as percent coarse CaCO₃)

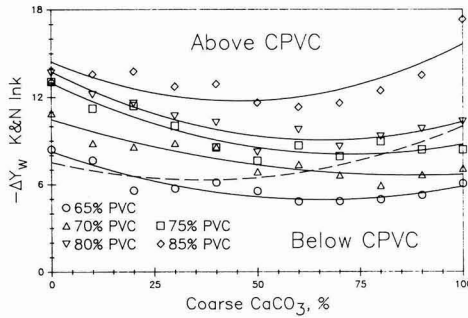


Figure 6C—K&N Ink as a function of CaCO₃ ratio (expressed as percent coarse CaCO₃)

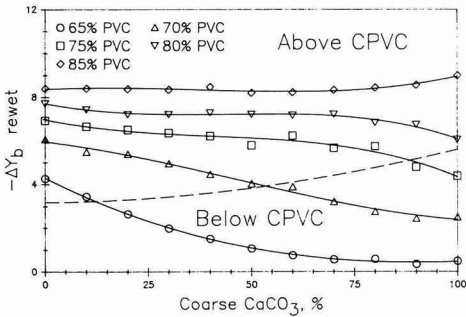


Figure 6D—Rewet with mineral oil as a function of CaCO₃ ratio (expressed as percent coarse CaCO₃)

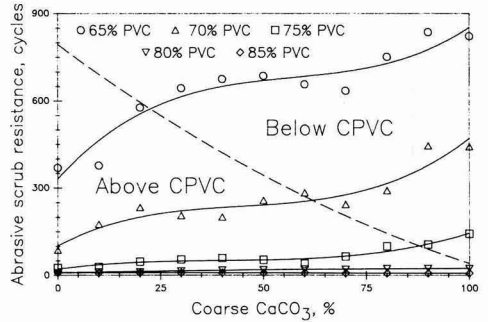


Figure 6E—Abrasive scrub resistance as a function of CaCO₃ ratio (expressed as percent coarse CaCO₃)

pigment separately. This calculation shows that, at a 60% PVC extender level, going from a 50 to 40% coarse CaCO₃ is approximately the same as increasing PVC of the 50% coarse paint to 62.3%. While these "Effective PVC" changes are not seen in any of the other testing performed, this method easily discerns these transitions, and in particular, the reduced PVC of the coating (Λ).

Packing Factors

The mixing of multiple component systems has been considered by Lee,⁷ and others.^{4,25} By calculating the packing factors, using a method outlined by Patton,²⁶ and graphing them versus percent coarse CaCO₃, a value for the blend which would result in the best packing could be determined. In order to calculate packing factors for the mixture, packing coefficients which relate a larger to a smaller particle group, and one which relates a smaller to a larger particle group need to be determined.

For these calculations, the values were read directly from the graph offered by Patton.²⁶ These values are listed in Table 5. Using the experimentally determined values for mean particle size and the volume ratios of pigments, the packing factors were calculated for the entire blend series. The following equations were used to derive the packing factor of the mixture (Φ_m) for each blend:

$$(\Phi_m)_s = 0.639v_s + \Phi_{si}v_i + \Phi_{si}(1 - v_s - v_i) \quad (5)$$

$$(\Phi_m)_i = \Phi_{is}v_s + 0.639v_i + \Phi_{ii}(1 - v_s - v_i) \quad (6)$$

$$(\Phi_m)_l = \Phi_{ls}v_s + \Phi_{li}v_i + 0.639(1 - v_s - v_i) \quad (7)$$

Where: (Φ_m)_s, (Φ_m)_i and (Φ_m)_l are the packing factors for the three systems possible, Φ_{is} is the packing coefficient used in relating a larger to a smaller particle group, Φ_{si} is the packing coefficient used relating a smaller to a larger particle group,

Table 5—Packing Factors and Constants For Φ_m Determinations

PVC of titanium dioxide.....	15%
Mean Particle Diameter.....	0.35 μ
Ratio of Pigment Diameters.....	1:6:32.86

Φ _{si}	Φ _{is}
Φ _{1:6} = 0.870	Φ _{6:1} = 1.075
Φ _{6:32.86} = 0.850	Φ _{32.86:6} = 1.020
Φ _{1:32.86} = 0.930	Φ _{32.86:1} = 1.364

Optimum Packing Factor Φ_m (calculated)

% Coarse	Total PVC of Coating				
	65%	70%	75%	80%	85%
0.....	0.739	0.733	0.726	0.721	0.716
10.....	0.756	0.749	0.743	0.738	0.733
20.....	0.772	0.766	0.760	0.755	0.751
30.....	0.788	0.782	0.777	0.772	0.768
40.....	0.805	0.799	0.794	0.789	0.785
50.....	0.821	0.815	0.811	0.806	0.803
60.....	0.837	0.832	0.828	0.824	0.820
70.....	0.849	0.848	0.844	0.841	0.838
80.....	0.854	0.854	0.845	0.837	0.830
90.....	0.844	0.824	0.815	0.806	0.798
100.....	0.806	0.794	0.784	0.775	0.767

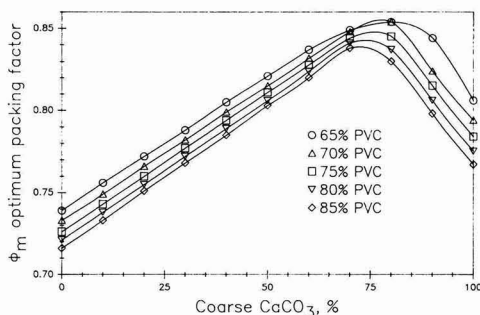


Figure 7—Calculated packing factor as a function of CaCO₃ ratio (expressed as percent coarse CaCO₃)

Φ_{si}, Φ_{is}, Φ_{li} and Φ_{il} are the packing coefficients necessary for including a third, intermediate sized particle, and

v_s, v_i and v_l are the volume fractions of the fine, intermediate and coarse particles, respectively.

For theoretical considerations, the lowest packing factor of the three calculated is considered the correct factor for the mixture. The lowest factor calculated for each blend was graphed versus coarse particle size concentration and is presented in Figure 7.

The packing factor can be used to estimate the point at which the ratio of fine to coarse particle extender is above or below CPVC. In general, when the packing factor for a blend is greater than PVC of that blend, the blend is below CPVC and conversely, when the packing factor is less than PVC, the blend is above CPVC.

Inspection shows that the calculations predict higher packing factors than the experimentally determined results. It must be remembered that the equations assume monodisperse spherical particles, without an adsorbed binder layer. Other researchers,^{4,6} have attempted to refine the assumptions to better predict packing. The results are encouraging, but the need for sophisticated computer calculations continue to make these methods far from routine. The use of ΔY_f - ΔY_m to experimentally see these transitions is much preferred.

SUMMARY

The ability to monitor changes in hiding during the film forming process has resulted in a new experimental tool to study a variety of film properties. This method is very sensitive to the transitions occurring during the blending of fine and coarse extender particles. Compared to other physical test methods, it has also been shown to be a simpler yet more powerful technique for the study of these transitions. In the study of pigment particle packing and its effects on the reduced PVC (Λ), the information derived from a direct observation of hiding changes is preferred to methods which infer this point from secondary effects. The results tend to confirm models of pigment packing which require consideration be given to the actual shape and a possible adsorbed binder layer when

predictions are attempted. Further studies to investigate solvent-based systems are being considered as well as studies to determine how severely microvoid pigments will effect the method.

ACKNOWLEDGMENTS

We would like to thank the following organizations for their cooperation and support in conducting these studies: Akron Paint and Varnish, Inc.; Case Western Reserve University; Coatings Research Group, Inc.; Day-Glo Color Corp.; E. I. du Pont de Nemours & Co., Inc.; Engelhard Corp.; Kent State University; Pfizer, Inc.; Plasti-Kote Co.; Seegott, Inc.; Sherwin-Williams Co.; and Tremco, Inc.

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Coupling Solvent Effects On Water-Reducible Alkyd Resins

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This research examined the coupling ability of various solvents, primarily glycol ethers, and the effect of glycol ether solvents on the stability of water-reducible alkyd resins. Perceived toxicity concerns with ethylene glycol n-butyl ether, EB, an ethylene-based (referred to as E-Series) glycol ether, have resulted in requests for propylene-based (P-Series) glycol ether alternatives.

This study characterized the effects of alternative solvents to EB on two alkyd resin systems. An accelerated aging study was employed to determine solvent performance in these alkyd systems.

It was determined that coupling performance data can be used as a predictive tool for determining initial viscosity of these alkyd systems. Data from the aging study demonstrated that P-Series glycol ethers and blends of P-Series and C4 alcohols exhibit equivalent behavior to EB with respect to stability of the resin system.

INTRODUCTION

This research examined the coupling ability of various solvents and solvent blends. Primary emphasis was on glycol ether solvents and C4 alcohols. The effect of glycol ether solvents on the stability of water-reducible alkyd resins was also examined. This work is important as the combination of higher solvent prices, increased energy costs, and VOC emission regulations has led to greater emphasis on technologies such as water-reducible coatings. Ethylene glycol n-butyl ether (EB) is the glycol ether most often used in water-reducible systems due to its good solvency properties and superior coupling efficiency. Perceived toxicity concerns with EB, an ethylene-based (referred to as E-Series) glycol ether, have resulted in requests for propylene-based (P-Series) glycol

ether alternatives. However, current studies indicate that EB can be used safely, commensurate with good industrial hygiene practices.

This study characterized the effects of alternative solvents to EB. The solvents for study were selected through use of the CHEMCOMPSM Program and coupling performance data. An accelerated aging study verified the alternative solvents' performance.

The resins utilized in the aging study were water-reducible, chain stopped alkyds. As the name implies, these resins can be diluted with water with the assistance of neutralizing agents and solvents such as glycol ethers and alcohols. The glycol ethers function in these systems to solubilize the resin and as coupling agents. They create and maintain a homogeneous solution between the organic (resin) and aqueous phases. This study showed that coupling performance data can be used as a predictive tool to determine initial viscosity for these alkyd systems. Data which demonstrated equivalent stability behavior of P-Series glycol ethers and blends of P-Series glycol ethers and C4 alcohols to the EB/secondary butyl alcohol (sBOH) control blend was generated in the aging study.

EXPERIMENTAL

The experimental design of this study consisted of four major segments. A schematic of the design is given in *Figure 1*. The design was divided into four main parts: solvent selection, coupling performance, an aging study, and an analysis of the results.

Solvent Selection

The CHEMCOMP Program was utilized for solvent selection. CHEMCOMP is a series of computerized solvent modeling programs that allow solvents to be com-

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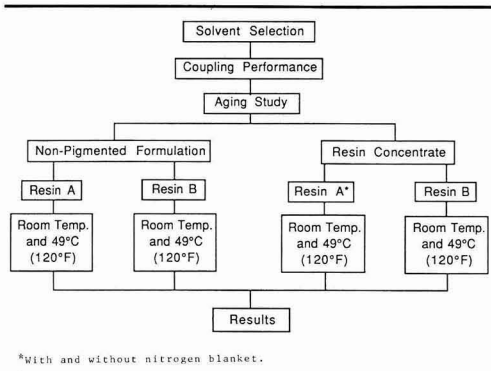


Figure 1—Experimental design

pared by physical properties. The Solvent Blend Program, a module of CHEMCOMP, was used to determine potential P-Series and alcohol blends that were suitable for the resins that were obtained for the study.

The Solvent Blend Program compared the solvency characteristics of a target solvent or blend to an extensive data base of over 200 solvents. Solubility parameters, hydrogen bonding parameters, and dipole moment were compared to the standards specified in the target. When the program found a match, it saved the information and looked for additional matches. A typical run involved several thousand searches. The program listed all the matches it found. The list of potential blends was narrowed based on a number of factors. These factors included the number of solvents comprising a blend, flash point and evaporation rate of the P-Series glycol ether, and those alcohols that are used in water-reducible paint formulations. Table 1 lists the nomenclature and structure of solvents used in the study.

Coupling Performance

Culver¹ has defined coupling as a method of compatibilizing a multiphase system that results in an increase in

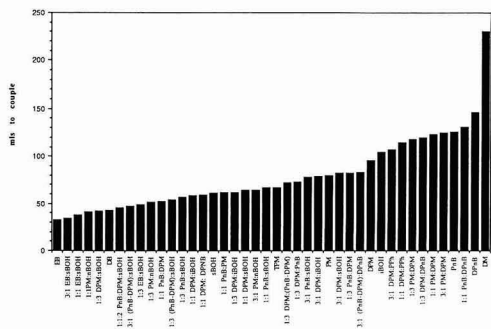


Figure 2—Coupling abilities of glycol ethers and alcohols

Table 1—Chemical Structure of Solvents Used in the Study

<chem>CH3CH2CH2CH2OCH2CH2OH</chem>
Ethylene Glycol n-Butyl Ether (EB)
<chem>CH3CH2CH2CH2OCH(CH3)CH2OH</chem>
Dipropylene Glycol Methyl Ether (DPM)
<chem>CH3CH2CH2CH2OCH2CH(OH)CH3</chem>
Propylene Glycol n-Butyl Ether (PnB)
<chem>CH3CH2CH(OH)CH3</chem>
secondary Butyl Alcohol (sBOH)

the degree of homogeneity of the system. The system chosen for this study was an organic solvent/aqueous mixture containing 10 mL mineral spirits and 10 mL water. The coupling ability of a solvent was the volume of product required to titrate the mineral spirits/water solution to a clear homogeneous solution at 25°C (77°F). The volumetric concentration of a solvent blend was varied at 75%/25%, 50%/50%, and 25%/75% by volume to determine the optimum coupling ability of a blend.

Aging Study

The resins were obtained for the study as 100% solids from two commercial resin manufacturers and, for the purposes of this study, were identified as resin A and resin B. Both resin A and B are chain-stopped alkyds air dry.

Design of the aging study involved evaluating the non-pigmented paint formulations and resin concentrates under real world (i.e., no oxygen control) conditions. Steps involved for both included development of a formulation, sample preparation, heat aging, and analysis. The non-pigmented samples were heat aged at room temperature and 49°C (120°F). For comparative purposes, resin A concentrates were aged under tightly controlled conditions (nitrogen blanketed) at room temperature and 49°C (120°F). Room temperature in this study refers to a constant temperature/humidity room with the temperature held at 24°C (75°F) and a relative humidity of 46%. Both systems were analyzed for percent solids, viscosity, acid value, and molecular weight distribution. Table 2 lists the composition of the aging study samples.

Sample Preparation

NON-PIGMENTED FORMULATIONS: The nonpigmented samples were prepared in batch by chipping out frozen (from conventional freezer) neat resin and adding the appropriate solvent blend, then mixing using a shaker and ball mill. At no time was heat used to solubilize the resin. The samples were then filtered and neutralized dropwise with ammonium hydroxide to a pH of 8.2 to 8.6 prior to

adding the water. Batch samples were then stirred until homogeneous. The batch was then divided into aliquots and placed in sample bottles. One sample bottle of each resin/solvent blend was placed in the oven and the other maintained at room temperature.

RESIN CONCENTRATES: The resin concentrates were prepared in batch by chipping out frozen neat resin then mixing with the appropriate solvent blend. Mixing of batch samples was achieved by alternating between a shaker and ball mill. One sample bottle of each resin/solvent blend was stored at room temperature and another was placed in the oven.

RESIN CONCENTRATES—NITROGEN PURGED/BLANKETED: The resin concentrate oxygen-excluded samples were prepared under a nitrogen blanket in a glove bag. Samples were prepared by chipping out frozen neat resin and adding the appropriate amount of solvent blend. Mixing was achieved by utilizing a modified blender equipped with a nitrogen blanket to exclude oxygen while dissolving/preparing the resin samples. The solution was then poured into individual sample bottles, sealed with Teflon tape, Teflon lids, and electrical tape. Samples were then aged at room temperature and 49°C (120°F).

ANALYSIS

Sampling

Sampling of the nonpigmented formulations and resin concentrate system was accomplished by drawing an aliquot sample from the sample bottles maintained at room temperature and 49°C (120°F) once each week for seven weeks.

For the nitrogen-purged resin concentrates, individual samples of the three solvent blends were aged at room temperature and 49°C (120°F). Sampling was accomplished for each solvent blend by removing one bottle from each temperature weekly. In all cases, samples were allowed to equilibrate to room temperature prior to taking measurements or performing analyses. When analyses were delayed, samples were frozen until time for each analysis.

Viscosity

Measurements for all samples were made using the Wells-Brookfield cone and plate viscometer, model RVT. General procedures were followed as outlined in ASTM Method D 2196-86.

Nonvolatile Content

The nonvolatile content of the nonpigmented formulations and resin concentrate samples was determined by a gravimetric analysis utilizing a forced-ventilation oven. This is a modification of ASTM Method D 1259-85. A 0.5 g sample was weighed and a 0.5 g sample of propylene glycol methyl ether (PM) was placed over the sample to allow the sample to spread out to an even film thickness to allow for evaporation of the solvent. The sample was then placed in the oven at 110°C (230°F) for 30 min,

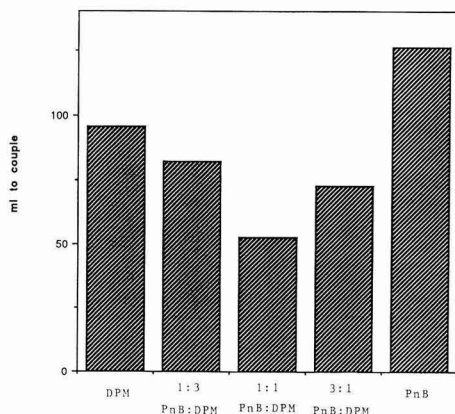


Figure 3—Synergistic effect from blending

weighed, and then placed back into the oven for an additional 30 min and reweighed.

The nonvolatile content of the oxygen controlled resin concentrate samples was measured on a Quintel EV-1 Evaporometer (Figure 3). This is an electronic balance which records the weight loss of a sample as a function of time and, if desired, temperature. For this study, a 0.5 g sample was heated at 149°C (300°F) for 40 min.

Acid Value

Acid value determination was carried out according to ASTM Method D 1980-85, in which a weighed quantity of sample dissolved in ethanol was titrated with potassium hydroxide to the phenolphthalein end point.

Acid Value = $(56.1 \times \text{mL KOH} \times \text{normality of KOH}) / \text{sample weight}$

Molecular Weight Determination

The molecular weight of the alkyd resin in nonpigmented formulation and resin concentrate samples was determined before and after heat aging by size exclusion chromatography. The technique is discussed by Wagenaar.²

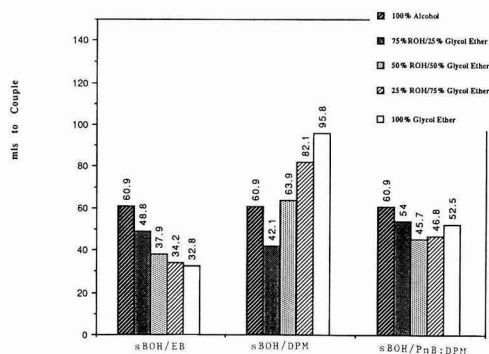


Figure 4—Blends of glycol ethers with sBOH

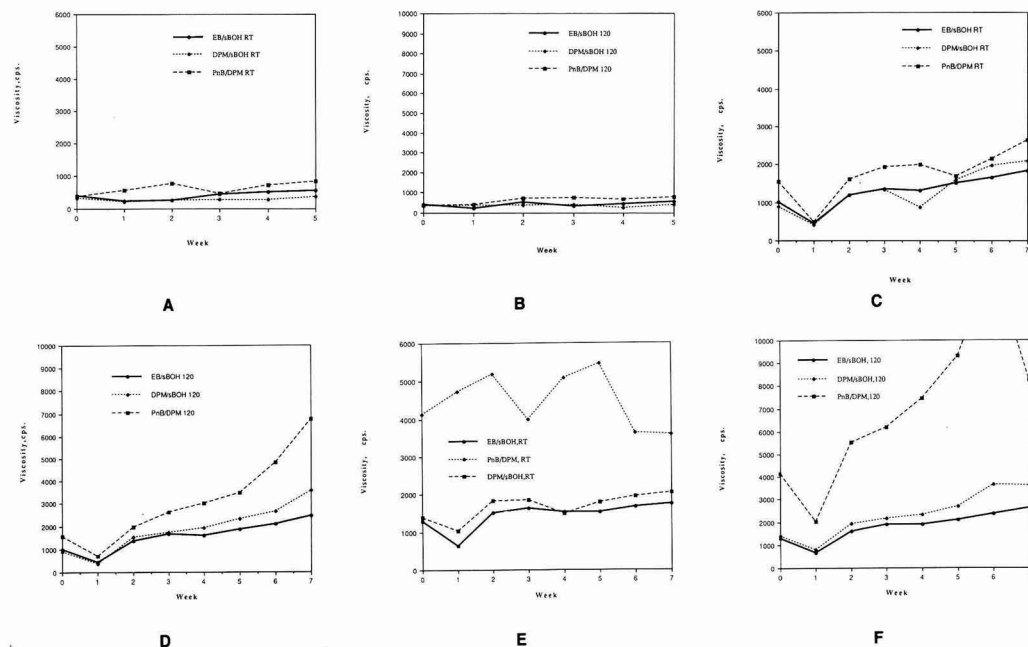


Figure 5—Resin concentrates viscosity behavior. A—Resin A concentrate nitrogen blanketed (room temperature); B—Resin A concentrate nitrogen blanketed (120°F); C—Resin A concentrate air environment (room temperature); D—Resin A concentrate air environment (120°F); E—Resin B concentrate air environment (room temperature); and F—Resin B concentrate air environment (120°F)

RESULTS AND DISCUSSION

Coupling Performance

Culver found that for a given multiphase system, more than one coupling agent may be appropriate and that combinations of coupling agents may achieve levels of activity superior to those of any single agent. Such was not the case with EB in our system of mineral spirits and water. That is, EB alone was better than any EB mixtures tested.

Figure 2 shows the results of the coupling performance of glycol ethers and alcohols in the mineral spirits and water system. The coupling performance of EB is unique,

and a P-Series which matches the coupling performance of EB as a one-to-one replacement was not found in this study. Blends of P-Series and blends of P-Series with C4 alcohols enhanced the coupling to approach that of EB. To be a good coupler, a solvent requires a balance between water-like (hydrophilic) and hydrocarbon-like (hydrophobic) character. Other beneficial structural features of EB are the linear molecular structure and the primary hydroxyl group that minimizes the effect of steric hindrance on hydrogen bonding.

A synergistic effect from using a blend of dipropylene glycol methyl ether (DPM) and propylene glycol n-butyl ether (PnB) is shown in Figure 3. This blend, optimized at a one-to-one ratio, is an example of where an optimum balance of hydrophobic and hydrophilic character is achieved.

Figure 4 shows the results of blending glycol ethers and alcohols. A positive effect results from the blending of DPM with sBOH and is optimized at a 75/25 blend of sBOH and DPM. In this case, the blend of DPM which possesses two ether linkages in a seven carbon molecule, and sBOH possessing a secondary hydroxyl which is sterically hindered, exhibits both hydrophobic and hydrophilic character. Further evidence of a unique balance of hydrophobic and hydrophilic character possessed by the

Table 2—Aging Study Samples

Nonpigmented Formulation Samples by Weight:

25% resin
20% solvent
55% water

Resin Concentrate Samples by Weight:

56% resin
44% solvent

EB molecule was demonstrated by the lack of synergism when blending EB with sBOH.

In order to further approach the coupling performance of EB, the optimized one-to-one blend of PnB/DPM was blended with sBOH. Optimization of this blend approximated that of the sBOH/DPM blend, thus indicating that PnB exhibits hydrophobic character similar to sBOH, and that further addition of hydrophobic character by addition of sBOH does not enhance the coupling performance. It also pointed out the necessity of a proper balance of hydrophobic and hydrophilic character in the solvent blend.

From Bouboulis³ findings and coupling performance data generated in our labs, the sBOH/DPM and PnB/DPM blends were chosen as alternatives to EB in the water-reducible systems under study. The sBOH/PnB/DPM blend was eliminated from the study at this time since it offered no advantages with respect to coupling performance over the PnB/DPM or sBOH/DPM blends. Previous work by Bouboulis found that the primary hydroxyl functionality, such as in EB, may contribute to water-reducible system instability, while coupling agents containing a secondary hydroxyl may enhance stability of these systems. Propylene-based ethers contain a secondary hydroxyl. Both of the P-Series blends selected contained predominantly secondary hydroxyl functionality, thus allowing for evaluation of the effects of secondary hydroxyl containing solvents on the resin stability.

Aging Study

Bouboulis reported resin concentrates for water-reducible coatings decreased in viscosity and molecular weight during normal storage and that viscosity decreased even faster on repeated heating, which is used to facilitate handling and storage. Further, he has attributed these decreases to chemical reactions between the hydroxyl group of a coupler and the polymeric resin, with transesterification being the predominant reaction. For this study, viscosity behavior of resin concentrates aged at oven and room temperature is illustrated in Figure 5.

These results indicated an increase in viscosity for both resin A and B aged in an air environment, that is, no nitrogen blanketing. As expected, the initial viscosity of each resin/solvent system closely approximated that of the solvent's coupling performance. That is, concentrates containing the PnB/DPM or DPM/sBOH blend exhibited higher viscosities and lower coupling efficiencies than the

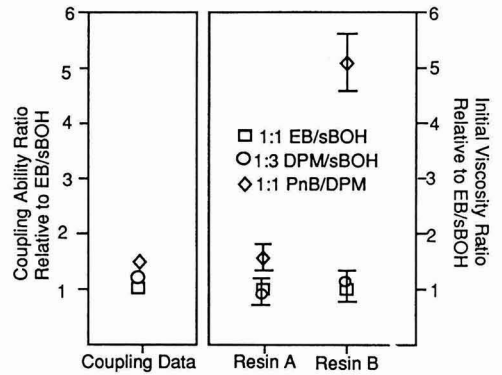


Figure 6—Coupling-viscosity comparison air environment

EB/sBOH blend. What was not expected was an increase in viscosity of the resin/solvent systems upon aging. As Figure 5 illustrates, comparable viscosity increases for the three solvent blends at both elevated and room temperatures were observed.

If a decrease in viscosity is indicative of instability due to transesterification, as indicated by Bouboulis, to what can the viscosity increase observed in this study be attributed? Examination of viscosity behavior of resin A under nitrogen blanketing was done to study the effects of crosslinking due to oxidation and/or evaporation of the solvent. Comparable viscosity increases for the three solvent blends were observed. A mass balance for these nitrogen blanketed samples ruled out effects due to evaporation of the solvent, which would cause a viscosity increase as a result of less available solvent to solubilize a given quantity of resin.

After five weeks of heat aging, a significant difference in viscosity was observed between the resin A concentrates prepared under nitrogen and the resin A concentrates prepared in air. This indicated that oxidation did occur in samples prepared and exposed to air. It also indicated that while viscosity increases were seen, the

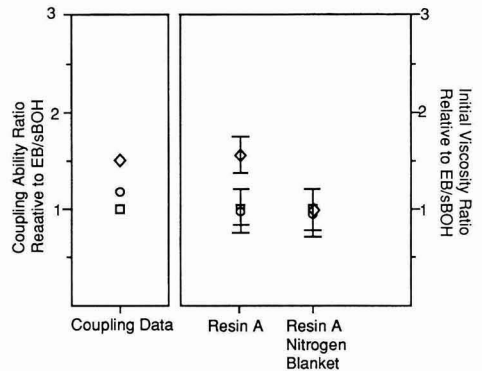


Figure 7—Coupling-viscosity comparison resin A concentrate air-nitrogen blanket

Table 3—Resin A Viscosity-Molecular Weight Comparison

Solvent Blend	Viscosity, cps		Molecular Weight	
	Room Temperature (120°F)	49°C (120°F)	Room Temperature (120°F)	49°C (120°F)
	EB/sBOH—Initial	1007	1007	165000
—Aged	2355	3686	338000	657000
DPM/sBOH—Initial	903	903	171000	171000
—Aged	2932	5939	390000	798000
PnB/DPM—Initial	1546	1546	145000	145000
—Aged	3584	19203	318000	804000

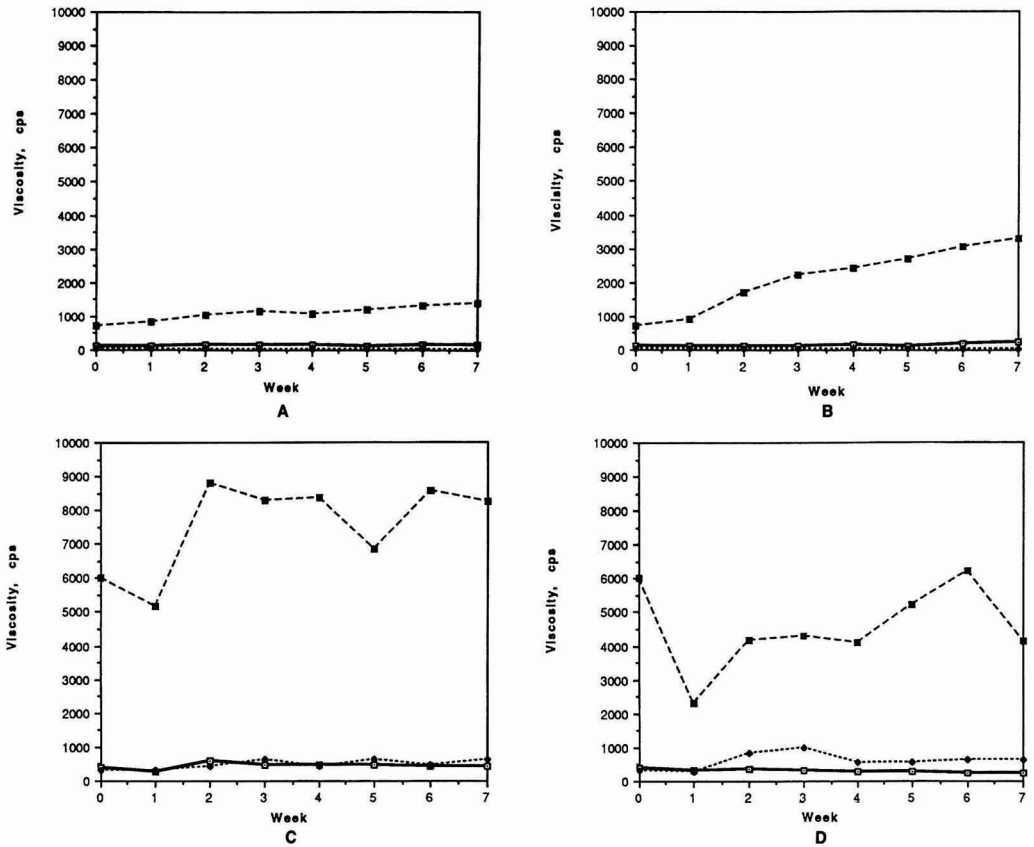


Figure 8—Nonpigmented formulation viscosity behavior. A—Resin A nonpigmented formulation air environment (room temperature); B—Resin A nonpigmented formulation air environment 49°C (120°F); C—Resin B nonpigmented formulation air environment (room temperature); and D—Resin B nonpigmented formulation air environment 49°C (120°F). —:EB/sBOH; ----:DPM/sBOH; and - - - - :PnB/DPM

relative stability of resin A in all three solvent blends was comparable.

A coupling-viscosity comparison of resin A and resin B concentrate samples is illustrated in *Figure 6*. As the data indicate, the initial viscosity of resin A and resin B can be predicted from coupling performance data.

Coupling data in *Figure 6* is a ratio of coupling ability of the DPM/sBOH and PnB/DPM solvent blends relative to the coupling ability of the EB/sBOH blend. The initial viscosity of resin A and resin B in the DPM/sBOH and PnB/DPM solvent blends (relative to the EB/sBOH control) followed the coupling performance data within experimental error for three out of four data points. From this data, we can predict that the initial viscosity of resin A in the PnB/DPM solvent blend would be approximately 1.5 times the initial viscosity of resin A in the control blend of EB/sBOH.

The effect of a nitrogen blanket on the initial viscosity of resin A is illustrated in *Figure 7*.

The initial viscosity of resin A concentrate samples in the DPM/sBOH and PnB/DPM solvent blends when prepared in an air environment followed the coupling performance data. However, when the resin concentrates were prepared under a nitrogen blanket, the initial viscosities (within experimental error) for the PnB/DPM and DPM/sBOH solvent blends were equivalent to the EB/sBOH control.

Viscosity behavior of nonpigmented formulations aged at oven and room temperature is illustrated in *Figure 8*. Again, the initial viscosity closely approximated that predicted by the coupling performance, that is, viscosity of EB/sBOH < DPM/sBOH < PnB/DPM.

Resin B exhibited an initial dip in viscosity for both elevated and room temperature samples after one week.

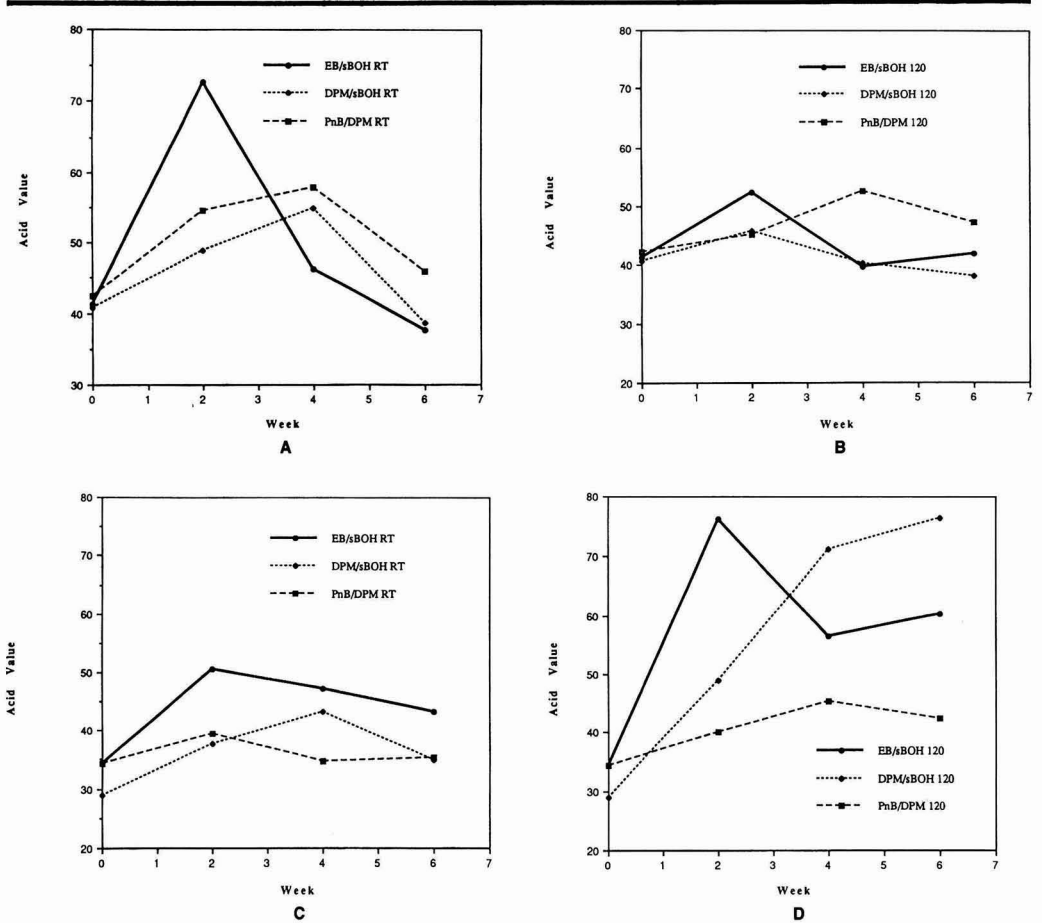


Figure 9—Nonpigmented formulation acid value behavior. A—Resin A nonpigmented formulation air environment (room temperature); B—Resin A nonpigmented formulation air environment (120°F); C—Resin B nonpigmented formulation air environment (room temperature); and D—Resin B nonpigmented formulation air environment (120°F)

The dip has been observed by the resin manufacturer, and it is speculated to be the result of the resin and solvent reaching physical equilibrium as the polymer particles redistribute in solution. Nonpigmented formulation viscosity results indicate that the DPM/sBOH solvent blend yielded comparable performance to the EB/sBOH control. The PnB/DPM solvent blend yielded higher initial nonpigmented formulation viscosities, but followed similar trends to the EB/sBOH and DPM/sBOH blends upon aging.

As the data in *Figure 9* demonstrate, acid values for all the nonpigmented formulations followed similar trends. The trend is an increase in acid value followed by a decrease in acid value. This indicates that these resins

containing P-Series solvent blends should show equivalent stability with respect to hydrolysis at the EB/sBOH control.

The rate of change of acid value is faster with EB/sBOH. The 1° hydroxyl functionality of EB likely reacts faster than the 2°OH of DPM or PnB. The initial acid value at two weeks will be higher due to greater reactivity of EB.

DPM/sBOH and PnB/DPM show an acid value increase with a decrease similar to EB/sBOH, but later than two weeks or not as much of an increase.

Resin A and resin B show a difference in acid value trends, but the trends for each resin are similar.

It is presumed the acid value increased due to transesterification and liberation of the fatty acid. The decrease is due to reaction of the glycol ether with the fatty acid or assimilation of the fatty acid back into the resin chain. The general expected trend is OH, 1° > 2°, and less sterically hindered > more sterically hindered. The expected reactivity would then be EB/sBOH > DPM/sBOH > PnB/DPM. Within the experiment's limitations, these trends are seen. However, all three solvent blends show the trend of increase and then decrease in acid value.

The exception is DPM/sBOH in resin B. This is slower in acid value increase. The question is will it decrease if tested longer? Presumably, yes.

Molecular Weight

Molecular weight results for resin A concentrate samples are illustrated in *Figure 10*. EB/sBOH, DPM/sBOH and PnB/DPM blends exhibited an increase in apparent molecular weight with aging. This is indicative of a solvent-resin interaction and/or crosslinking reaction taking place. The DPM/sBOH and PnB/DPM blends showed the same broadening of molecular weight upon aging as that demonstrated by the EB/sBOH control. The increase in viscosity of the resin concentrate samples discussed earlier could be attributed to the increase in higher molecular weight polymer fractions that are formed upon aging. Refer to *Table 3* for quantitative correlation between molecular weight and viscosity changes.

CONCLUSIONS

This research examined the coupling ability of glycol ether solvents and the effect of glycol ether solvents on the stability of water-reducible alkyd resins. As a result of

this investigation, the following conclusions can be made:

(1) Based on the coupling performance data of individual solvents evaluated in this study, a one-for-one substitute for EB was not defined.

(2) Blends of P-Series glycol ethers and blends of P-Series glycol ethers and C4 alcohols demonstrated enhanced coupling performance. Several blends of P-Series glycol ethers and C4 alcohols were defined which approached the coupling ability of EB.

(3) Performance of a solvent system is resin system dependent.

(4) Initial viscosity of the resin/solvent systems examined in this study could be predicted from coupling performance trends.

(5) PnB/DPM and DPM/sBOH blends have demonstrated equivalent stability behavior to EB/sBOH in the resin systems examined in this study.

ACKNOWLEDGMENTS

The authors thank Kari Sursely, Sherry Rizer, Vickie Knost, John Collins, Wes Archer, Carol Davies, and Budd Lee for their help in preparing this paper.

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Viscoelastic and Adhesion Properties Of Air-Drying Coating Films

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Temperature dependencies of dynamic viscoelasticity and peel strength of commercial air-drying coating films and experimental nitrocellulose (NC)/alkyd lacquers were measured. Moreover, the correlations between the surface tension of a plastic substrate, on which a coating film was brushed, and the adhesion of the coating film to the plastic substrate, were also studied. All the results are summarized as follows:

(1) The dynamic viscoelasticity of a commercial air-drying coating film at temperatures above the glass transition temperature (T_g) showed a plateau elastic modulus ranging from 10^9 dyne/cm² to 10^7 dyne/cm², which corresponds from highly-crosslinked to low-crosslinked structures, respectively. Noncrosslinked type coating films, like NC lacquers, flow at a higher temperature than their T_g .

(2) Temperature dependencies of the peel strengths of air-drying type coating films showed bell-shape curves, independent of the structures of the coating films. The temperature where the peel strength is maximum is characteristic to the coating film.

(3) Correlations between the surface tensions of plastic substrates and peel strengths of the coating films showed bell-shape curves having a maximum peel strength at a certain surface tension.

INTRODUCTION

Physical properties of coating films are usually determined by means of Japanese Industrial Standard (JIS), ASTM, or conventional tests, and the resulting data are often utilized to estimate the practical properties or quality control of the coatings. However, the data are not

valuable for discussing fundamentally the properties of coating films in connection to their structures or deforming characteristics. The physical properties of coating films depend mainly on the surface tension and the bulk rheological properties. Therefore, the tests concerning the physical properties of surfaces and bulk can provide much information on the characteristics of coating films. Recently, various dynamic tests for the coating films have been done and much useful knowledge has been accumulated.

Currently, various kinds of paints are produced for many uses and they can be classified into two types, that is, thermosetting and air-drying types. Thermosetting coatings are used mainly for industrial purposes; for high efficiency and high speed drying; and they are easily attained under a controlled condition. However, thermosetting coatings usually need an oven for drying, so air-drying coatings are used mainly for conventional purposes.

There are several kinds of air-drying coatings: Japanese lacquers, that solidify through the aid of enzymes;

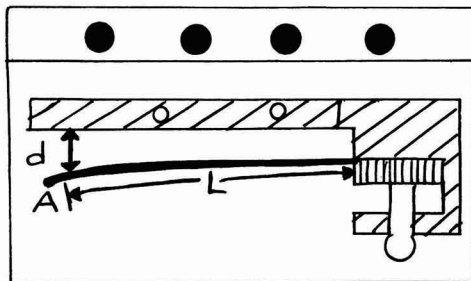


Figure 1—Schematic drawing of the experimental system. A—test piece; d—deflection of the test piece; and L—length of the test piece

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Table 1—Physical Properties of the Paints

	Urethane Enamel	Alkyd-Resin Enamel	NC-Lacquer Enamel
Coating	Highrock white	Sunrock white	Rock lacquer white
Residue after heated (%)	61	60	40
Viscosity (KU)	75-80	85-95	88-98
Pigment/binder (weight ratio)	27/34	29/31	10/30
Resin/solidifier (weight ratio)	4/1	—	—

Table 2—Compositions (Wt%) of Japanese Lacquer and Air-Treated Japanese Lacquer

	Urushiol or Rachol	Water	Rubber	Nitrogen
Japanese lacquer ^a	64.8	25.0	7.8	2.4
Sugurome Japanese lacquer ^b	80.0	3.3	9.7	7.0

(a) Japanese lacquer was produced at China (Hu Bei Sheng Zhu Xi) in 1983.

(b) Preparation of Sugurome Japanese lacquer: After filtration of Japanese lacquer, it was heated from the upper part and stirred at less than 45°C under air until the excess amount of water volatilized. It took about 4 hr until the color changed from milky-gray to dark-brown which was the termination of the reaction.

Table 3—Composition of Kashu-Resin Clear Lacquer

Component	Wt %
Kashu resin	67.0
Alkyd resin	2.5
Aliphatic hydrocarbon	25.0
Aromatic hydrocarbon	4.0
Drying agent (metal soap)	1.5

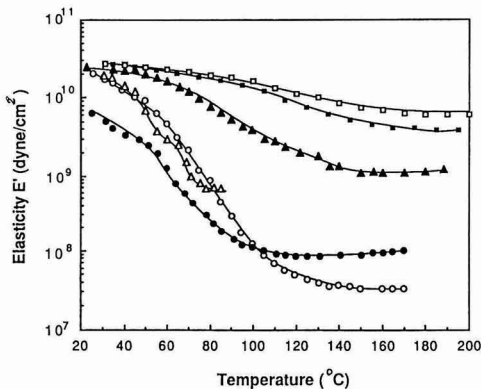


Figure 2—Temperature dependencies of elastic modulus E' of commercial air-drying coating films. □—Sugurome Japanese lacquer; ■—Japanese lacquer; ▲—kashu-resin clear lacquer; ●—alkyd-resin enamel; and ○—urethane-coating enamel

alkyd-resin enamels, that solidify by air-oxidation; urethane enamels, that solidify by a reaction of hydroxyl groups of binders and isocyanate groups; and nitrocellulose (NC) lacquers, that solidify by evaporation of solvent. In this paper, commercial air-drying coatings and experimental NC/alkyd coatings were used to elucidate the physical properties of coating films by measuring the dynamic viscoelasticity and adhesion at various temperatures. Moreover, the surface tensions of plastic substrates and adhesion of the coating films on the substrates were also studied.

EXPERIMENTAL

Materials

The physical properties and compositions of urethane-coating enamels, alkyd-resin enamels, NC-lacquer enamels, and Japanese lacquers produced in China are summarized in *Tables 1, 2, and 3*, respectively.

A castor-oil alkyd resin was prepared according to the usual method. The NC/alkyd lacquers were prepared by blending the alkyd resins and NC. In *Tables 4 and 5*, the compounding ratios and their physical properties are shown.

In most cases, the coatings were brushed on the test plates, controlling the film thickness within $60 \pm 5 \mu\text{m}$. All of the coatings were dried for three months at room temperature ($25 \pm 5^\circ\text{C}$) before use. Japanese lacquer was aged for 12 hr at $25 \pm 5^\circ\text{C}$ and $80 \pm 5\%$ relative humidity (RH) and then dried.

Measurements

DYNAMIC VISCOELASTICITY: A tin thin film was placed on galvanized steel, onto which a coating was brushed and dried for three months at room temperature. Then the sample film was removed from the galvanized steel by dissolving the tin film by the mercury-amalgam method.

Viscoelastic behavior of the sample film was measured on a Rheovibron® Model DD-II-EA (Toyo Baldwin Company) at a frequency of 110 Hz.

INTERNAL STRESS: Each coating was brushed on the surface of a test piece ($0.1 \times 10 \times 98 \text{ mm}$) of phosphor bronze. After drying for three months at room temperature ($20 \pm 5^\circ\text{C}$), the bent d of the test piece was measured on a cathetometer (see *Figure 1*). All the measurements were carried out at 20°C and 65% RH. The average thickness of the film was $100 \pm 20 \mu\text{m}$. From the value of d , the internal stress S (kgf/cm^2) was calculated using the following equation¹;

$$S = \frac{dE_1t_1^3}{(3t_2L^2)(t_1 + t_2)(1 - \nu_1)} \quad (1)$$

where E_1 is Young's modulus ($12.24 \times 10^5 \text{ kgf}/\text{cm}^2$), ν_1 is Poisson's ratio, t_1 is the thickness (mm), L is the length (mm) of the test piece of phosphor bronze, and t_2 is the thickness (mm) of the coating film, respectively.

PEELING TEST: Following surface pretreatment of the test pieces for the peeling test, coatings were applied at an average thickness of 0.65 mm and then dried for three months. All of the measurements were carried out on a

Tensilon (Model 10 TM-III-500, Toyo Baldwin Company) under the conditions of 180° peel angle and 300 mm/min pulling rate.

CROSS-CUT ADHESION TEST: According to JIS K 5400-1979, all of the tests were carried out and the results were represented by the total number of lattices remaining. The lattice distance of the cross-cut lines was 2 mm.

SURFACE TENSION: After sanding the surface of a plastic substrate with abrasive paper #240 and rinsing with ethanol, surface tension of the plastic substrate was measured according to ASTM D 2578-67.

RESULTS AND DISCUSSION

Viscoelasticity

COMMERCIAL COATING FILMS: Figures 2 and 3 show the temperature dependencies of the dynamic viscoelasticities (E' and $\tan \delta$) of the air-drying commercial coating films, and Table 6 summarizes the elastic modulus $E'g$ at room temperature, the plateau elastic modulus $E'r$, the glass transition temperature T_g and the $\tan \delta$ at T_g ($\tan \delta_m$). From the temperature dependencies of the viscoelasticity curves, the following conclusions could be drawn:

Highly-crosslinked coating films—The Japanese lacquer coating films and kashu-resin coating films, which have a T_g higher than 100°C, an $E'r$ of 10^9 dyne/cm² order, and small $\tan \delta_m$, are highly crosslinked and their mechanical properties are dependent somewhat on the temperature change, that is, their thermal resistance is superior. Sugurome Japanese lacquer increased the $E'r$ of the coating film.

Low-crosslinked coating films—The $E'g$ of the alkyd-resin enamel coating film is 5×10^9 dyne/cm² and not

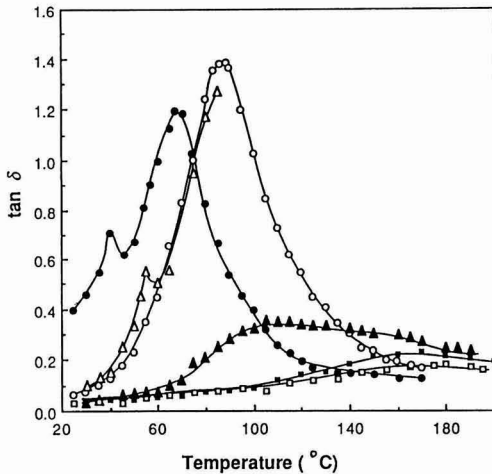


Figure 3—Temperature dependence of $\tan \delta$ of commercial air-drying coating films. The symbols are the same as those in Figure 2

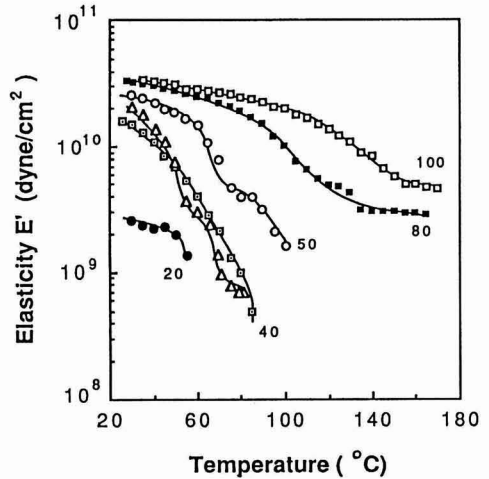


Figure 4—Temperature dependence of the elastic modulus of NC/alkyd coating films. Numbers in the figure represent the content of NC in wt%. The symbol Δ represents the commercial NC-lacquer enamel coating film

very large, and the $E'r$ is 9×10^7 dyne/cm² and is larger than that of the urethane-coating enamel films. This coating film shows a subtransition point at about 40°C and the $\tan \delta_m$ is large. Therefore, this coating film is flexible despite the large $E'r$.

Although the $E'g$ of the urethane-coating enamel film is 1.8×10^{10} dyne/cm² and is large, the $E'r$ is 3×10^7 dyne/cm² and $\tan \delta_m$ is large. The elastic modulus of the glassy state is larger than that of the rubbery state by three

Table 4—Physical Properties of Nitrocellulose and Alkyd Resin

Polymer	Abbreviation	Nonvolatile (Wt%)	Preparation
Nitrocellulose	NC	20	1/2 sec and 1/4 sec NC of S type were blended with 50/50 (wt%) and dissolved in ethyl acetate/isopropyl alcohol/toluene = 40/10/50 solution
Alkyd resin ^a	PBA	50	CO/PE/BA/PA ^b = 40/21/13/26 (wt%) (Mw = 12497, Mn = 5327, and Mw/Mn = 2.3) was dissolved in xylene

(a) The cooking schedule of the alkyd resin was 3 hr at 230°C after making up monoglyceride with pentaerythritol and castor oil.
 (b) CO—castor oil; PE—pentaerythritol; BA—benzoic acid, and PA—phthalic acid.

Table 5—Compounding Ratio of NC/PBA

Sample Number	B-0	B-1	B-2	B-3	B-4	B-5
NC (wt%)	100	80	60	50	40	20
PBA (wt%)	0	20	40	50	60	80

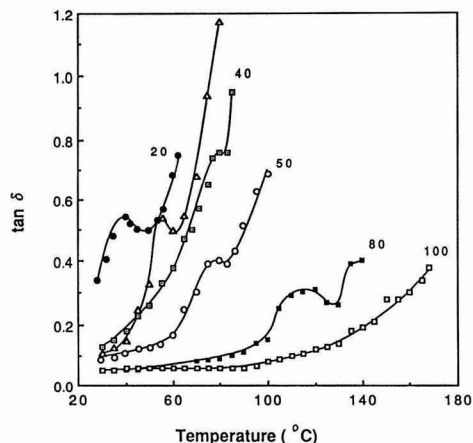


Figure 5—Temperature dependence of $\tan \delta$ of NC/alkyd coating films. Numbers in the figure represent the content of NC in wt%. The symbol Δ represents the commercial NC-lacquer enamel coating film

orders, but its temperature dependence is relatively small. Taking the temperature dependence of $\tan \delta$ and the value of T_g into consideration, we can conclude that the urethane-coating enamel film not only has proper hardness, but also good flexibility, heat resistance, and solvent resistance, that is, the urethane-coating enamel films have the proper physical properties for a superior coating film.

Noncrosslinked coating films—The E'_g of the NC-lacquer enamel coating film is 1.9×10^{10} dyne/cm² and the T_g is 55°C above which the coating film is fluid; that is, this coating film is hard at room temperature, but its heat resistance and solvent resistance are poor.

NITROCELLULOSE/ALKYD COATING FILMS: Figures 4 and 5 show the temperature dependence of the viscoelastic behaviors of the NC/alkyd coating films. As the NC-lacquer coating film is noncrosslinked, it flows at temperatures above the T_g . However, when the content of NC is about 80-100 wt%, the viscoelasticity shows a plateau-like region that reflects the rigid structures of NC. The castor-oil alkyd resin acts as a polymer plasticizer of NC² and, therefore, increases the compounding ratio of alkyd resin results by reducing the rigid structures of NC and softening of the lacquer coating films. Thus, the E'_g and T_g are reduced and $\tan \delta m$ is enlarged.

Commercial NC lacquers are usually used for woodenware or metalware and the compounding ratio of NC to alkyd resin is around 1/1.5 (weight ratio).³ In Figures 4 and 5, the results of the commercial NC-lacquer enamel coating, of which temperature dependence is almost the same as that of NC/alkyd=40/60 (weight ratio) are shown. Usually a commercial NC lacquer contains plasticizer, softener, pigment, and so on, together with the NC and alkyd resin. Therefore, the temperature dependence of $\tan \delta$ is a little larger than that of the same composition

NC/alkyd, reflecting the complicated composition of the coating films.

NC lacquers should pass the print test,* so the content of NC should be larger than 40 wt% to make its T_g higher than 50°C.

Adhesion

The peeling test is an important test in adhesives, but is scarcely used in thermosetting coating films because they are restricted to be cured at baking schedules. However, adhesions of air-drying coating films can be determined by the peeling test. Measurements of the adhesion of air-drying coating films were taken.

Figure 6 shows the temperature dependencies of the peel strength of the air-drying coating films. All the coating films show bell-shaped convex curves having a maximum, the temperature of which differs for each. Mizumachi⁴ reported that the peel strength reduced with increasing or decreasing elastic modulus of adhesives, that is, there is a proper value of elastic modulus for the maximum peel strength. According to Mizumachi, the peel strength is a maximum at about $E' = 10^8$ dyne/cm² for the (ethylene-vinyl acetate copolymer/terpene-phenol resin) blend adhesives. Kiryu and Masuda⁵ studied the peel strength of the NC-lacquer coating films and reported the similar bell-shape relation. The maximum appeared at $E' = 10^9$ dyne/cm².

In this experiment, peel strength became maximum at $E' = 10^9 - 10^{10}$ dyne/cm², and E' of NC/alkyd lacquer (10^9 dyne/cm²) is smaller than that of Japanese lacquer (10^{10} dyne/cm²).

*The print resistance was carried out at 40 ± 2°C under the following conditions: a 40 mm diameter cylindrical weight of 500g hung for 18 hr, according to JIS K 5531-1975, JIS K 5532-1975.

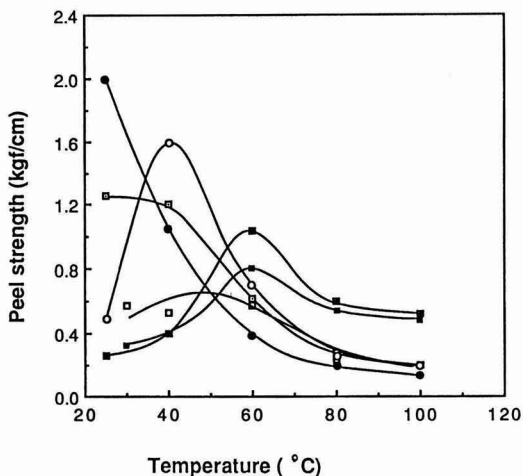


Figure 6—Temperature dependence of peel strength of air-drying coating films. Coatings were brushed on glass plates. □—B-2 (NC/alkyd = 60/40); ○—B-3 (NC/alkyd = 50/50); □—B-4 (NC/alkyd = 40/60); ●—B-5 (NC/alkyd = 20/80); □—Sugurume Japanese lacquer; and ■—Japanese lacquer

Table 6—Physical Characteristics of Free-Dry Type Coating Films

	Eg' (30°C) ^a	Er' ^b	T _g	tanδ _m ^c
Japanese lacquer	2.51 × 10 ¹⁰	3.94 × 10 ⁹ (180°C)	165	0.23
Air-treated Japanese lacquer	2.51 × 10 ¹⁰	6.51 × 10 ⁹ (180°C)	165	0.18
Kashu-resin clear lacquer	2.49 × 10 ¹⁰	1.16 × 10 ⁹ (180°C)	116	0.36
Urethane-coating enamel	1.80 × 10 ¹⁰	3.37 × 10 ⁷ (160°C)	86	1.4
Alkyd-resin enamel	5.00 × 10 ⁹	9.48 × 10 ⁷ (160°C)	67 (40 ^d)	1.2 (0.7 ^e)
NC-lacquer enamel	1.90 × 10 ¹⁰	—	55 (83 ^e)	0.55 (1.3 ^e)

(a) Eg—elastic modulus at room temperature (dyne/cm²).
 (b) Er—elastic modulus at plateau (dyne/cm²).
 (c) tanδ_m—tanδ at T_g.
 (d) Subtransition point.
 (e) Four point.

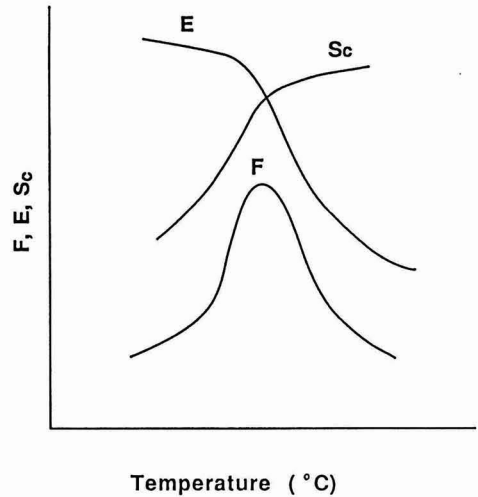


Figure 7—Schematic profile of temperature effects on the elastic modulus E', relaxation of stress concentration Sc, and peel strength F

Appearance of the maximum can be explained qualitatively as follows. As the test film is bent, the coating film is easily peeled from the test film due to highly concentrated stress at the top of peeling front when the elastic modulus of the test film is high. As shown in Figure 7, E' of the coating films decreased and peel strength increased with increasing temperature. However, the effect of concentrated stress at the previously stated T_g is small, and the peel strength is decreased with decreasing E' of the coating film. Therefore, the temperature dependencies of the peel strength show a bell-shaped curve.

Figure 8 shows the effects of the alkyd-resin content on the peel strength and the internal stress of the NC/alkyd

coating films. Coating films are susceptible to peeling when the content of alkyd resin is less than 20 wt%. The peel strength increases sharply when the content of the alkyd resin is increased above 40 wt%. On the other hand, the internal stress changes inversely when compared with the change of the peel strength, and relaxation of internal stress is suggested to be necessary to improve the adhesion of coating films. Figure 8 shows that the elastic modulus of NC/alkyd coating films at 30°C decreased slightly with the alkyd resin content until 50 wt% and then decreased sharply. This is probably due to the widening of the distance of the two neighboring NC molecules by mixing the alkyd resin as a polymer plasti-

Table 7—Effects of Sanding on the Surface Tension and the Adhesion

	PP ^a		PE ^b		PAC ^c		ABS ^d		Epoxy		6-N ^e	
	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
Surface tension (dyne/cm)	32	34	33	34	36	40	38	43	40	45	52	54
Cross-cut adhesion test^f												
Urethane enamel	0/100	0/100	0/100	50/100	0/100	100/100	100/100	100/100	100/100	100/100	100/100	100/100
Alkyd enamel	0/100	0/100	0/100	40/100	0/100	80/100	100/100	100/100	90/100	100/100	80/100	100/100
NC lacquer	0/100	0/100	0/100	0/100	0/100	100/100	100/100	100/100	80/100	95/100	90/100	100/100
Peel strength^h												
Urethane enamel	0	500	0	600	380	1350	1650	2750	2150	3100	1700	2250
Alkyd resin	100	400	200	580	150	500	1200	1650	1150	1250	850	1050
NC lacquer	100	130	0	130	100	150	1060	1650	950	1100	680	950

(a) PP—polypropylene.
 (b) PE—polyethylene.
 (c) PAC—polyacetal.
 (d) ABS—acrylnitril-butadiene-styrene copolymer.
 (e) 6-N—6-nylon.
 (f) Plastic substrate was sanded with #240 abrasive paper.
 (g) Lattice distance of the cross-cut lines was 2 mm.
 (h) Peel strength (gf/cm).

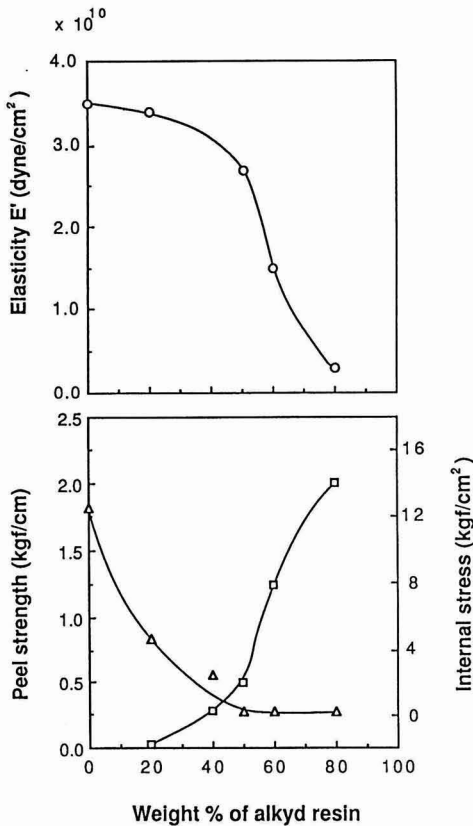


Figure 8—Effects of alkyd-resin contents on the peel strength F , internal stress S , and elastic modulus E' of NC/alkyd coating films

cizer. Therefore, the elastic modulus and the internal stress decreased linearly with increasing content of alkyd resin. On the other hand, with an alkyd content higher than 60 wt%, the main component of the coating film is the alkyd resin and NC acts as a hardener of the coating film. Thus, the elastic modulus decreased sharply and the internal stress became almost zero, as shown in Figure 8. Similarly, the steep increase of peel strength can be explained in terms of the reduction of stress concentration due to the decrease of E' and small S .

Table 7 summarizes the surface tensions of sanding surfaces of plastic substrates and the adhesion of coating films. Adhesion of a coating film to a plastic substrate, except for a polyolefin substrate, is improved by sanding the surface, which provides an increase in the surface tension of the surface. In this study, increasing of surface tension greater than 38 dyne/cm provided good adhesion of the coating film. Moreover, sanding the surface stabilized adhesion. Lindberg⁶ and Hirasawa and Ishimoto⁷ also reported improvement of adhesion at a greater surface tension than 38 dyne/cm. In the case of the ABS

resin, however, good adhesion is realized without sanding; this is probably because of the formation of a diffusion layer between the ABS and the coating film caused by partial dissolution of ABS by the solvent in the coatings.

Figure 9 shows the relationship between the peel strength of the coating film and the surface tension of the plastic substrate. Bell-shaped curves were observed with a maximum, the value of which is 45 dyne/cm for the urethane-coating enamel and 43 dyne/cm for alkyd resin enamel and NC-lacquer enamel. The following relationships are expected between the adhesion of a coating film and the surface tension of a plastic substrate.

(1) Adhesion becomes maximum when the surface tension of polymer (substrate) γ_S and of coating film γ_L are almost equal.^{8,9}

(2) An increase of γ_S provides good adhesion for the same coating film. However, when γ_S is larger than γ_L , adhesion of the coating film is almost constant.¹⁰

According to the theory of interfacial science, adhesion of the coating film is expected to be maximum when the interfacial tension γ_{SL} between a plastic substrate and a coating film is minimum.^{11,12} However, the adhesion of a coating film is not only dependent on the wetting of the plastic substrate, but also is related to the viscoelastic properties of the coating film, so it is difficult to conclude the correlations between the surface tension and the adhesions within this work.

However, it is true that the wettability of the plastic substrate to the coating film is one of the most important factors for the adhesion of the coating film. Pretreatment of the surface to improve the wetting is necessary to achieve good adhesion. Moreover, the high peel strength and the good adhesion of the urethane-coating enamel compared to the alkyd-resin enamel or NC-lacquer enam-

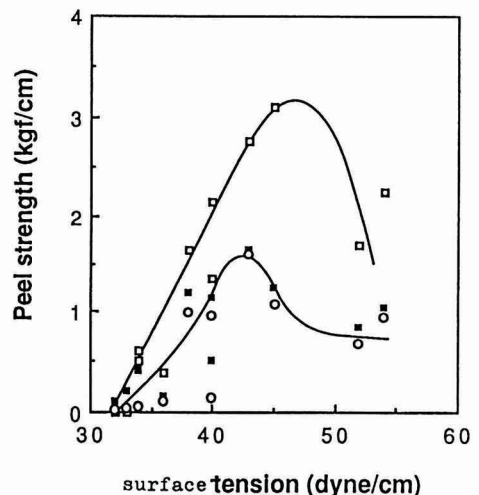


Figure 9—Relationship between the peel strength of coating films and surface tension of plastic substrates. □—urethane-coating enamel; ■—alkyd-resin enamel; and ○—NC-lacquer enamel

el is due to its suitable hardness at room temperature and its crosslinked and tough structure with a plateau elastic modulus of 10^7 dyne/cm².

CONCLUSION

Temperature dependencies of dynamic viscoelasticity and peel strength of commercial air-drying coating films and experimental nitrocellulose/alkyd lacquers, were measured. Moreover, the correlations between the surface tension of a plastic substrate and the adhesion of the coating film to the plastic substrate were also studied. The results are summarized as follows:

The plateau elastic modulus of a commercial air-drying coating film measured at above its T_g ranges from 10^9 dyne/cm² for highly-crosslinked Japanese lacquer with high heat resistance to 10^7 dyne/cm² for the loosely-crosslinked urethane-coating enamel film. The noncross-linked type coating films, for example, an NC lacquer, flow at a temperature higher than their T_g s.

It is possible to determine the compounding ratio of a commercial NC lacquer by measuring the viscoelasticity. Therefore, measuring the physical properties of a coating film is a valuable method in the investigations of coating films.

Temperature dependencies of the peel strengths of air-drying coating films showed bell-shaped curves. For good adhesion of a coating film, reduction of the internal stress of the coating film is needed.

Adhesion of a coating film to a plastic substrate, except for a polyolefin substrate, is improved by sanding the surface, which provides an increase in the surface tension of the surface. Moreover, the correlations between the surface tensions of plastic substrates and peel strengths of the coating films showed bell-shaped curves having a maximum peel strength at a certain surface tension.

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- _____ "Sealants and Caulks"—J. Prane _____
- _____ "Aerospace and Aircraft Coatings"—A.K. Chattopadhyay and M.R. Zentner _____
- _____ "Introduction to Coatings Technology"—A. Brandau _____
- _____ "Cationic Radiation Curing"—J. Koleske _____
- _____ "Rheology"—C. Schoff _____

Technical Volumes

- _____ Paint/Coatings Dictionary (Mbr.-\$30; Non-Mbr.-\$50) _____
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- _____ Glossary of Color Terms (\$6.00) _____

Audio/Visual Presentations (Slide/tape except where noted)

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Society Meetings

CDIC SEPT.

"Organic Hybrids"

Donald J. Roettker, of B.H. Roettker Company, Inc., presented the Hüls gavel to incoming Society President James Flanagan, of Flanagan Associates, Inc.

The meeting's educational speaker was Donald Wells, from Ameriflora '92, an exposition honoring the 500th anniversary of Christopher Columbus' landing on the shores of America.

The expo is scheduled to run from April 20, 1992 to October 12, 1992. Included on the 88-acre site will be exhibits, restaurants, amusement rides, and more.

Dipak Narula, of Dow Corning Corporation, gave the meeting's technical presentation. Mr. Narula spoke on "WATERBORNE SILICONE ORGANIC HYBRIDS."

The chemistry of silicone resins was discussed. The speaker pointed out that silicone resins are suited for a number of high performance applications. He said resins with a high phenyl content will exhibit high temperature resistance and oxidation resistance, and form tough films. Silicone resins with a high methyl content are fast curing, and exhibit chemical resistance, UV resistance, and gloss retention.

Mr. Narula explained that low solid silicone resins are approximately 50-60% solids and are silanol functional. High solid resins can be either silanol or alkoxy functional.

According to the speaker, using waterborne systems is the way to meet today's VOC air quality compliance requirements. He said silicones can be emulsified either via water emulsification or mechanical means. Mr. Narula devoted much of the remainder of his talk to resins via the mechanical technique.

The waterborne systems are offered as nonionic or anionic emulsions, stated the speaker. Also, the systems are available in soft, medium, and hard films. Some of the systems discussed by Mr. Narula were state-of-the-art high solids systems.

The speaker described, in detail, the recent developments in waterborne silicone intermediates and the coating systems formulated on them.

In addition, organic silicone hybrids along with some typical formulations were discussed.

Q. Do most of these resins contain a hydroxyl group as the functional group and

are most of these waterborne resins cured with titanate catalysts?

A. Yes, titanates are normally what is used.

PAUL R. GUEVIN, JR., *Secretary*

LOS ANGELES SEPT.

"Waterborne Coatings"

A moment of silence was observed in memory of Society Honorary Member and Past-President Trevellian V. Whittington and Mandy Rosenbach who passed away during the summer.

The Society officers for 1991-92 were installed as follows: President—James D. Hall, of Major Paint Company; Vice President—Sandra L. Dickinson, of Synergistic Performance Corporation; Secretary—Philip C. Bremenstuhl, of Ashland Chemical Company; and Treasurer—V.C. Bud Jenkins, Consultant.

Jan P. Van Zelm, of Byk-Chemie USA, will continue to serve as the Society Representative to the Federation's Board of Directors.

Robert Backlin, of Hüls America, Inc., presented the Hüls gavel to Mr. Hall.

Educational Committee Chairman Joseph C. Reilly, of Rohm and Haas Company, and Frank Peter, instructor of the Society-sponsored "Paint Technology" course, presented diplomas to the course graduates.

Edward B. Edrosa was presented with the Outstanding Student Award, having finished first in a class of 19 graduates.

The meeting's speaker was Chicago Society member Glenn N. Robinson, of Angus Chemical Company. Mr. Robinson spoke on "AMINES AND WATERBORNE COATINGS."

Waterborne coatings types were defined and the particle size of each was described. The speaker said that high molecular weight, low acid value, and low solvent content are desirable features of a paint resin. According to Mr. Robinson, these properties interact in water-soluble polymers. He stated that a choice of amine offers a more favorable combination of these properties to the coatings formulator.

The speaker emphasized that molecular weight, base strength, and solubility parameter are important characteristics governing amine efficiency. He compared triethylamine, 2-amino-2-methylpropanol,

dimethylaminoethanol, ammonia, morpholine, and 2-methyl-2-dimethylamino-propanol for these features.

Mr. Robinson discussed the safety and emissions of amines. He listed the LD50 values of amines, and explained that high amine reactivity can be a positive factor in thermosetting coatings.

Q. How do the various amines rate for flash rust prevention?

A. Flash rust resistance is directly proportional to boiling point of the amine; low volatility amines help reduce flash rusting.

Q. Which amine works best with ammonia to keep VOC to a minimum?

A. The technique of blending amines works well to optimize performance of a variety of resins. For example, amine reactivity reduces VOC in baking systems.

PHILIP C. BREMENSTUHL, *Secretary*

NORTHWESTERN SEPT.

"Waterborne Resin Coatings"

James W. Alseth, of Hüls America, Inc., presented the Hüls gavel to President Daniel W. DeChaine, of Ti-Kromatic Paints, Inc.

Environmental Affairs Committee Chairman Mark W. Uglen, of Hirschfield's Paint Mfg. Company, is seeking input from local or area companies interested in becoming more informed of pending legislation affecting the coatings industry.

Mr. Uglen has proposed forming a council, and perhaps hiring a lobbyist, to track legislative bills and testify on behalf of the coatings industry.

The meeting's first speaker was Society member Al Heitkamp, of Cargill, Inc. Mr. Heitkamp's topic was "WATERBORNE RESIN COATINGS FOR PENETRATING STAINS."

The speaker said penetrating stains are used to protect wood surfaces and to bring out the grain of the wood. The traditional penetrating stains were linseed or alkyd based and formulated in mineral spirits, resulting in high VOC. According to Mr. Heitkamp, new waterborne penetrating stains are gaining in market share.

Some of the new waterborne systems, including vinyl acrylic/alkyd, acrylic/alkyd, chemically modified drying oils, pre-neutralized chemically modified drying oils, and chemically modified polyolefins were discussed. The speaker said in the U.S., aes-

Constituent Society Meetings and Secretaries

BALTIMORE (Third Thursday—Willow Grove Restaurant, Linthicum, MD). JOHN KURNAS, Mineral Pigments Corp., 12116 Conway Rd., Beltsville, MD 20705.

BIRMINGHAM (First Thursday—Strathallan Hotel, Birmingham, England). D.C. MORRIS, PPG Industries (UK) Ltd., P.O. Box 359, Birmingham, B16 0AD, England. CDIC (Second Monday—Location alternates between Columbus, Cincinnati, Dayton, and Indianapolis). PAUL R. GUEVIN, JR., P.R. Guevin Associates, P.O. Box 811, Westerville, OH 43081-0811.

CHICAGO (First Monday—Sharko's Restaurant, Villa Park, IL). GREGORY E. McWRIGHT, ANGUS Chemical Co., 2911 Sanders., Northbrook, IL 60062.

CLEVELAND (Third Tuesday—Brown Derby, Independence, OH in Sept., Oct., Nov., Dec., Feb., March; Jan. and Apr. meetings, Landerhaven, Mayfield Heights, OH). FREDUN ANWARI, Coatings Research Group, Inc., 2340 Hamilton Ave., Cleveland, OH 44114.

DALLAS (Thursday following second Wednesday—The Harvey Hotel, Dallas, TX). MIKE EVANS, J.M. Huber Corp., 803 Pleasant Valley, Richardson, TX 75080.

DETROIT (Second Tuesday—meeting sites vary). RON ANDRUS, BASF Corp., 5935 Milford Ave., Detroit, MI 48210.

GOLDEN GATE (Monday before third Wednesday—alternates between Francisco's in Oakland, CA, and Holiday Inn in S. San Francisco). DONALD NOLTE, John K. Bice Co., 280 Missouri St., San Francisco, CA 94107.

HOUSTON (Second Wednesday—Sonny Look's Sirlion Inn, Houston, TX). RICHARD W. RYAN, Exxon Chemical Co., P.O. Box 5200, Baytown, TX 77520.

KANSAS CITY (Second Thursday—Cascone's Restaurant, Kansas City, MO). YVONNE D'ARCY, Cook Paint & Varnish Co., P.O. Box 419389, Kansas City, MO 64141.

LOS ANGELES (Second Wednesday—Steven's Steakhouse, Commerce, CA). V.C. BUD JENKINS, Consultant, 3366 Somis Dr., Riverside, CA 92507.

LOUISVILLE (Third Wednesday—Executive West Motor Hotel, Louisville, KY). MIKE R. MOILANEN, United Catalysts, Inc., P.O. Box 32370, Louisville, KY 40232.

MEXICO (Fourth Thursday—meeting sites vary). ANTONIO JUAREZ, Amercoat Mexicana, via Gustavo Baz 3999, 54030 Tlalnepantla, edo de Mexico.

MONTREAL (First Wednesday—Le Biftheque, Ville St. Laurent, Quebec). JACQUES BROUILLETTE, BAPCO, 1470 Nobel St., Boucherville, Que., J4B 5H3, Canada.

NEW ENGLAND (Third Thursday—Sheraton Lexington Hotel, Lexington, MA, alternate meetings twice a year in Sturbridge, MA and Providence, RI). JOANNE E. MONIQUE, Ashland Chemical Inc., 400 Main St., Tewksbury, MA 01876.

NEW YORK (Second Tuesday—Landmark II, East Rutherford, NJ). ARMAND J. STOLTE, RHEOX Inc., P.O. Box 70, Hightstown, NJ 08520.

NORTHWESTERN (First Tuesday after first Monday—Jax Cafe, Minneapolis, MN). SARAH OEBSER, H.B. Fuller Co., 1200 Wolters Blvd., Vadnais Heights, MN 55110.

PACIFIC NORTHWEST (PORTLAND SECTION—Third Tuesday; PUGET SOUND SECTION—Third Wednesday; VANCOUVER SECTION—Third Thursday). FLORA WONG, Saguardo Ltd., 106-150 E. Fifth St., N. Vancouver, B.C., V7N 1L5, Canada.

PHILADELPHIA (Second Thursday—Williamson's Restaurant, GSB Bldg., Bala Cynwyd, PA). BRIAN O'CONNOR, McWhorter Resins, Inc., 7600 State Rd., Philadelphia, PA 19136.

PIEDMONT (Third Wednesday—Ramada Inn Airport, Greensboro, NC). DENNIS GILLESPIE, Lomas Minerals and Chemicals, P.O. Box 605, Indian Trails, NC 28079.

PITTSBURGH (Second Monday—Montemurro's Restaurant, Sharpsburg, PA). TIMOTHY ZEFFIRO, J.M. Gillen Co., P.O. Box 588, Bridgeville, PA 15017.

ROCKY MOUNTAIN (Monday following first Wednesday—Zangs Brewery, Denver, CO). LOUIS HARTNELL, Hert & Hartnell Co., 791 Chambers Rd., #555, Aurora, CO 80041.

ST. LOUIS (Third Tuesday—Salad Bowl Restaurant, St. Louis, MO). MICHAEL SCHINURMAN, Kop-Coat, Inc., 328 Henley Ind. Ct., St. Louis, MO 63144-1599.

SOUTHERN (GULF COAST SECTION—third Thursday; CENTRAL FLORIDA SECTION—third Thursday after first Monday; ATLANTA SECTION—third Thursday; MEMPHIS SECTION—bi-monthly on second Tuesday; and MIAMI SECTION—Tuesday prior to Central Florida Section). MARY G. FINNIGAN, Unocal Chemicals Div., 8901 Research Dr., Charlotte, NC 26845.

TORONTO (Second Monday—Cambridge Motor Hotel, Toronto). DAVID JACK, Technical Coatings Co Ltd., 1164 Walkers Ln., Burlington, Ont., L7M 1V2, Canada.

WESTERN NEW YORK (Third Tuesday—meeting sites vary). MARKO MARKOFF, 182 Farmingdale Rd., Cheektowaga, NY 14225.

thetic characteristics of the wood are brought out through the use of semi-transparent stains. These stains are generally low in solids and viscosity. However, in Europe, stains are higher in solids and viscosity, and more often, opaque to produce a protective coating on the wood.

Other components and additives used in waterborne stains, including UV absorbers, driers, mildewcides, and wood preservatives, were discussed.

In conclusion, Mr. Heitkamp said all the systems discussed performed similarly in crack resistance, and in QUV and Florida exposures. The modified polyolefin had the best in-can stability in both oven aged and room temperature samples, showing the best retention of drying characteristics, pH, viscosity, and water resistance. The polyolefin was prone to chalking and fading, but showed superior mildew resistance and recoatability.

Jay Austin, of Halox Pigments, presented a talk on "FORMULATION AND EVALUATION OF NONTOXIC, ANTICORROSIVE COATINGS." Mr. Austin is a member of the Chicago Society.

The speaker began his talk by stating that nontoxic anticorrosive coatings can be formulated to be as effective as lead—or chromate-containing coatings. He said nontoxic systems are effective over a narrow PVC range.

Mr. Austin stated the four criteria that can be used to reformulate anticorrosive coatings: equal volume, equal weight, equal cost, or equal performance. He said the equal volume method should never be used. It was suggested that for loadings of a 1 lb/gal or more, an equal weight should be used. For loadings of less than 1 lb/gal, an equal cost basis may be a better method. If equal performance is required, a matrix of PVC versus loading should be used to maximize efficiency.

According to the speaker, salt spray is often used to evaluate the performance of anticorrosive coatings. However, it was emphasized that salt spray is a static test, it does not correlate well with the real world, and it can lead to the development of less effective materials.

Mr. Austin discussed alternative accelerated aging tests currently being evaluated, including prohesion testing, which appears to be a replacement for salt spray. Specifiers in the U.K. have accepted prohesion as a replacement test for salt spray. The Envirotest is another accelerated test in which samples are subjected to immersion, heat, and UV radiation.

In conclusion, Mr. Austin made three recommendations:

- (1) do not ignore exterior testing;
- (2) conduct more correlative work and share it with specifiers; and
- (3) begin serious investigations into basic mechanisms of corrosion degradation.

SARAH E. OEBSER, *Secretary*

Future Society Meetings

Birmingham

(Dec. 5)—"BLOCKING AGENTS IN URETHANE COATINGS—POWDER AND LIQUID PAINTS"—Frank Schollick Memorial Lecture—Mel Kaplan, Allied-Signal Inc.

(Jan. 9)—"NON-AUTOMOTIVE APPLICATIONS OF ELECTROPAINT TECHNOLOGY"—Peter Hope, L.V.H. Coatings Limited.

(Feb. 6)—"THE IMPACT OF ENVIRONMENTAL LEGISLATION ON THE COATINGS INDUSTRY"—Mini-Symposium. Various speakers.

CDIC

(Nov. 11)—"IDENTIFICATION OF PIGMENTS WITH MODERN INSTRUMENTATION IN A PAINT LAB"—Dr. Romesh Kumar, Hoechst Celanese Corp.

(Dec. 9)—"ENVIRONMENTAL BASELINING: THE NEED FOR ENVIRONMENTAL AUDITS"—Bob Shelar, Tetracon Environmental, Inc.

(Jan. 13)—"DRIER RECOMMENDATIONS FOR HIGH SOLIDS-LOW VOC ALKYD RESIN COATINGS"—Marvin Landau, Hüls America, Inc.

(Feb. 10)—"NON-THIXOTROPIC RHEOLOGICAL ADDITIVES"—Robert Dey, RHEOX Inc.

Cleveland

(Nov. 19)—"THE ROLE OF THE U.S. EPA TO THE COATINGS INDUSTRY"—A. Richard Winkhofer, Eastern District Office, Region V, U.S. Environmental Protection Agency.

(Jan. 21)—Joint Meeting with Cleveland PCA. "IMPROVING THE RETURN ON YOUR R&D DOLLAR"—H. David Warren, Tremco, Inc.

(Feb. 18)—"THE USE OF HANSEN SOLUBILITY PARAMETERS IN REFORMULATING SOLVENT-BASED COATINGS"—Wes Archer, The Dow Chemical Co.

(Mar. 17)—"DRIER SYSTEMS FOR HIGH SOLIDS COATINGS"—Marvin Landau, Hüls America, Inc.

(Apr. 21)—"THE ADVENTURES OF A CHEMIST-COLLECTOR"—Dr. Alfred Bader, Aldrich Chemical Co.

(May 19)—"ADVANCES IN RESIN TECHNOLOGY FOR WATERBORNE STAINS"—Al Heitkamp, Cargill Inc.

Detroit

(Dec. 10)—"WASTE MINIMIZATION"—Charles Rooney, Orr & Boss.

(Jan. 14)—"AUTOMOTIVE SPECIFICATIONS FOR COATINGS"—Marilyn Perchard, Ford Motor Co.

(Feb. 11)—"ALUMINUM PIGMENTS FOR WATERBORNE COATINGS"—Frank Passen, Obron Atlantic.

(Mar. 10)—"UV ABSORBERS AND HINDERED AMINE LIGHT STABILIZERS"—Mark Holt, CIBA-GEIGY Corp.

(Apr. 14)—"POLYVINYL CHLORIDE RESINS"—Speaker from ICI Chemicals, Inc.

(May 12)—"COLOR THEORY"—Speaker from Byk-Gardner, Inc.

Golden Gate

(Nov. 18)—"OPAQUE POLYMER—THE ALL PURPOSE PIGMENT"—Elmer Williams, Rohm and Haas Co.

(Jan. 13)—"THE HISTORY AND FUTURE OF COLOR MACHINES"—Jim DeGroff, Color Tec Co.

(Mar. 16)—"SMOOTHNESS OF CLEAR FLAT FINISHES"—Sam Maskery, Crosfield Chemicals Co.

(Apr. 13)—"WATERBORNE RESINS"—Rich Johnson, Cargill, Inc.

(May 18)—"STATISTICAL PROCESS CONTROL"—Dan Baker, McWhorter, Inc.

(June 15)—Manufacturing Committee Seminar.

Montreal

(Nov. 13)—"ALKYD RESIN TECHNOLOGY"—Marc Lemieux, Reichhold Ltd.

(Feb. 5)—Annual Mini-Symposium.

(Jan. 8)—Title and Speaker to Be Announced.

New England

(Nov. 21)—Federation Officers Visit.

Philadelphia

(Dec. 12)—"IMPROVED CORROSION CORRELATION: PROHESION COMBINED WITH QUV FOR TESTING RESISTANCE TO SALT, MOISTURE, AND UV"—Pat Brennan, The Q-Panel Co.

(Jan. 9)—Joint Meeting with Philadelphia PCA. "ENVIRONMENTAL UPDATE"—Hugh M. Smith, Sun Chemical Co.

(Feb. 13)—"SURFACE TREATED PIGMENTS: A 90'S SOLUTION TO SOME COATING PROBLEMS"—D. Romesh Kumar, Hoechst Celanese Corp.

(Mar. 12)—"WAX EMULSIONS IN AQUEOUS POLYMERIC COATINGS: CONTRIBUTIONS AND MECHANISMS"—Marty Reihemann, Michelmann Inc.

(Apr. 24)—Awards Night.

(May 14)—"THE MALCOLM BALDRIDGE PROCESS—A FRAMEWORK FOR IMPROVEMENT"—Ross C. Loeser, E.I. du Pont de Nemours & Co., Inc.

Piedmont

(Nov. 20)—"INTRODUCTION TO PAINT TECHNOLOGY"—Thad Broome, J.M. Huber Corp.

(Dec. 18)—"ECONOMIC OUTLOOK FOR 1992"—Art Werts, Eastman Chemical Products.

Pittsburgh

(Jan. 13)—"UNDERSTANDING THE DIFFERENCE IN ASSOCIATIVE THICKENERS"—Emitt Partain, Union Carbide Corp.

(Feb. 10)—Federation Officers Visit.

(Mar. 9)—"HIGH-SOLIDS COATINGS"—Bernie Taub, Reichhold Chemicals Corp.

(Apr. 13)—Title and Speaker to Be Announced.

(May 11)—Title and Speaker to Be Announced.

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People

Troy Corporation, East Hanover, NJ, has appointed **Timothy M. Savage** as National Sales Manager. In this position, Mr. Savage will direct the company's sales force in providing Troy's biocides and performance additives for liquid and powder coatings, plastics, printing inks, metalworking fluids, textiles, adhesives, and sealants. He is a member of the New York Society.

Patrick M. Fay has joined the staff of Seegott Inc., Solon, OH, to manage sales and technical services in the company's Pittsburgh district which encompasses western Pennsylvania, western New York, and northern West Virginia. Mr. Fay is a Past President and current Board Member of the Chemical Association of Pittsburgh. He is a member of the Pittsburgh Society.

Paul Driscoll, International Sales Manager, has been assigned by Whittaker, Clark & Daniels, Inc., South Plainfield, NJ, to spearhead a new sales effort in the company's new European sales and marketing office in Brussels, Belgium.

In addition, **James P. Lobermann** has been named Senior Account Manager for the Northeastern regional sales staff for Whittaker. Mr. Lobermann will be responsible for field sales in the New England states. He previously represented the company in the Midwestern states.

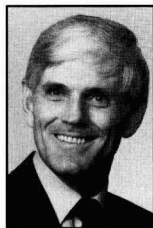
United Gilsonite Laboratories (UGL), Scranton, PA, has named **Joseph McGraw** as its Director of Advertising. Among other duties, Mr. McGraw will be responsible for overseeing the company's national television and print advertising efforts. Prior to this promotion, he served as Marketing Services Manager.

Also, **Barbara Tarabek** has been appointed Marketing Service Manager for UGL. The firm's merchandising, tradeshow and point-of-purchase display program will be under Ms. Tarabek's direction in this position. She most recently served as Co-op Advertising Coordinator.

Donald R. Pinkston, with nearly 30 years experience in the plastics industry, has joined the staff of Avecor, Inc., Vonore, TN as Sales Representative. Mr. Pinkston will be in charge of the sale of Avecor's complete line of color products throughout Texas and in sections of Louisiana and Arkansas. He will be based in Jacksonville, TX.



T.M. Savage



P. M. Fay



W. Stricker



R. Berrios

The appointment of **William Stricker** as a Senior Sales Representative for the Humko Chemical Division of Witco Corporation, New York, NY, has been announced. Mr. Stricker, who will represent the division in South Carolina and portions of Tennessee and Kentucky, joined the company in 1985 after seven years of previous industrial sales experience.

Terry Hill has been promoted to Branch Manager for Tulsa and Oklahoma City for Van Waters & Rogers Inc., Seattle, WA. In this capacity, Mr. Hill will also have responsibility for the firm's distribution location in Amarillo, TX. He most recently served as the Manager of the company's Grand Prairie, TX, branch.

C. George Hollis, Vice President of Research and Development, Buckman Laboratories International, Inc., Memphis, TN, has been selected by The Society for Industrial Biology (SIM) as an SIM Fellow. He is being honored with this fellowship for his achievements in the field of industrial microbiology.

KRONOS, Inc., Houston, TX, has appointed **Simo T. Bergado** Technical Service Chemist at the company's laboratory facility in Hightstown, NJ. Prior to joining KRONOS, Mr. Bergado was an Applications Specialist for BASF. He also served as a Technical Service Specialist for Atochem.

In addition, the promotion of **Tammy L. Hoffman** to Customer Service Representative has been announced. In her new duties, Ms. Hoffman will be responsible for serving customers and distributors throughout the United States. Ms. Hoffman joined KRONOS in 1989 as a Senior Secretary to the human resources department.

The newly created position of Materials Manager for CMI International, Elk Grove Village, IL, has been accepted by **Robert Berrios**. Mr. Berrios will be responsible for the purchasing and inventory control functions for CMI. He previously served as Inventory Control Supervisor for Shiff Photo Mechanics, Costa Mesa, CA.

The promotion of **W.R. (Ric) Pedersen** to Research Chemist/Polymer Group, has been announced by The Dexter Corporation's Packaging Products Division, Waukegan, IL. A six-year employee, Mr. Pedersen began his career with Dexter as a Senior Development Chemist/Polymer Group.

ASTM Presents Awards

Thomas J. Sliva, Assistant Technical Director of D/L Laboratories, New York, NY, is the 1991 recipient of ASTM's Henry A. Gardner Award. The award, presented by ASTM Committee D-1 on Paint and Related Coatings and Materials, recognizes Mr. Sliva's outstanding contributions in the operations of Subcommittees D01.23 and D01.47. He is a member of the New York Society.

Douglas J. MacKenzie, Vice President of Marketing and Sales for ARi Industries, Inc., Addison, IL, has received the organization's Robert D. Thompson Award for 1991. The award, established in 1974, was presented by Committee E-20 on Temperature Measurements in recognition of Mr. MacKenzie's outstanding work within the committee.

Thomas J. Miranda, formerly Staff Scientist for The Whirlpool Corporation, Benton Harbor, MI, has joined the staff of Consolidated Research, Inc., Mount Prospect, IL. In addition to serving as Technical Editor of the *JOURNAL OF COATINGS TECHNOLOGY* since 1972, Dr. Miranda has served as Federation Publications Committee Chairman and a member of the JCT's Editorial Review Board for the past 16 years. In 1980, he was the recipient of the Federation's George Baugh Heckel Award and in 1984, Dr. Miranda presented the Mattiello Memorial Lecture entitled "Reading the Signals of Society: Technology Push or Market Pull," at the Federation's Annual Meeting in Chicago, IL.



Prior to joining Whirlpool, he was Director of Research for The O'Brien Corporation and has also taught at San Jose State, Indiana University, and the University of Notre Dame. Dr. Miranda has authored more than 50 publications and holds a number of patents ranging from coating compositions to resins to rocket fuel. Dr. Miranda is a member of the Chicago Society.

Synergistic Performance Corporation (SPC), Emeryville, CA has announced the appointments of **Bill Haigh** and **Wally Whitney** to the company's Los Angeles branch sales group. Mr. Haigh joined SPC after five years with California Central Chemical in chemical sales. Prior to this appointment, Mr. Whitney spent 21 years with Unocal Chemicals Division as Regional Technical Manager and later as Senior Sales Representative.

Peter Kovacs has accepted the position of Senior Vice President of Kelco Division of Merck & Company, Inc., San Diego, CA. Prior to this promotion, Mr. Kovacs served for two years as Chairman of BritCair, an alginate fiber wound dressing business in Aldershot, England, which was acquired by Merck in 1989.

Grow Group, Inc., New York, NY, has promoted **Joseph Quinn** to the newly created position of Executive Vice President and Chief Operating Officer. Mr. Quinn will continue to be headquartered in Louisville, KY, where he currently serves as President of both Devoe & Raynolds Company and Devoe Coatings Company.

SINCO Inc., East Hampton, CT, has named **Kevin D. Ouellette** Engineering Manager. In this capacity, Mr. Ouellette will overlook the planning and organization of the firm's Engineering Department. Prior to joining SINCO, he was an Engineering Consultant at Aetna Life and Casualty, Hartford, CT, where he was responsible for technical support on engineering and construction issues associated with construction projects across North America.

Wacker Silicones Corporation, Adrian, MI, has named **Steve Wolcott** National Sales Manager. Mr. Wolcott has held several sales and marketing positions during his 12 years with the company. He most recently served as U.S. Marketing Delegate to Wacker-Chemie in Munich, Germany.

The newly created position of Manufacturing Manager/Powder Coatings for Pratt & Lambert, Inc., Buffalo, NY, has been accepted by **Scott N. McMillan**. In this capacity, Mr. McMillan will be responsible for all powder coatings manufacturing operations for the company's Industrial Coatings Division.

Dennis H. Reilley has been named Vice President and General Manager/White Pigment and Mineral Products for Du Pont Chemicals, Du Pont Company, Wilmington, DE. He succeeds **Charles N. Masten**, who is retiring after 40 years of service with the company. Currently Director of titanium dioxide operations, Mr. Reilley transferred to the parent company from Conoco, a Du Pont subsidiary, in 1989. He held a number of managerial positions with Conoco, including President and Managing Director of Conoco-Ireland from 1987 to 1989.

Wayne J. Harrison has been appointed Vice President of Operations for the Macbeth Division of Kollmorgen Instruments Corporation, Newburgh, NY. Mr. Harrison will assume the responsibility for Macbeth's manufacturing, materials, and maintenance operations. He was associated with Dranetz Manufacturing, Northrop, ITT Avionics, and the Singer Company prior to joining Macbeth.

The position of Manager/Safety & Environmental Affairs for Lonza, Fair Lawn, NJ, has been accepted by **Robert E. Miller**. In this capacity, Mr. Miller will be responsible for directing the safety, industrial hygiene, and environmental programs at the company's Mapleton, IL, facility.

Why Renew?

Check Out Five Great Reasons Why You Should Renew Your Membership In The FSCT

- A 1-year subscription to the *JOURNAL OF COATINGS TECHNOLOGY*, the technical publication of the coatings industry, is included with your membership.
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- Federation publications and seminars are available to you at substantial \$\$ savings.
- Special **Member rates** for registration to the FSCT's Annual Meeting and Paint Industries' Show.

Your Membership In The Local Society Includes Membership In The Federation



For more information, contact your local Society, or write to Federation of Societies for Coatings Technology, 492 Norristown Rd., Blue Bell, PA 19422

FT-IR Thermal Sampling

The introduction of an FT-IR sampling accessory for the analysis of heatable substances has been made through literature. The instrument permits the sampling of a wide range of substances such as waxes, films, gels, oils, pastes, and liquids. For further details on the Thermal ATR FT-IR sampling accessory, write Spectra-Tech Inc., 652 Glenbrook Rd., P.O. Box 2109-G, Stamford, CT 06906.

Elastomer Adhesive Products

A newsletter focusing on recent product developments, including adhesives for bonding TPEs, environmentally resistant adhesives, one-coat adhesives, regulatory-compliant products, specialty elastomer adhesives, cyanoacrylate adhesives, and flock adhesives has been printed. Color graphics depict applications, facilities, and end uses, and informative product comparison charts are also included. For more information on the newsletter Chemlok Solutions®, Vol I, No. 1-4, write Lord Corp., Elastomer Products, 2000 W. Grandview Blvd., P.O. Box 10038, Erie, PA 16514-0038.

Ceramic Fiber

A specification sheet describing the chemical and physical properties and also providing an overview of typical applications of a ceramic fiber has been issued. The ceramic fiber is designed to be used in a variety of applications, including molded thermoset and thermoplastic composites; ablative materials; high-performance adhesives and sealants; and automotive and industrial friction products. To obtain a copy of the specification sheet (Form C-1322-10), write The Carborundum Co., Fibers Div., P.O. Box 808, Niagara Falls, NY 14302-0808.

Adhesives Testing

An application bulletin detailing the rheological characterization of adhesives using a solids analyzer has been released. Included are case studies of hot melt adhesives and studies of order-disorder transitions in block copolymers. Application Bulletin #21 on testing adhesives is obtainable from Rheometrics, Marketing Dept., One Possuntown Rd., Piscataway, NJ 08854.

Color Measurement System

A four-color illustrated brochure introducing a goniospectrophotometer designed to make accurate color measurements of metallic paints, pearlescent coatings and inks, anodized aluminum, grained plastics, metallized films, and other difficult-to-measure surface effects has been released. The brochure contains diagrams and photographs of system components, discusses its modular software package, and lists specifications. For copies of the literature detailing the Color-Eye® 5010 measurement system, contact Macbeth, P.O. Box 230, Newburgh, NY 12550-0230.

Latex Binder

A technical brief detailing a styrene butadiene latex binder designed specifically for coated paper use in the rotogravure printing market has been published. The latex is used in coatings that require elasticity and compressibility of the dried coating layer, such a rotogravure coatings for paper. More information on 76 RES 4121 latex binder can be obtained by writing Unocal Polymers, 1700 E. Golf Rd., Schaumburg, IL 60173-5862.

CAS Catalog

The 1992 Chemical Abstracts Service (CAS) catalog has been printed. The 76-page publication provides descriptions of CAS's printed and microform services, online information services, and special services. Information is also given on documentation and workshops that are available for support users of CAS services. To obtain the 1992 CAS catalog, contact CAS, Customer Service, 2540 Olentangy River Rd., P.O. Box 3012, Columbus, OH 43210.

Monitoring System

An advanced microprocessor-based telemetry system offering remote monitoring of product supply levels is the subject of a data sheet. The system is suited for applications that require a constant monitoring of product levels, and is recommended for high-volume users, undersized tanks, remote tank locations, and sites with restricted delivery times. Write Air Products and Chemicals, Inc., IGD Operations Services, 7201 Hamilton Blvd., Allentown, PA 18195-1501 for more in-depth information on the Telalert® product supply monitoring system.



Solution to October's "CrossLinks"

Accelerated Weathering

An accelerated outdoor device which uses the sun as the source of radiant energy to test the weatherability of materials is the focus of a product release. The system tracks the sun to maximize the amount of radiant energy focused on samples throughout the day and accelerates the photodegradation. For further details on SUN10® accelerated outdoor device, contact Larry Bond, South Florida Test Service, Desert Site, 31818 N. 203 Ave., Wittmann, AZ 85361.

Aqueous Urethane Hybrid Polymers

A new line of aqueous urethane hybrid polymers is the subject of a data sheet. The publication highlights various applications and includes a table listing the typical emulsion, film, and coating properties of the line. Write Air Products and Chemicals, Inc., Polymer Chemicals Div., 7201 Hamilton Blvd., Allentown, PA 18195-1501 for a copy of the data sheet, "Flexthane™ EXP Polymers."

Polyphenylene Sulfide

Applications of a polyphenylene sulfide engineering thermoplastic are outlined in a new automotive applications guide. The brochure discusses the performance characteristics of the sulfide for the automotive industry. For a copy of the 16-page bulletin on Ryton® polyphenylene sulfide, contact Phillips 66 Co., c/o Select Marketing, 9020 II Capital of Texas Hwy. N., Austin, TX 78759.

Glossmeter

A portable, battery-operated glossmeter, capable of reading and storing gloss values has been introduced through a data sheet. The instrument is also designed to provide average, range, and standard deviation statistics, and transmits information to a computer or printer. Information on the ProGloss™ glossmeter is obtainable by writing Hunterlab, 11491 Sunset Hills Rd., Reston, VA 22090.

Metering Pumps

A new line of modular diaphragm metering pumps is highlighted in a data sheet. The pumps feature low stoking speeds and a rugged construction designed to handle water treatment chemicals and similar applications. Contact Olivia Mady, Proportioner Metering Pumps, 150 Elmgrove Park, Rochester, NY 14624 for in-depth details on the Series 2200 metering pumps.

Cellulose-Based Fiber

Two grades of fiber specifically suited for use in asphalt pavement resurfacer coatings is the subject of a data sheet. These new fibers have been tested for asphaltic formulations and designed to be an effective replacement for asbestos fibers. For more details, write Interfibe Corp., 6001 Cochran Rd., #A-202, Solon, OH 44139.

Cartridge Filters

A cartridge filter designed to meet critical coatings friction requirements has been introduced through literature. Applications include final filtration of coatings, resins, and solvents during tote-tank and bulk container filling and removal of gels and particulate contamination in batch and continuous operations. Write Millipore Corp., 80 Ashby Rd., Bedford, MA 01730 for further details on the Polygard™-CT clarifying filters.

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University of Missouri-Rolla Releases 1992 Coatings Short Course Schedule

The Continuing Education Program at the University of Missouri-Rolla (UMR), Rolla, MO, has announced its schedule of short courses for 1992.

The upcoming paint and coatings short courses slated for UMR include:

"The Basic Composition of Coatings" (64th Introductory Short Course)—March 9-13;

"Paint Formulation" (24th Introductory Short Course)—March 30-April 3;

"Physical Testing of Paints and Coatings"—May 11-15;

"The Basic Composition of Coatings" (65th Introductory Short Course)—September 14-18; and

"Paint Formulation" (25th Introductory Short Course)—September 28-October 2.

The class on "Composition of Coatings" is designed to introduce the newcomer, as well as those involved in raw material manufacture, sales, and technical service to the technical aspects of paint composition, manufacture, testing, and use. Topics of discussion will include: history of paint; materials used in manufacture; simple for-

mulating techniques that can be put to immediate use; an introduction to the equipment used to make and test modern protective coatings, and modern chemical instrumentation applied to coatings; and simple costing that allows beginners to start on a stable economic basis.

"Paint Formulation" will feature five intensive days of study and work in a laboratory. The class will offer the opportunity to study and experiment with: basic raw materials and their influences on the performance of the finished coating; formulation and testing of coatings in the laboratory to meet the special demands of the job; limitations of plant production equipment

and formulation variables for moving a coating from the laboratory to the plant; modern chemical instrumentation as applied to coatings; and statistical experimental design.

Prerequisites for the course include: experience in a coatings laboratory or raw materials and manufacturing company; completion of the UMR introductory short course on "The Basic Composition of Coatings"; or some basic training in chemistry.

For more short course details, contact Norma R. Fleming, Coordinator, Continuing Education Program, UMR, 119 M.E. Annex, Rolla, MO 65401-0249.

Painting and Decorating Contractors of America Convention and Show Slated for March 6-7

The 108th Annual Convention and Paint and Paper Pro Show of the Painting and Decorating Contractors of America (PDCA) is slated for March 6-7, 1992, at Bally's Casino Resort, in Las Vegas, NV.

The theme of the '92 Convention is "Innovations." The program will focus on the need to increase knowledge of the latest techniques and products used in the painting and wallcovering industry. Contractors will have the choice of attending over 25 educational sessions throughout the week. Lead-

ership, management, and technical sessions will be led by top professionals from the industry.

The Paint and Paper Pro Shop will feature the latest state-of-the-art equipment, materials, and services available in the industry today. The exhibition will feature 172 booths from the industry's leading suppliers.

For more information on the Paint and Paper Pro Show, write PDCA, 3913 Old Lee Highway, Suite 33B, Fairfax, VA 22030.

Lehigh University to Sponsor Course on Latex Technology

The 23rd annual one-week short course entitled, "Advances in Emulsion Polymerization and Latex Technology," is scheduled for June 2-6, 1992. The course is being sponsored by Lehigh University.

The class is an in-depth study of the synthesis and properties of high polymer latexes. The subject matter will include a balance of theory and applications, as well as a balance between chemical and physical problems.

Lectures will be presented by leading academic and industrial workers. These lectures will begin with introductory material and reviews, and progress through recent research results.

The short course is designed for engineers, chemists, other scientists, and managers who are actively involved in emulsion work and for those who wish to develop expertise in the area.

Further information is available from: Dr. Mohamed S. El-Aasser, Emulsion Polymers Institute, Lehigh University, 111 Research Dr., Bethlehem, PA 18015.

SYMCO 1992

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FEDERATION MEETINGS

For information on FSCT meetings, contact Federation of Societies for Coatings Technology, 492 Norristown Rd., Blue Bell, PA 19422 (215) 940-0777, FAX: (215) 940-0292.

1992

(May 17-20)—Federation "Spring Week." Board of Directors Meeting on the 17th; Incoming Society Officers Meeting on the 18th; Spring Seminar on the 19th and 20th. Sheraton Boston Hotel and Towers, Boston, MA.

(Oct. 21-23)—70th Annual Meeting and 57th Paint Industries' Show. McCormick Place, Chicago, IL.

1993

(Oct. 27-29)—71st Annual Meeting and 58th Paint Industries' Show. World Congress Center, Atlanta, GA.

1994

(Oct. 12-14)—72nd Annual Meeting and 59th Paint Industries' Show. New Orleans Convention Center, New Orleans, LA.

SPECIAL SOCIETY MEETINGS

1992

(Jan. 23)—Chicago Society. SYMCO '92—"Sharing Technology." Holiday Inn Crowne Plaza, Lisle, IL. (John DeVaney, Cabot Corp., Cab-O-Sil Div., 2655 Irving St., Portage, IN 46368).

(Feb. 26-28)—Southern Society. 19th Annual Waterborne, Higher-Solids, and Powder Coatings Symposium. Co-sponsored by the Department of Polymer Science at the University of Southern Mississippi (USM), New Orleans, LA. (Robson F. Storey and Shelby F. Thames, Co-Organizers, WBHS&PC Symposium, Dept. of Polymers Science, USM, Southern Station Box 10076, Hattiesburg, MS 39406-0076).

(Mar. 11-13)—Southern Society Annual Meeting. Grosvenor Resort Hotel, Orlando, FL. (Billy Lee, Kemira, Inc., P.O. Box 368, Savannah, GA 31402).

(Mar. 29-31)—Houston and Dallas Societies. Southwestern Paint Convention. South Shore Harbour Resort & Conference Center, League City (Houston), TX. (Dennis Crozier, Crozier-Nelson Sales, Inc., 2505 Collingsworth, Houston, TX 77026).

(May 1-2)—Pacific Northwest Society. Annual Symposium. (John Westendorf, Lipscomb Chemical Co., 2627 N.W. Nicolai St., Portland, OR 97210).

OTHER ORGANIZATIONS

1991

(Nov. 18-22)—North American Research Conference on Crosslinked Polymers. Sponsored by the Division of Polymeric Materials: Science and Technology of the American Chemical Society. Marriott's Hilton Hotel Resort, Hilton Head, SC. (Angelos V. Patsis, Institute of Materials Science, State University of New York, New Paltz, NY 12561).

(Nov. 19-21)—14th Resins & Pigments Exhibition. Sponsored by the Oil & Colour Chemists' Association. The Paint Research Association's 11th International Conference on November 18-20. Brussels Exhibition Center, Belgium. (Jane Malcolm-Coe, PR & Publicity Manager, FMJ International Publications Ltd., Queensway House, 2 Queensway, Redhill, Surrey, RH1 1QS, United Kingdom).

(Nov. 21)—"Lithographic Printing—From Raw Materials to Waste Recycling—The Integrated Approach." International symposium sponsored by the Oil & Colour Chemists' Association (OCCA), Brussels, The Netherlands. (Yvonne Waterman, OCCA, Priory House, 967 Harrow Rd., Wembley, Middlesex, England HA0 2SF).

(Dec. 2-4)—"Electrochemical Techniques for Corrosion Measurement." Sixth annual symposium and refresher course sponsored by EG&G Princeton Applied Research. New Orleans, LA. (EG&G Princeton Applied Research, P.O. Box 2565, Princeton, NJ 08543).


(Dec. 2-6)—Fall Meeting of the Materials Research Society. Also, three short courses to be presented include: "Cementitious Materials," "Shape-Memory Materials," and "Biomaterials." Boston, MA. (Materials Research Society, Meetings Dept., 9800 McKnight Rd., Pittsburgh, PA 15237).

(Dec. 5)—Technical seminar on "Powder Coating." Sponsored by The Powder Coating Institute (PCI). Wilson World Hotel at DFW Airport, Dallas, TX. (PCI, 1800 Diagonal Rd., Ste. 370, Alexandria, VA 22314).

1992

(Feb. 18-20)—Hazardous Materials Management Conference and Exhibition/Northern California. San Jose Convention Center, San Jose, CA. (Tower Conference Management Co., 800 Roosevelt Rd., Bldg. E—Suite 408, Glen Ellyn, IL 60137-5835).

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(Feb. 23-26)—Williamsburg Conference, "Comparison of Color Images Presented in Different Media." Co-sponsored by the Inter-Society Color Council and the Technical Association of Graphic Arts, Colonial Williamsburg, VA. (Milton Pearson, RIT Research Corp., 75 Highpower Rd., Rochester, NY 14623).

(Mar. 6-7)—108th Annual Convention and Paint and Paper Pro Show. Sponsored by Painting and Decorating Contractors of America (PDCA). Bally's Casino Resort, Las Vegas, NV. (PDCA, 3913 Old Lee Hwy., Ste. 33-B, Fairfax, VA 22030).

(Mar. 9-13)—PITTCON '92 Conference. New Orleans Convention Center, New Orleans, LA. (Pittsburgh Conference, Dept. CFP, 300 Penn Center Blvd., Ste. 332, Pittsburgh, PA 15235-5503).

(Mar. 11-13)—7th Annual Architectural Spray Coaters Association (ASCA) Conference. Saddlebrook Resort, Tampa, FL. (ASCA, 230 W. Wells St., Ste. 311, Milwaukee, WI 53203).

(Mar. 17-18)—Electrocoat'92. Sponsored by *Products Finishing* magazine. Drawbridge Inn, Ft. Mitchell, KY. (Greater Cincinnati Airport Area). (Cindy Goodridge, Gardner Management Services, 6600 Clough Pike, Cincinnati, OH 45244).

(Mar. 22-27)—35th Annual Technical Conference of the Society of Vacuum Coaters (SVC). Hyatt Regency on the Inner Harbor, Baltimore, MD. (SVC, 440 Live Oak Loop, Albuquerque, NM 87122).

STATEMENT OF OWNERSHIP, MANAGEMENT AND CIRCULATION
(Act of August 12, 1970: Section 3685, Title 39, United States Code)

Title of Publication: Journal of Coatings Technology

Date of Filing: October 1, 1991

Frequency of Issue: Monthly

Number of Issues Published Annually: 12

Annual Subscription Price: U.S./Canada—\$30.00; Europe—\$60.00; Other Countries—\$45.00

Location of Known Office of Publication: 492 Norristown Rd., Blue Bell, PA 19422

Location of Headquarters of General Business Offices of the Publisher: Same as above

Names and Addresses of Publisher, Editor, and Managing Editor:

Publisher—Federation of Societies for Coatings Technology, 492 Norristown Rd., Blue Bell, PA 19422

Editor—Patricia D. Viola, 492 Norristown Rd., Blue Bell, PA 19422

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Known Bondholders, Mortgages, and Other Security Holders Owning or Holding One Percent or More of Total Amount of Bond, Mortgages, or Other Securities: None.

The Purpose, Function, and Nonprofit Status of This Organization and the Exempt Status for Federal Income Tax Purposes: Have Not Changed During the Preceding 12 Months

Extent and Nature of Circulation:

Average No. Copies Each Issue During Preceding 12 Months

Actual No. Copies of Single Issue Nearest to Filing Date

	Average No. Copies Each Issue During Preceding 12 Months	Actual No. Copies of Single Issue Nearest to Filing Date
A. Total No. of Copies Printed (Net Press Run)	10,717	10,568
B. Paid Circulation		
1. Sales Through Dealers and Carriers, Street Vendors and Counter Sales	0	0
2. Mail Subscriptions	9,597	9,627
C. Total Paid Circulation	9,597	9,627
D. Free Distribution by Mail, Carrier, or Other Means, Samples, Complimentary, and Other Free Copies	297	305
E. Total Distribution	9,894	9,932
F. Copies Not Distributed		
1. Office Use, Left Over, Unaccounted, Spoiled After Printing	823	636
2. Returns From News Agents	0	0
G. Total	10,717	10,568

I certify that the statements made by me are correct and complete. (signed) Patricia D. Viola, Editor

(Mar. 23-26)—WESTEC '92—29th Exposition & Conference. Sponsored by Society of Manufacturing Engineers (SME), ASM International, American Machine Tool Distributors' Association, and The Association for Manufacturing Technology. Los Angeles Convention Center, Los Angeles, CA. (SME Customer Service Center, One SME Dr., P.O. Box 930, Dearborn, MI 48121-0930).

(Mar. 24-26)—Surface Coating '92. Conference and Trade Show sponsored by Chemical Coaters Association International (CCAI). Indianapolis Convention Center, Indianapolis, IN. (CCAI, P.O. Box 54316, Cincinnati, OH 45254).

(Apr. 1-8)—Surface Treatment '92 Exhibition. Hannover Fairgrounds, Hannover, Germany. (Hannover Fairs USA Inc., 103 Carnegie Ctr., Princeton, NJ 08540).

(Apr. 5-10)—"Water-Based Coatings" Symposium. Sponsored by American Chemical Society, Division of Polymeric Materials: Science and Engineering. San Francisco, CA. (F. Louis Floyd, The Glidden Co., 16651 Sprague Rd., Strongsville, OH 44136, or John L. Massingill Jr., The Dow Chemical Co., Bldg. B-1603, Freeport, TX 77541).

(May 11-14)—Powder & Bulk Solids '92 Conference/Exhibition. O'Hare Exposition Center, Rosemont (Chicago), IL. (Cahners Exposition Group, Dept. Powder & Bulk Solids '92, 1350 E. Touhy Ave., P.O. Box 5060, Des Plaines, IL 60017-5060).

(May 19-21)—PaintCon '92. Conference and exhibition sponsored by *Industrial Finishing Magazine*. O'Hare Expo Center, Chicago (Rosemont), IL. (PaintCon '92, 2400 E. Devon Ave., Des Plaines, IL 60018).

(June 1-4)—Fifth International Symposium on Polymer Analysis and Characterization. Inuyama Hotel, Inuyama City, Japan. (Howard Barth, Du Pont Co., Experimental Station, P.O. Box 80228, Wilmington, DE 19880-0228).

(June 2-6)—"Advances in Emulsion Polymerization and Latex Technology." Short course sponsored by Emulsion Polymers Institute, Lehigh University, Bethlehem, PA. (Mohamed S. El-Aasser, Emulsion Polymers Institute, Lehigh University, 111 Research Dr., Bethlehem, PA 18105).

(June 14-18)—XXIth FATIPEC Congress. RAI International Congress Centre, Amsterdam, The Netherlands. (General Secretary Francis Borel, 34 Chemin du Halage, La Bonneville, Mery sur Oise, France).

(June 15-17)—Euroformula '92. International Trade Fair. RAI International Exhibition and Congress Centre. Amsterdam, The Netherlands. (RAI, Europaplein, 1078 GZ, Amsterdam, The Netherlands).

(June 21-24)—ISCC 61st Annual Meeting and AIC 25th Anniversary. International symposium on "Computer Color Formulation." Princeton University, Princeton, NJ. (Danny Rich, ISCC Secretary, ACS Datacolor, 5 Princess Rd., Lawrenceville, NJ 08648).

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'Humbug' from Hillman

I have frequently observed that some stories keep circulating for years and as they go round and round, they pop up in my mail again and again—sometimes in slightly altered form. In September 1990, we published "Medical Terminology for the Layman," sent to me by Saul Spindel. I have recently received from Carl Engelhardt, Past-President of the New York Society (when it was a "Club"), a similar list titled, "Hillbillies Medical Terminology"—with a few additions noted below.

I might note that I posted Saul's list on a wall of our local medical center months ago. Sure enough, a friend copied the whole thing and handed it to me saying, "Here's some good stuff for your column!"

Carl's Additions

Coma A punctuation mark
Grippe A suitcase
Morbid A higher offer
Secretion Hiding any thing

I was delighted to get a note from Saul Spindel again with a contribution for the column, plucked from "Veteran's Voice." It is interesting to note that many (if I have many) readers will remember reading similar stuff written in previous columns but in different context. For those folks, here's an opportunity for a second laugh.

The "Write" Stuff Can Send the Wrong Message

A picture, according to an ancient Chinese proverb, is worth more than a thousand words. A misplaced word, however, can occasionally conjure up a multitude of pictures and not necessarily what one would expect.

Over the years, the Army's Finance Center at Fort Ben Harrison, Indiana, has received many heart-wrenching letters from spouses and dependents of soldiers appealing for help . . . (Spelling and grammar remain as originally written.)

—In accordance with your instructions, I have given birth to twins in the enclosed envelope.

—I have already wrote to the President and if I don't hear from you I will write Uncle Sam.

—I have already had no clothing for a year and have been regularly visited by the clergy.

—This is my eight child. What are you going to do about it?

—You change my little girl to a boy. Does this make a difference?

—Please find out for certain if my husband is dead as the man I am living with won't eat or sleep or do anything till he nose for sure.

—I am glad to say that my husband who was reported missing is now dead.

—I has no children as my husband is a truck driver and works night and day.

—I am annoyed to find that you have branded by child illiterate. It is a shame and a dirty lie, as I married his father a week before he was born.

—Sir, I am forwarding my marriage certificate and two children, one of which is a mistake as you can see.

—Unless I get my husband's money soon, I will be forced to live an immortal life.

—Both sides of my parents is poor and I can't expect nothing from them as my mother has been in bed with the same doctor for one year and won't change.

In the same issue a headline announces "Gulf Troops Warned of Exotic Diseases" and Saul observes, "In my day, Sally Rand was 'exotic.'"

My daughter-in-law, Pat Hillman, an "Information Systems Manager" and a certified (by me) "non nerd," forwarded a copy of the *Journal of Systems Management* which contained an informative article by Darrell S. Corbin, "From Nerd to Normal in 10 Easy Steps." To begin with, it is necessary to take the following determining test.

Nerd Quotient (NQ) Test

The purpose of this test is to quickly determine if you are a nerd or have nerd tendencies. Answer all questions honestly and quickly. Put your answer, a Y (yes) or N (no), by each question. Maybe is not allowed (there's nothing worse than a wimpy nerd).

Do you like computers, especially ones that are blue?

Do you read *Computer World*, *Datamation*, or *Journal of Systems Management*?

Do you have a home computer?

Did your mother give you a mug that says, "Computer people don't get old, they just lose their memory?"

Have you ever said "DOS" or "OS/2" in public?

Do you remember when GE and RCA made computers?

Do you have a special data modeling joke?

Does your heartbeat increase when you walk by a software store?

Do you salivate when you're in a computer center?

Do you know the difference between Jad and Rad?

Do you start to perspire when OS/2, UNIX, and GUI are mentioned?

Do you wear anything plaid?

Did you take a portable PC on vacation?

Is your pocket protector more than a year old?

Do you still have ink stains on your shirt or blouse?

Have you read more than two James Martin books?

Do you have pictures of animals or rocks at work?

Do you know how to operate a slide rule?

Have you ever drooled in a Radio Shack store?

Did you take COBOL and like it?

Did you take Pascal and like it better?

Does your pet still bite you?

Did you ever own a VW bus or bug?

Do you sometimes chuckle when looking in the mirror?

Add up all the "yes" answers:

15-25—No question about it. You are a certified nerd. Your NQ is 4.86.

10-14—You have latent nerd tendencies. You're able to fool some of the people 34% of the time. You're probably one of those smart aleck end users who thinks you know it all. Your NQ is 2.86.

0-9—You're too smart to be true. You need psychiatric help immediately. Your NQ is 0.

—Herb Hillman
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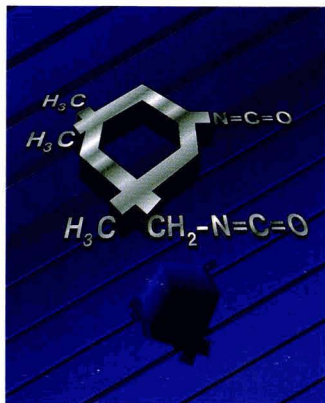
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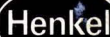
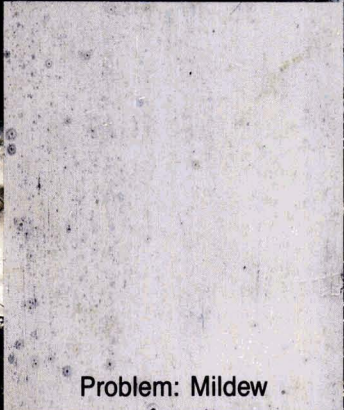
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HÜLS AMERICA INC.
hüls

The Henkel logo, consisting of the word "Henkel" in a white serif font inside a white oval, is positioned in the top right corner of the advertisement.A rectangular white sample of paint that has been heavily affected by mildew, showing numerous dark, irregular spots and a mottled texture. The text "Problem: Mildew" is printed at the bottom of this sample.

Problem: Mildew

A rectangular white sample of paint that has been treated with Nopcocide Mildewcides. The surface is clean, smooth, and free of any mildew spots, appearing as a uniform off-white color. The text "Solution: Nopcocide® Mildewcides" is printed at the bottom of this sample.

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