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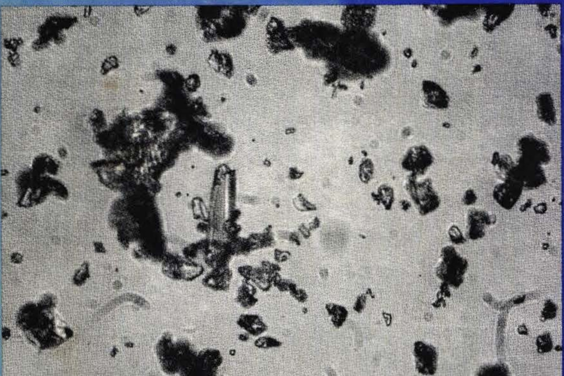
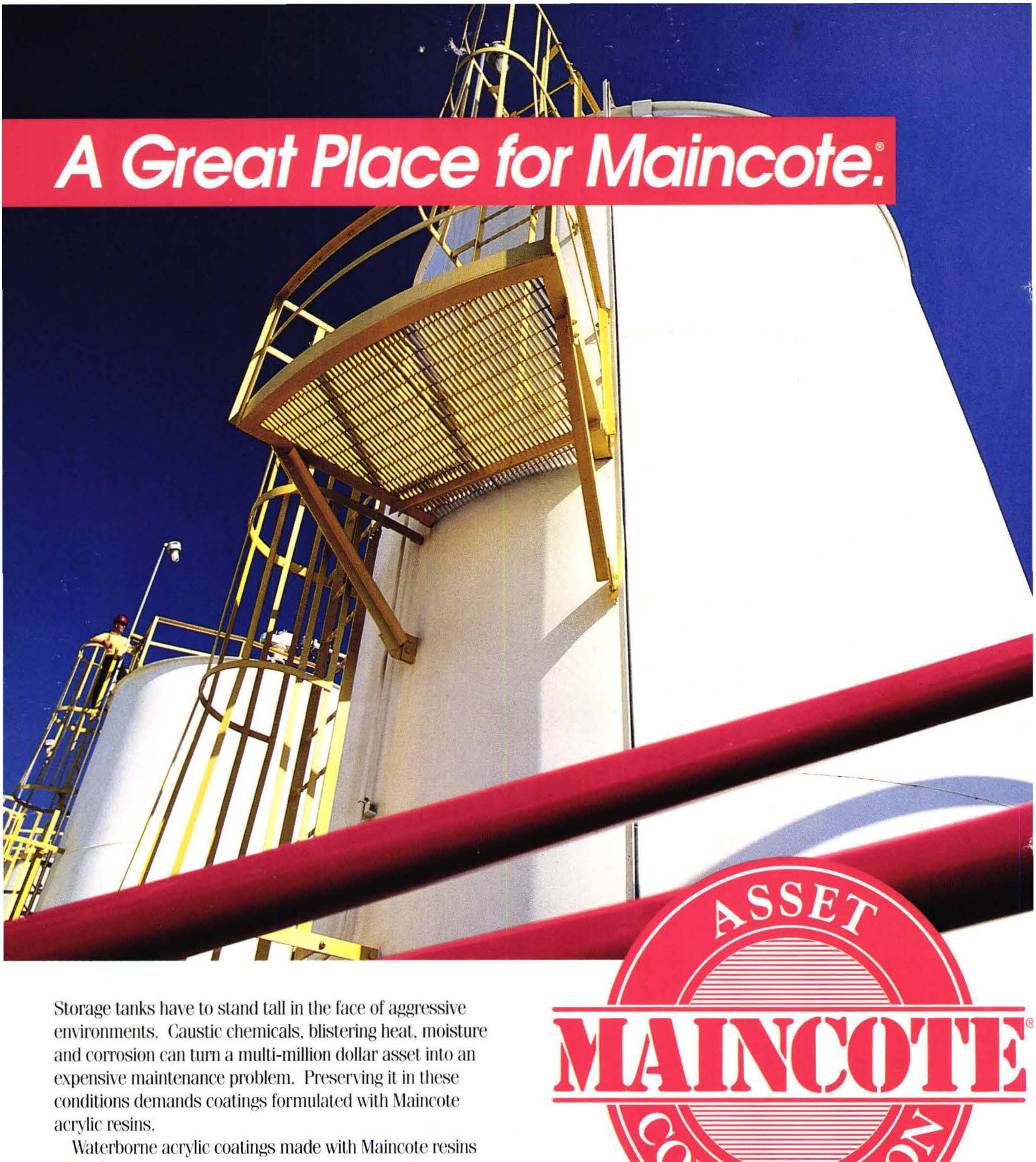


Comparison of the Effectiveness of Electric IR and Other Energy Sources to Cure Powder Coatings.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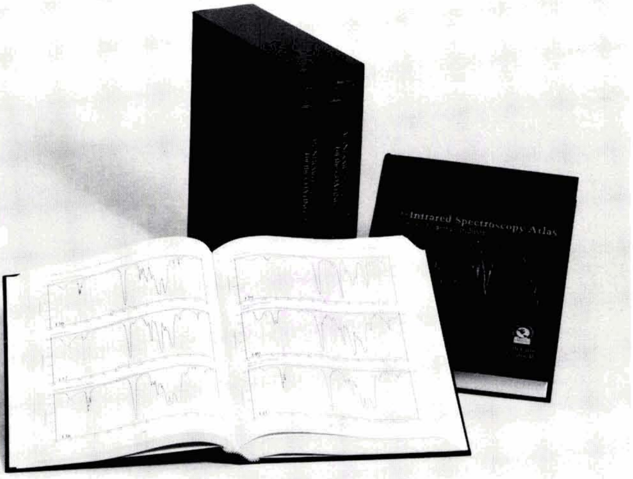

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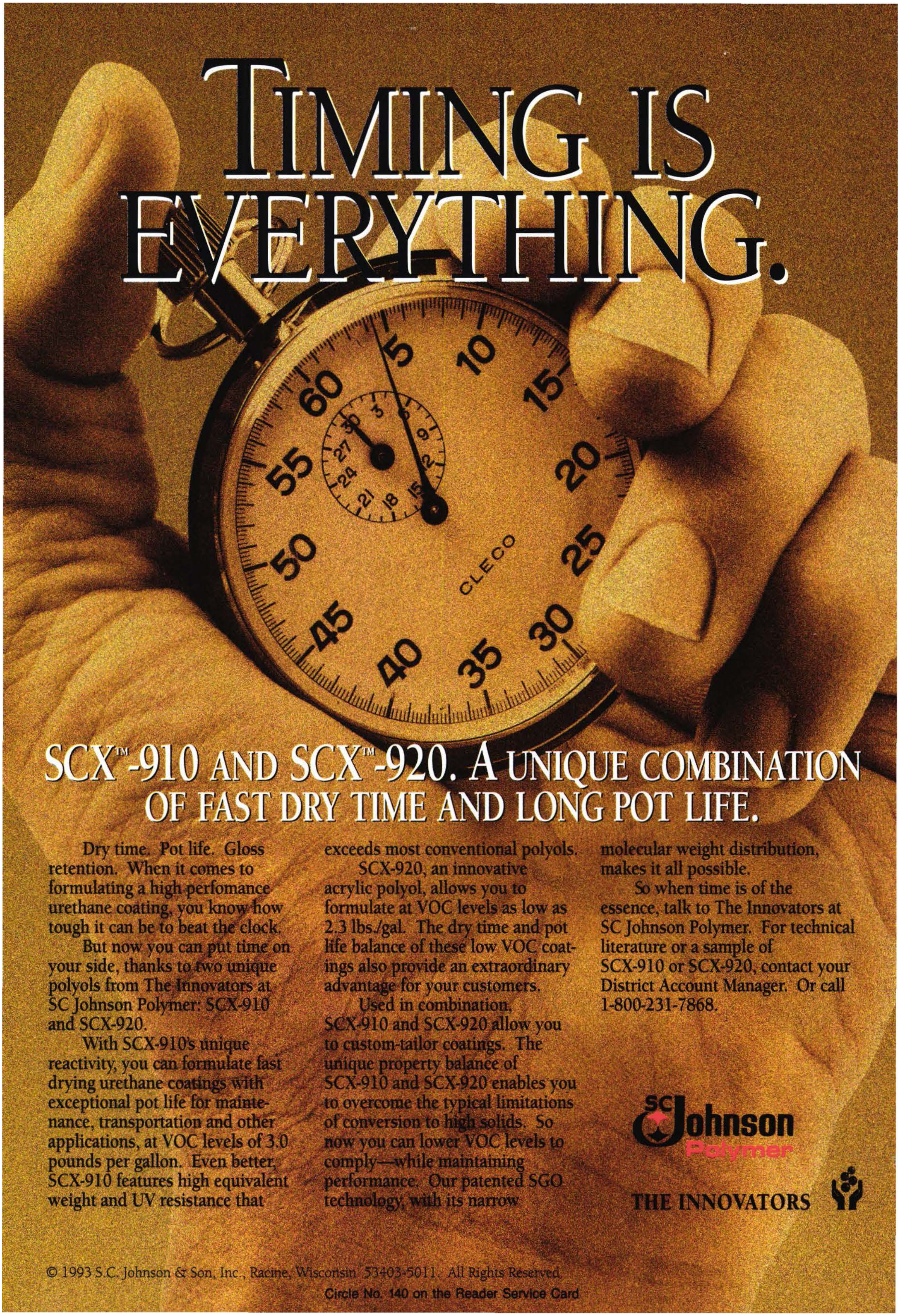
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Comment

The Difference Between the Great and the Near Great

Recently, we heard a news report quoting a survey of sports fans which said that over 75% would not buy a ticket to watch Michael Jordan play major league baseball. We expect that most readers know who Mr. Jordan is and that he is attempting to start a new career in the "summer sport." But, what has this to do with the Federation or its members?

While we don't know it for a fact, we do have a strong suspicion that Mr. Jordan is not changing careers for the sake of his fans. No one, let alone a major sports figure, would put himself into a position of risking failure, embarrassment, and harassment, to impress a group who have been known to be somewhat fickle in their support. No, he is doing this for himself. And, whether his reasons include facing new challenges, self-fulfillment, or ego, his attempt is admirable and his courage cannot be denied.

The parallel between Mr. Jordan and each and every one of us is obvious: we all wish to be the best we can be in whatever capacity we find ourselves. The difference is that while we all want to improve, some people make the attempt while others make plans.

Membership in the Federation and its Constituent Societies offers the opportunity to make the attempt. Attendance at the FSCT Annual Meeting and Paint Show and industry seminars, interacting with colleagues at Society meetings, and reading the variety of publications produced by the FSCT, are the means by which improvement is made.

If you are not a member, take a look at what the FSCT has to offer. If you are a member, get involved and take on challenges. Mr. Jordan may be the best basketball player to ever set foot on a court, but baseball gives him something that his old sport never did — a *real* opportunity to succeed.

If you take the chance to get involved, take the challenge to improve, you may be able to say (to paraphrase Garrett Morris' character on *Saturday Night Live*), "The FSCT has been very, very good for me!"

Robert F. Ziegler

Robert F. Ziegler
Executive Vice President

Abstracts of Papers in This Issue

(Translations provided by: French—Montreal Society Member Alain Brisson, of Hoechst Canada, Inc. and Spanish—Mexico Society Member Cesar Fuentes Carrasco, of Instituto Mexicano de Tecnicos en Pinturas y Tintas.)

Comparison of the Effectiveness of Electric IR and Other Energy Sources of Cure Powder Coatings—R.J. Dick et. al.

JCT, 66, No. 831, 23 (Apr. 1994)

A study has been conducted to compare the effectiveness of electric IR and other energy sources to cure powder coatings. Four energy sources (high-intensity electric IR, gas IR, electric convection oven, and gas convection oven) have been employed to cure nine commercially available powders. The powders include: white epoxy, black epoxy, white acrylic, white urethane, white polyester, white polyester hybrid, white nylon, clear polyester, and fine white polyester (classified by manufacturer to less than 25-30 μ). Manufacturer's curing recommendations (time-at-peak metal temperature) were used for convection oven curing. Powder cure in electric and gas IR ovens was optimized using experimental methods. The curing conditions are presented as time-at-voltage (electric IR) and time-at-BTU expressed as water column pressure (gas IR).

Physical and performance properties of the nine coatings cured with the four different energy sources are presented. Films of each powder were deliberately under- and over-cured and evaluated to note changes in physical and performance properties with the degree of cure. These data demonstrate the efficiency of using IR curing methods to obtain optimum performance properties in powder coatings.

The mechanisms by which film formation and cure occur in powder coating materials depends on the specific means used to impart heat to the coating and the coated substrate. All of these methods of cure involve conduction, convection, and thermal radiation processes. The fundamental concepts of each of these mechanisms of heat transfer are reviewed. Special attention is given to convective and thermal radiation (IR) processes, as these two methods of heat transfer are of primary importance to the methods of powder cure evaluated in this work. Discussion is presented which defines the variables important to each process, and the effects of these variables on cure in powder coatings. Possible mechanisms for the cure process of powder coatings applied to substrate materials are presented for each of these processes, and the implications of these processes are discussed. In the case of IR cure of powder coatings, some questions are raised regarding the exact mechanism of the cure process. The advantages and disadvantages of convection and IR cure of powder coatings are addressed in detail.

The powders evaluated were examined with photoacoustic FT-IR (PA FT-IR) spec-

Comparaison de L'Efficacité de l'IR Electrique et autres Sources D'Energie Pour la Réticulation des Revêtements en Poudre—R.J. Dick et al.

JCT, 66, No. 831, 23 (Apr. 1994)

Une étude a été entreprise pour comparer l'efficacité de l'IR électrique ainsi que d'autres sources d'énergie pour la réticulation des revêtements en poudre. Quatre sources d'énergie (IR électrique à haute intensité, IR au gaz, four à convection électrique, et four à convection au gaz) ont été employées pour réticuler des revêtements en poudre commerciaux. Ces derniers sont; époxy blanc, époxy noir, acrylique blanc, uréthane blanc, polyester blanc, polyester hybride blanc, nylon blanc, polyester clair, et polyester blanc fin (moins de 25-30μ). Les recommendations de réticulation du fabricant (temps à la plus haute température du métal) ont été utilisées pour la réticulation dans un four à convection. La réticulation des poudres dans les fours IR électrique et au gaz a été utilisée avec l'aide des méthodes expérimentales. Les conditions de réticulation sont présentées comme temps de voltage (IR électrique) et temps de BTU exprimé par la pression d'une colonne d'eau (IR au gaz).

Les performances et propriétés physiques de neuf revêtements reticulés avec quatre sources d'énergie différentes sont présentées. Chaque revêtement a été délibérément sous et sur-réticulé afin d'évaluer les performances et changements physiques avec le degré de réticulation. Ces données démontrent l'efficacité de l'utilisation des méthodes de réticulation IR pour obtenir des performances optimales pour les propriétés des revêtements en poudre.

Les mécanismes par lesquels la formation du film et la réticulation se produisent dans les matériaux des revêtements en poudre dépendent de la façon utilisée pour chauffer le revêtement et le subjectile. Toutes ces méthodes de réticulation impliquent des procédés de conduction, convection et radiation thermique. Les concepts fondamentaux de chacun de ces mécanismes de transfer de chaleur sont revisés. Une attention spéciale est donnée aux procédés IR de convection et de radiation thermique, puisque que ces deux méthodes de transfer de chaleur sont d'une grande importance pour les méthodes de réticulations évaluées. Une discussion est présentée pour définir les variables importantes de chaque procédé, et les effets de ces dernières sur la réticulation des revêtements en poudre. Les mécanismes possibles des procédés de réticulation des revêtements en poudre appliqués sur des

Comparison de la Efectividad de la Energia Electrica IR y Otras Fuentes de Energia Para el Curado de Recubrimientos en Polvo—R.J. Dick et. al.

JCT, 66, No. 831, 23 (Apr. 1994)

Un estudio ha sido dirigido para comparar la efectividad de la energía eléctrica IR y otras fuentes de energía para el curado de los recubrimientos en polvo. Se emplearon cuatro fuentes de energía (Alta intensidad electrica IR, gas IR, horno de convención eléctrica y un horno de gas) para curar nueve recubrimientos comerciales en polvo disponibles. Entre estos sistemas en polvo se incluyen: blanco epoxy, negro epoxy, blanco acrilico, blanco uretano, blanco poliester, híbrido poliester blanco, blanco nylon, claro poliester y un poliester fino blanco (clasificado por el fabricante en menos de 25-30 μ). Las recomendaciones de los fabricantes para el curado (tiempo en temperatura máxima del metal) fueron usados para curados en hornos convencionales. El curado de polvos en hornos electricos y de gas IR fueron optimizados usando métodos experimentales. Las condiciones de curado se presentaron como tiempo a voltaje (IR electrico) y tiempo a BTU expresados como la presión en una columna de agua (gas IR).

Se presentaron las propiedades físicas y de desarrollo de los nueve recubrimientos curados con las cuatro diferentes fuentes de energía. Las películas de cada recubrimiento en polvo fueron deliberadamente curadas por debajo y sobre las condiciones o grados optimos y evaluados para notar los cambios en sus propiedades fisicas y de desarrollo con el grado de curado. Estos datos demuestran una eficiencia al usar métodos de curado IR en recubrimientos en polvo para obtener desarrollos óptimos.

El mecanismo por el cual la formación de películas y el curado ocurren en materiales de recubrimiento en polvo dependen de los medios específicos usados para impartir calor al recubrimiento y al sustrato del recubrimiento. Todos estos métodos de cura involucran procesos de conducción, convección y radiación. Son revisados los conceptos fundamentales de cada uno de estos mechanismos de tranferencia de calor. Candose una especial atención a los procesos de convección y radiación (IR), en este trabajo estos dos métodos de transferencia de calor son de importancia para los métodos de evaluación en el curado de recubrimientos en polvo y se presenta una discusión la cual define la importancia de las variables de cada proceso y los efectos de estas variables en troscopy and differential scanning calorimetry (DSC). The DSC work ascertained the melting and curing temperatures of the powder coatings. Most of the coatings melted in the 160-180°C range and cured in the 220-240°C range. The PA FT-IR work illustrated the transparency of the coatings to IR in the 1-3 μm range and the infrared absorption in the 3-20 μm range. These infrared data also raised questions concerning the cure mechanism with respect to substrate conduction or coating absorption of the infrared radiation. Evidence collected during the course of this work suggests that the coatings cure through conduction with some absorption of IR by the coating. The conduction of the energy, primarily from the substrate to the coating, allows the coating from the substrate outwards to the coating surface.

A model has been developed for describing how powder particles fuse and coalesce into a continuous film structure. Parameters, such as density of the powder coating, solubility parameters, surface tension, and melt viscosity, were correlated with the ability of the powder particles to flow together and form a continuous film structure.

Chemical Reactivity of Sulphur Dioxide with Unsaturated Drying Oils—W.H. Simendinger and C.M. Balik

JCT, 66, No. 831, 39 (Apr. 1994)

Differential scanning calorimetry (DSC) and fourier transform infrared spectroscopy (FTIR) were used to characterize the chemical reaction occurring between sulphur dioxide (SO_2) and unsaturated drying oils present in typical alkyd paints. Specifically, linolenic acid, linoleic acid, and oleic acid were studied. It was found that prior exposure of linolenic and linoleic acids to SO_2 would suppress the DSC exotherm associated with the auto oxidative crosslinking reaction. Similar behavior had been noted previously when a fully formulated alkyd paint was exposed to SO_2 and then scanned in the DSC. Oleic acid was unreactive toward SO_2, due to the lack of any doubly activated allylic hydrogen atoms. FTIR spectra of linolenic and linoleic acids exposed to SO_2, air, or both showed loss of allylic hydrogen atoms, a configurational change from *cis-* to *trans-*about the double bonds, and incorporation of —SO_2— groups when SO_2 was present. A reaction scheme is proposed that involves reaction at doubly activated allylic sites, and subsequent incorporation of —SO_2— groups into the crosslinks.

Cost-Effective Pigments in Alkyd Primers for Steel: Barrier Anti-Corrosion Mechanism—W.C. Johnson

JCT, 66, No. 831, 47 (Apr. 1994)

A major cost of alkyd primers for the protection of steel is the chemically active pigment. A low concentration of a pigment sufficient to just neutralize the acids that are

subjectiles sont présentés pour chacun de ces procédés, et les répercussions de ces derniers sont discutés. Pour le cas de la réticulation IR des revêtements en poudre, quelques questions sont posées sur le mécanisme exact du procédé de réticulation. Les avantages et les désvantages de la réticulation des revêtements en poudre par les procédés IR et de convection sont discutés en détail.

Les revêtements évalués ont été examinés avec l'aide de la spectroscopie photoacoustique FT-IR (PA FT-IR) et la calorimétrie à balayage différentielle (DSC). Les données de DSC ont confirmé les températures de fusion et de réticulation des revêtements en poudre. La plupart des revêtements ont eu un point de fusion dans la gamme de 160-180 °C ainsi qu'un degré de réticulation de 220-240°C. Le travail de PA FT-IR illustre la transparence des revêtements à l'IR dans la gamme des 1-3μm et l'absorption infrarouge dans la gamme de 3-20μm. Ces données d'infrarouge ont amené des questions au sujet du mécanisme de réticulation, plus particulièrement au sujet de la conduction du subjectile ou de l'absorption de la radiation infrarouge par le revêtement. Les évidences recueillies dans cette étude suggèrent que la réticulation des revêtements se produit par conduction et absorption infrarouge. La conduction de l'énergie, principalement du subjectile vers le revêtement, permet au revêtement de réticuler du subjectile vers la surface du revêtement.

Un modèle a été pour décrire comment les particules de poudre fusionnent pour former un film continu. Des paramètres tels la densité du revêtement en poudre, paramètres de solubilité, tension de surface, et viscosité de fusion, ont été corrélés avec l'aptitude des particules de poudre à former un film continu.

Réactivité Chimique du SO_2 Avec des Huiles Siccatives Non-Saturées—W.H. Simendinger and C.M. Balik

JCT, 66, No. 831, 39 (Apr. 1994)

La Calorimétrie à Balayage Différentielle (DSC) et la Spectroscopie à Transformée de Fourier (FTIR) ont été utilisées pour la caractérisation de la réaction chimique se produisant entre le SO_2 et les huiles siccatives non-saturées présentes dans des revêtements alkydes types. Plus spécifiquement, les acides linoléniques, linoléiques et oléiques ont été étudiées. Il a été trouvé qu'une exposition des acides linoléniques et linoléiques au SO_2 supprimerait l'exotherme du DSC associée avec la réaction de réticulation auto-oxidante. Un comportement similaire a été noté précédemment lorsqu'un revêtement alkyde a été exposé au SO_2 et puis balayé avec l'aide du DSC. L'acide oléique n'a pas réagi avec le SO_2 dû à l'absence d'atomes d'hydrogènes allyliques doublement activés. Les spectres FTIR des acides linoléniques et linoléiques exposées au SO_2, à l'air, ou à une combinaison des deux, a démontré la

el curado de recubrimientos en polvo. Los posibles mecanismos para los procesos de curado en los recubrimientos en polvo aplicados a los materiales del sustrato son también presentados para cada uno de estos procesos y se discuten las implicaciones de cada uno de estos procesos. En el caso del curado IR de recubrimientos en polvo algunas observaciones en cuanto a los mecanismos exactos de los procesos de curado son vistas. Las ventajas y desventajas de la convección y curado IR de recubrimientos en polvo son vistos en detalle.

Los polvos evaluados fueron examinados con espectroscopia fotoacústica FT-IR (PA FT-IR) y por calorimetría de escaneo diferencial (DSC). El DSC trabaja investigando las temperaturas de fusión y curado de recubrimientos en polvo. La mayoría de los recubrimientos se fusionaron en el rango de 160-180°C y curaron en el rango de 220-240°C. El PA FT-IR trabaja esclareciendo la transparencia de los recubrimientpos en el rango de 1-3 μm y la absorción infrarroja en el rango de 3-20 μm. Estos datos infrarrojos también clarifican algunas cuestiones concernientes a los mecanismos de cura con respecto a la conducción de sustratos o absorción de recubrimientos de radiación infrarroja. Las evidencias reunidas durante el curso de este trabajo han sugerido el curado de recubrimientos através de conducción con alguna absorción de IR por el recubrimiento. La conducción de la energía, primordialmente desde el sustrato al recubrimiento permite al recubrimiento una cura desde el sustrato externo a la superficie del recubrimiento.

Un modelo ha sido desarrollado para describir como las partículas de polvo se funden y unen dentro de una estructura de película continua. Parámetros como la densidad del recubrimiento en polvo, parámetros de solubilidad, tensión superficial y viscosidad melt fueron correlacionadas con la habilidad de las partículas de polvo para fluir juntas y formar una estructura de película continua.

Reactividad Quimica de SO_2 Con Aceites Secantes Insaturados—W.H. Simendinger y C.M. Balik

JCT, 66, No. 831, 39 (Apr. 1994)

La calorimetría de escaneo diferencial (DSC) y la espectroscopía infraroja de transformación de Fourier (FTIR) fueron usadas para caracterizar la reacción quimica ocurrida entre el SO_2 y aceites secantes insaturados presentes en pinturas típicas alquidalicas. Especificamente se estudiaron el acido linolenico, ácido linoleico y ácido oleico. Se encontró que la exposición previa los acidos linolenicos y linoleicos con SO_2 suprimiría la exóterma asociada DSC con la reacción de entrecruzamiento auto-oxidativo. Un comportamiento similar se notó previamente cuando una pintura alquidalica fué expuesta a SO_2 y después "escaneada" en el DSC. El ácido oleico no reacciono con el SO_2, debido a la escazes de algunos formed during the drying process produces soaps and salts and eliminates chemically active acids and alkalis. Thus, barrier properties of the binder are secured. This reduces the raw material cost and increases the protection.

A review of collected literature on the chemistry of alkyd primers and on exposure studies provides an understanding of barrier protection as related to alkyd primers. Formulating practices for alkyd primers to obtain superior protection at low cost are explained.

A Critique of the Taguchi Approach—Part II: An Alternative That is More Efficient—J.L. McGovern

JCT, 66, No. 831, 55 (Apr. 1994)

A previous paper showed that the Taguchi approach to experimental design and analysis has some serious deficiencies. A more efficient and powerful approach, which is free of these defects, is presented in this paper and is illustrated by re-examining a paper that appeared recently in this Journal in which the Taguchi approach was employed.

perte des atomes d'hydrogènes allyliques, un changement de la configuration cis à trans des doubles liaisons, ainsi que l'incorporation des groupes -SO_2- lorsque le SO_2 était présent. Une réaction est proposée impliquant la réaction aux sites allyliques doublement activés, et l'incorporation subséquente des groupes -SO_2- à l'intérieur des réticulations.

Apprêts Alkydes à bas Coûts Pour le Métal—W.C. Johnson

JCT, 66, No. 831, 47 (Apr. 1994)

Le coût le plus important des apprêts alkydes pour la protection du métal provient du pigment chimiquement activé. Un pigment à concentration optimale neutralise les acides formés lors du procédé de séchage et produit des savons et des sels et élimine les acides et alcalis actifs. Donc, les propriétés du liant sont préservées. Ceci réduit le coût des matières premières et augmente la protection.

Une revue de la littérature sur la chimie apprêts alkydes et les études des expositions procure une compréhension de la protection des apprêts alkydes. La formulation d'apprêts alkydes pour obtenir une protection supérieure à bas coûts est revue.

Une Critique de L'Approche Taguchi-2è Partie: Une Alternative Plus Efficace—J.L. McGovern

JCT, 66, No. 831, 55 (Apr. 1994)

Il a été démontré dans une publication antérieure que l'approche Taguchi pour l'analyse et le design expérimental possède des déficiences importantes. Une approche plus efficace exempte de ces défauts est présentée et illustrée en ré-examinant une publication récemment parue dans ce Journal où l'approche Taguchi a été employée.

átomos dobles de hidrógeno alilico activado. El espectro FTIR de los acidos linolencios y linoleicos expuestos a SO_2, a aire o ambos, mostraron pérdida de átomos de hidrógeno alilicos y cambios configuracionales de cis a trans de las dobles ligaduras e incorporación de grupos -SO_2- cuando el SO_2 estuvo presente. Un esquema de la reacción propuesta involucra a la reacción en sitios alilicos doblemente activados y la subsecuente incorporación de grupos -SO_2- dentro del entrecruzamiento.

Costo Efectivo de Primers Alquidalicos Para Acero—W.C. Johnson

JCT, 66, No. 831, 47 (Apr. 1994)

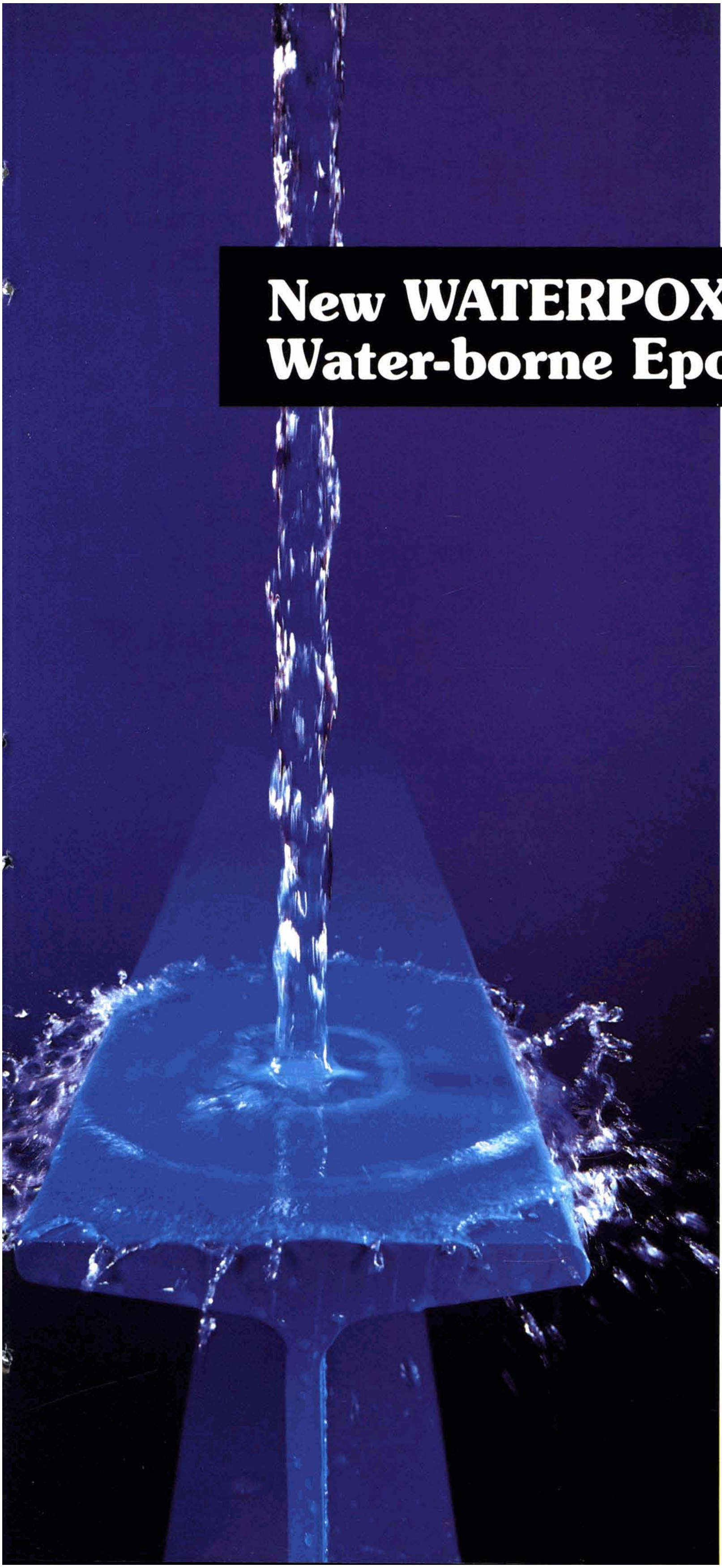
Un mayor costo de primers alquidalicos para la protección del acero es el pigmento químicamente activado. Una baja concentración de un pigmento suficiente solo para neutralizar a los acidos que fueron formados durante el proceso de secado producen jabones y sales y eliminan acidos químicamente activos y alcális. Así, propiedades de barrera del aglutinante estan aseguradas. Esto reduce el costo de la materia prima e incrementa la protección.

Una revisión de la literatura en la química de primarios alquidalicos y en estudios de exposición proveen un entendimiento de la protección de barrera relativa a los primarios alquidalicos. Practicas de formulación para primarios alquidalicos para obtener una protección superior a bajo costo es explicada.

Critica del Metodo Taguchi Parte II: Una Alternativa Mas Eficiente—J.L. McGovern

JCT, 66, No. 831, 55 (Apr. 1994)

Ha sido mostrada en un documento anterior que el método Taguchi para diseños experimentales y análisis tiene algunas deficiencias serias. Un método mas eficiente y mas poderoso el cual esta libre de estos defectos es presentado en este documento y es ilustrado por re-examinación un documento el cual apareció recientemente en esta revista en el cual el método Taguchi fue empleado.



Federation News

"Adhesion in Coatings: Technology and Characterization," to Be Highlighted at 1994 FSCT Spring Week, May 12-13 in Minneapolis

"Adhesion in Coatings: Technology and Characterization" is the theme for FSCT's Spring Week Technical Program, slated for Thursday and Friday, May 12-13, 1994. The meeting will be held at the Marriott City Center Hotel in Minneapolis, MN. This year's program has been developed by FSCT's Technical Advisory Committee.

Critical to meeting coatings performance requirements is a formulator's ability to understand and measure the adhesion of a coating to a substrate. This has become even more difficult as newer substrates are introduced, most of which require new coatings formulations. Added to this challenge is the state of substrate technology, which is developing newer and stronger materials everyday. These advancements demand universal adhesion by coatings (that is, one coating to adhere to a variety of substrates).

The two-day program will include presentations by 17 experts in the field, with topics ranging from Surface Technology to Lab Information Management. Seminar attendees will also have ample time to discuss problems and learn time-honored solutions to these problems with the speakers throughout the event.

Program

Topics and speakers for the event include the following:

Thursday, May 12, 1994

•Surfaces/Adhesion—*Dr. Gene Sparrow, Advanced R&D, Lake Elmo, MN*

•Corrosion/Adhesion—*Speaker to Be Announced*

•Effects of Sudden Temperature Changes on Multilayer Coated Composites—*Satchit Srinivasan, D&S Plastics International, Grand Prairie, TX*

Thermoplastic polyolefins are being increasingly utilized as materials of choice for exterior automotive applications. These materials are often coated with flexible automotive coatings. The durability of these systems in the presence of adverse environmental conditions is of increasing interest. This presentation will discuss the performance of multilayer coated polyolefins in the presence of steep temperature gradients. The effects of coatings and coating process parameters will be discussed, and a theoretical model of the system will be proposed.

•In-Mold Plasma—*Jon Skelley, Ford Motor Co., Detroit, MI*

•Surface Modification of Molded Polyolefin Parts with Electrical Discharges—*Mark Blitshteyn, Tantec, Schaumburg, IL*

Molded and extruded parts made of polyolefins find use in automotive components and medical products. These materials provide sufficient cost and property advantages leading to their increasing use. However, thermoplastic olefins have very poor adhesive properties and poor wettability due to their intrinsic nonpolar chemical structure, and require surface treatment before bonding and application of coatings.

Plasma existing in air at atmospheric pressure in the corona, glow, and arc discharges can be used effectively for polymer surface modification. The electrical discharge treatment at atmospheric pressure offers such advantages to users, as the high treatment level, repeatability and the environmentally safe nature of the process.

This presentation reviews theoretical and practical aspects of electrical discharge treatment for molded and extruded polyolefin parts for improved adhesion. Experimental data as well as case studies are presented.

•An Investigation into How Chlorinated Polyolefins Promote Adhesion of Coatings to Polypropylene—*Jonathan Lawniczak, Eastman Chemical, Kingsport, TN*

The mechanism by which chlorinated polyolefin (CPO) primer coatings promote adhesion of paints to polypropylene and thermoplastic polyolefins (TPO) has been examined by surface characterization techniques including electron spectroscopy for chemical analysis (ESCA), energy dispersion X-ray analysis (EDX), time-of-flight secondary ion mass spectrometry (ToFSIMS), and transmission electron microscopy (TEM). The coatings, their interfacial failures, and tapercut cross-sections were studied, use both waterborne and solvent-borne CPO primers. The results were then correlated with peel strength and crosshatch adhesion tests. CPO primers do not penetrate deeply into the polyolefin substrates, but are quite mobile following application of the topcoat. Solvent-borne CPOs generally showed adhesive failure at the CPO/polyolefin interface when dried at ambient temperatures. Test results are also reported for waterborne CPO adhesion promoters.

•Powder Coating for Nonmetallic Substrates—*C. David Green, Ferro Corporation, Cleveland, OH*

Powder coatings are most commonly perceived as being only practical for metallic substrates. Cure temperature requirements, difficulties in electrostatic spraying on nonconductive substrates and poor adhesion are some of the perceived barriers to the use of powder coatings on nonmetallic substrates. This presentation will discuss how these problems have been overcome and how powder coatings can provide both decorative and protective properties to these substrates. Examples of commercial applications of powder coatings on nonmetallic substrates will be described.

•How to Maximize Powder Coating Adhesion and Corrosion Resistance—*Chuck Danick, RUCO Polymers, Plymouth, MN*

Powder coatings have been recognized for their support for their corrosion resistance, adhesion, flexibility, etc. Many factors contribute to this extraordinary performance. What once was considered an industry standard, iron phosphate with chroma seal rinse, contributed significantly to powder coating adhesion and corrosion resistance.

Environmental factors have curtailed the use of chroma seal rinse for metal pretreatment. This leaves us with pretreatment techniques that do not provide as good adhesion and corrosion resistance for powder coatings.

This presentation will provide data that will help maximize adhesion and corrosion resistance of powder coatings.

•Nondestructive Ultrasonic Gaging of Paint Coating Layers on Plastic or Metal—*Sam Rosenberg, JSR, Pittsford, NY*

High frequency (greater than 90 MHz) pulse-echo ultrasound can be used to measure the thickness of the individual coating layers of a finish on either plastic or metal substrates. Recent advances in ultrasonic transducer technology, instrumen-

(Continued on page 14.)

"ADHESION IN COATINGS: TECHNOLOGY AND CHARACTERIZATION"

REGISTRATION FORM

May 12-13, 1994 • Marriott City Center Hotel, Minneapolis, MN

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CHECK-IN TIME IS 3:00 PM, CHECK-OUT TIME IS 12 NOON.

Reservations must be made no later than **April 20, 1994** to guarantee availability and rates.

Attendees paying the registration fee with a credit card can FAX the form to: (610) 940-0292

Return completed form and check(s) to:

Federation of Societies for Coatings Technology
492 Norristown Rd., Blue Bell, PA 19422-2350

Continued from page 12.

tation, and the employment of microcomputers have made this technology feasible for the ranges of coating thicknesses commonly found in automotive finishing.

Friday, May 13, 1994

•High-Speed and Low-Temperature Curing Using UV for Processing of Coatings, Inks, and Adhesives—*Dick Stowe, Fusion UV Curing Systems, Rockville, MD*

Several aspects of UV-curing systems and their relationship to decorating on plastics and product finishing are presented with some basics of UV sources, including the microwave-powered lamp. UV curing is highly adaptable to coating, marking, and assembling electronic components and systems owing to some of its key attributes; i.e., a low-temperature process, a high-speed process, and a solventless process—cure is by polymerization rather than by evaporation.

The selection of UV spectra can be used to produce markedly different results in cured products, such as improved surface properties, opacity, depth of cure, and adhesion. New, high-powered lamp systems provide high performance results in printing and coating. Some of the latest activities in the continuing development of UV materials technology are solar, chemical, and weather-resistant coatings on a wide variety of molded, cast, sheet, and film plastics. Established and growing applications of this nonpolluting technology also include scratch and abrasion resistant coatings and decoration on products for consumer and industrial markets, such as packaging, electronics, medical, and automotive products. It is also used on paper, metal, glass, wood, and composite materials.

•VOC Reduction of TPO Adhesion Promoter Using Supercritical Fluid Spray Process—*Russell F. Pierce, Red Spot Paint & Varnish Co., Inc., and Wayne Paul Miller, Union Carbide Chemicals and Plastic, Inc.*

Reducing the VOC of typical solvent-borne TPO adhesion promoters raises their viscosity significantly making them nearly impossible to spray conventionally. Through utilization of liquid CO_2 as a diluent, this higher viscosity/lower VOC material can be spray applied using the supercritical fluid spray process. Performance testing has been performed using this spray process for adhesion promoter application and found to have no effect when compared to testing using conventionally applied adhesion promoter.

•Water-Base Paint Technologies for Automotive Plastics—*Dr. Robert Piccirilli, PPG Industries, Cleveland, OH*

Water-base coatings for a variety of plastics for automotive use have been developed. These coatings include adhesion promoters for thermoplastic olefin (TPO), primers for RIM polyurethane, primers for rigid substrates such as nylon and unsaturated polyester (SMC), and pigmented basecoats for use with solvent-base clearcoats. The application of these coatings in terms of humidity and temperature variation is a key issue which needs to be addressed by the parts painter. Performance as relates to adhesion, appearance, and durability is, in many cases, enhanced by the use of water-base coatings due to significant differences in polymer technology. The switch from solvent-base to water-base coatings is ready to occur now.

•Coil Coating—*To Be Determined*

•Surface Quality Analysis of 'Class A' Surfaces for Automotive Application—*Steve Dawson, Diffracto, Windsor, Ont.*

The appearance requirements for automotive exterior panels are very stringent and are summarized in the term "Class A Surface Quality." A major difficulty in the successful application of plastic composite materials, such as SMC, RTM, etc., to automotive exterior panel applications is the achievement of acceptable Class A surface quality in a high-volume production environment. An inspection tool to provide a means to rapidly determine the surface quality of automotive panels and attributes of coatings in a full field noncontact manner is discussed.

•Stone Impact Damage to Automotive Paint Finishes: Techniques to Evaluate the Loss of Adhesion at the Metal/Polymer Interface—*A.C. Ramamurthy, Ford Motor Co., Detroit, MI*

A common source of damage to automotive paint finishes is due to the impact of small stones and road debris lofted by tires and passing vehicles. Damage to coatings can be cosmetic in nature (physical loss of paint) or can result in loss of adhesion at the metal/coatings interface. Loss of adhesion at the metal/coatings interface due to impact stress leads to the formation of a corrosion cell leading to delamination of the coating and in extreme cases to perforation.

This presentation will highlight both experimental and numerical techniques appropriate for simulation of stone impact and damage analysis procedures which can be brought to bear to assess loss of adhesion at the metal/coatings interface. A novel approach for impact data analysis based on Artificial Neural Nets will be presented.

•Managing Analytical Laboratory Data for Research, Product Development, and Production—*Jeff Cawley, Northwest Analytical, Portland, OR*

The analytical laboratory is an important data collector and sensor in the enterprise. To be fully utilized, the collected data must be demonstrated to be valid, and must be easily retrievable by clients in the organization. Laboratory Information Management Systems (LIMS) are departmental data systems that when properly implemented fulfill this function. In general, the LIMS must support and encourage good laboratory practice. This includes the ability to manage sample and data flow, store data while providing for data integrity guarantees, and effective data retrieval. The LIMS provides the structure for the quality assurance program so that data quality is demonstrated and maintained. An effective LIMS provides the tools for integration into the rest of the enterprise with accessible reporting by both paper and electronic means. Output should provide for text, graphic, and statistical reporting and analysis.

Registration

The registration for the event is $175 for FSCT members and $225 for non-members.

The registration fee includes two luncheons, refreshment breaks and a portfolio containing information on the papers presented at the event.

Housing

Requests for seminar room accommodations at the Marriott City Center must be made on the seminar registration form and returned to FSCT Headquarters.

The guest room rate is $111 for single or double occupancy. The cut-off date for reservations is April 20, 1994.

Located in the city's financial and retail district, the Marriott City Center Hotel is directly connected to the world famous Skyway System. The hotel features 584 guest rooms and offers two restaurants, a lounge and health club facilities.

Transportation

Discounted air travel arrangements on Northwest Airlines are available for the Spring Week seminar. Contact the FSCT Travel Desk at **1 (800) 448-FSCT** and mention the code **FSCT-SW,** or contact Northwest directly at **1 (800) 328-1111** and reference the code **NCU9N** to receive the discounted fares.

Shuttle transportation from Minneapolis-St. Paul International Airport to the Marriott City Center Hotel is available via Airport Express. The fare is $10 one way and $15.50 round trip. Airport Express shuttle service departs from the airport at Area No. 8 every 15 minutes from 6 am to midnight.

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This Agreement, and the License contained herein, may not be assigned by Licensee.

18. Force Majeure

Licensor shall not be responsible for any failure to perform (or delay in performance), in whole or in part, due to unforeseen circumstances or circumstances beyond Licensor's control, including but not limited to acts of God, war, riot, embargoes, acts of civil or military authority, fire, flood, accidents, strikes and shortages of transportation, facilities, fuel, labor, or materials.

19. Entire Understanding

This Agreement represents the entire understanding of the parties with respect to the subject matter hereof, and there are no representations, promises, warranties, covenants or understandings with respect thereto other than those contained in this Agreement. Without limiting the generality of the foregoing, it is expressly agreed that the terms of any purchase order issued by Licensee with respect to this Agreement of the Product shall not be applicable and that any acceptance of such purchase order by Licensor shall be for acknowledgment purposes only.

20. Illegality and Unenforceability

If a term or condition of this Agreement is found by a court or administrative agency to be invalid or unenforceable, the remaining terms and conditions shall be enforceable to the maximum extent permitted by law.

20. Governing Law

This Agreement shall be governed by and construed in accordance with the laws of the Commonwealth of Pennsylvania without giving effect to the principles of conflict of law thereof.

1994 Paint Show Exhibitors

ACT Laboratories, Inc.
Adhesion International
Advanced Software Designs
Air Products & Chemicals, Inc.
Air Quality Sciences, Inc.
Alcan-Toyo America, Inc.
Alcoa Industrial Chemicals
Allied Signal Corp.
Alt-Chem International
ACS/C&E News
ACS/Industry Relations
Amoco Chemical Co.
ANGUS Chemical Co.
Anker Labelers USA, Inc.
Aqualon Co.
Arco Chemical Co.
Ashland Chemical, Inc.
Atlas Electric Devices Co.
Aztec Peroxides, Inc.

BASF Corp.-Chem. Div.
Blackmer
Brookfield Eng. Labs, Inc.
Brookhaven Instruments Corp.
Buckman Laboratories
Burgess Pigment Co.
BYK-Chemie USA
BYK-Gardner, Inc.

Cabot Corp.
Calgon Corp.
Cappelle, Inc.
Cardolite Corp.
CB Mills, Inc.
CCP Polymers
Celite Corp.
Ciba-Geigy Corp.
The Coatings Laboratory Inc.
Color Corp.
Colorgen Industrial Group, Inc.
Color Tec Associates
Columbian Chemicals Co.
Consolidated Research Inc.
CPI Purchasing Magazine
CR Minerals Corp.
Crosfield Co.
Cuno, Inc.
Custom Fibers International
CYDEC, Inc.
CYTEC Industries

D/L Laboratories
Daniel Products Co., Inc.
Datacolor International
Degussa Corp.
University of Detroit-Mercy
Disti
Dominion Colour Corp.
Dow Chemical USA
Dow Corning Corp.
Draiswerke, Inc.
Drew Industrial Div.
Dry Branch Kaolin Co.
DSA Consulting, Inc.
DSM Resins U.S., Inc.

Eagle Zinc Co.
Eastern Michigan University
Eastman Chemical Co.
Ebonex Corp.
ECC International
Eiger Machinery, Inc.
Elcometer, Inc.
Elf Atochem North America, Inc.
Elmar Industries, Inc.
EM Industries, Inc.
Engelhard Corp.
Engineered Polymer Solutions
Epworth Mfg Co., Inc.
EQ-The Environmental Quality
Etna Products Inc.
European Coatings Journal
Exxon Chemical Co.

Fawcett Co., Inc.
Federation of Societies for Coatings Technology
Filter Specialists Inc.
Fischer Technology, Inc.
Fluid Management L.P.
FMJ Int'l Publications Ltd.
H.B. Fuller Co.

Paul N. Gardner Co., Inc.
Georgia Pacific Resins Inc.
BFGoodrich Co.
Goodyear Tire & Rubber Co
W.R. Grace & Co.
Guertin Polymers

The C.P. Hall Company
Halox Pigments
Harcros Pigments, Inc.
William Harrison Corp.
Henkel Corp.
Heraeus DSET Labs, Inc.
Hilton-Davis Co.
Hockmeyer Equipment Corp.
Hoechst Celanese-Pigments Div.
Horiba Instruments Inc.
J.M. Huber Corp., Calcium Carbonate Div.
J.M. Huber Corp., Clay Div.
Hüls America, Inc.
Hunter Associates Lab., Inc.

ITT Marlow Pumps/ITT A-C Pumps
Ideal Mfg. & Sales Corp.
INSITEC, Inc.
International Resources Inc.
International Spec. Chems., Inc.

S.C. Johnson Polymers
Journal of Coatings Technology

KTA-Tator, Inc.
K-T Feldspar Corp.
Kemira, Inc
Kenrich Petrochemicals Inc.

King Industries, Inc.

LaQue Center-Kure Beach Atmos. Testing
Leeds & Northrup
Liquid Controls Corp.
Littleford Day Inc.
The Lubrizol Corp.
Luzenac America

3M, Specialty Chem Div
3M/Zeelan Industries Inc.
MacBeth, Div. of Kollmorgen
Magnesium Elektron, Inc.
Malvern Minerals Co.
The McCrone Group
McWhorter, Inc.
The Mearl Corp.
Michelman, Inc.
Micro Powders, Inc.
Micromeritics Instrument Corp.
Mid-States Eng & Mfg Co.
Milton Can Co.
Milwhite, Inc.
Mineral Pigments
MiniFibers, Inc.
Minolta Corp.
Mississippi Lime Co.
Modern Paint & Coatings
Morehouse Cowles, Inc.
Morton International Inc.
Mountain Mineral Co. Ltd.
Myers Engineering

Nacan Products Ltd.
National Paint & Coatings Assoc.
Netzsch Inc.
Neupak, Inc.
New Way Packaging Mach. Inc.
Norman International
North Dakota State University
NYCO Minerals Inc .

Oak Printing
Obron Atlantic Corp.
Ohio Polychemical Co.
Olin Chemicals
Ortech International
OSi Specialities, Inc.

Paar Physica USA, Inc.
Pacific Micro Software Eng.
Paint & Ctgs. Ind. Magazine
Pen Kem Inc.
Peninsula Polymer
Phenoxy Associates
Poly-Resyn, Inc
PPG Industries Inc., Silica Products
PPG Industries, Inc., Specialty Chem. Group
PQ Corporation
Premier Mill Corp.
Progressive Recovery, Inc.
Pyosa S.A. De C.V.

The Q-Panel Co.
Quantachrome Corp.
K.J. Quinn & Co., Inc.

Raabe Corp.
Ranbar Technology, Inc.
Red Devil Equipment Co.
Reichhold Chemicals Inc.
Rheox, Inc.
Rohm and Haas Co.
Ronningen-Petter
Charles Ross and Son Co.
Russell Finex, Inc.

SCM Chemicals
Sandoz Chemicals Corp.
Schuller Filtration Inc.
Scott Bader
Semi-Bulk Systems
Serac, Inc.
Shamrock Technologies Inc.
Sheen Instruments Ltd.
Shell Chemical Co.
Sherwin-Williams Chemicals
Silberline Mfg. Co., Inc.
Sino-American Pigment Sys.
Software 2000 Inc.
South Florida Test Services
Southern Clay Products Inc.
Univ. of Southern Mississippi
Spartan Color Corp.
Specialty Minerals, Inc.
Steel Structures Painting Council
Steeltin Can Corp.
Sub-Tropical Testing Service
Sud-Chemie
Sun Chemical Corp.
Sunkyong Industries
Systech Environmental Corp.

TA Instruments, Inc.
Tayca Corp.
Texaco Chemical Co.
Thiele Engineering Co.
Troy Chemical Corp.

U.S. Borax, Inc.
U.S. Sack Corp.
Union Carbide Corp.
Union Miniere
Union Process, Inc.

Van Waters & Rogers Inc.
R.T. Vanderbilt Co., Inc.
Versa-Matic Pump Co.
Viking Pump, Inc.
Vorti-Siv/MM Industries, Inc.

Wacker Silicones Corp.
Witco Corp.

X-Rite, Inc.

Zeneca Biocides, Zeneca Inc.
Zeneca Resins

Eastman Chemical Co. Recipient of 1993 Baldrige Award; Only "Chapter One" in Never-Ending Quality Journey

When Chairman and Chief Executive Officer Earnest W. Deavenport accepted the 1993 Malcolm Baldrige National Quality Award on behalf of Eastman Chemical Co., Kingsport, TN, from President Bill Clinton, it was just the company's first leg of the never-ending quality journey. In fact, Dr. Robert C. Joines, Vice President—Quality, summarized the lessons Eastman learned about quality to date as "chapter one." He went on to say that Dr. W. Edwards Deming was right when he said "the more you learn the more frustrated you become because you keep identifying more opportunities for improvement."

Speaking to participants at Quest for Excellence, the official conference of the Malcolm Baldrige National Quality Award in February, Mr. Deavenport said "Leadership is where the quality journey begins." Eastman's Senior Management Team has created an inspiring and challenging vision, which promotes customer focus through the values captured in the foundation documents of Strategic Intent, the Quality Policy, The Eastman Way, and Responsible Care®. Quality is the foundation for each document.

Preparing the Baldrige Application gave Eastman insight in learning what total quality management is about. Dr. Joines shared the ten lessons Eastman has learned about quality, which are woven throughout the application. He cites those lessons as the following: leadership is absolutely essential; quality requires teamwork; to be effective, quality has to be systematic; quality requires a big investment in training; remove symbols and social barriers; quality is a major investment; The Baldrige application process is a learning tool; the more you know, the more there is to know; and the customer is our top priority. Dr. Joines said those lessons will help Eastman move to chapter two, which began on January 1 as the company was spun-off from Eastman Kodak Co.

In addition, the Foundation for the Malcolm Baldrige National Quality Award noted Eastman's customer satisfaction process as a quality improvement characteristic. Eastman's customer satisfaction survey is a key component in the company's customer satisfaction process. About 2,000 surveys are provided each year to Eastman customers around the world. More than 70% of those surveys are completed and returned.

The company's no-fault policy for its plastics products is a direct result of Eastman's extensive customer surveys. Believed to be unique in the plastics industry, the policy states a customer may return any plastic product for any reason for a full refund.

On-line, telephone-accessible technical databases are available 24 hours a day. Other company-wide databases help Eastman track customer preferences, future requirements, concerns, and expectations, as well as complaints. Customer advocates follow up on and resolve the complaints. A customer Interface Core Competency Team monitors changes in customer satisfaction, determines root causes, and develops improvement methods.

The commitment to quality expands to the public as well. According to R. Wiley Bourne, Jr., Vice Chairman and Executive Vice President, "Public responsibility and corporate citizenship are important to our business." He said Eastman uses quality management to generate the processes and improvement projects needed to accomplish environmental and community perception goals. Mr. Bourne noted that the company is committed to Responsible Care, an initiative developed by the Chemical Manufacturers Association (CMA). He said CMA member companies seek to continuously improve health, safety, and environmental performance; and to speak openly to the public about environmental issues.

Mr. Bourne said Eastman uses a variety of media to communicate with residents of plant communities. He said Eastman is also active in community programs like Junior Achievement, chambers of commerce, and other service organizations.

"At Eastman, we believe in partnership," Bourne said. "One of our most exciting and important partnerships is with educators." He said "Putting Children First," a partnership with school systems near its world headquarters in Northeast Tennessee, and GLOBE, a partnership in East Texas, are examples of cooperation between industry and education.

Eastman Chemical Co. manufactures and markets chemicals, fibers, and plastics. Eastman reported sales of $3.9 billion in 1993.

Only 19 companies have won the Baldrige Award since it was established in 1987 to recognize the U.S. companies that have world-class systems for managing their operations and people satisfying their customers. The award is administered by the U.S. Department of Commerce's National Institute of Standards and Technology.

Pacific Northwest State Paint Council Added to NPCA's Grassroots Network

The Pacific Northwest Paint Council has joined the network of paint councils in the National Paint and Coatings Association (NPCA), Washington, D.C.

The Pacific Northwest group becomes the ninth NPCA paint council, following New Jersey, California, Illinois, Massachusetts, Texas, Minnesota, Kentucky, and Ohio. As the first regional paint council, it will be serving Oregon and Washington state.

This most recent council was established in response to NPCA members' concerns that legislative and regulatory initiates in those two state were leaving the industry vulnerable to attack. It was felt that a grassroots presence such as those established and successful in protecting the industry's interests in other states was needed to educate Oregon and Washington legislators about paint industry concerns. This year, the Pacific Northwest Paint Council will focus primarily on the Washington legislature, since the Oregon legislature is not in session.

The Pacific Northwest Paint Council was officially started at a meeting in Olympia, WA, on February 24, 1994. Larry Larison, of Columbia Paint Co., was elected to serve as Chairman of the new council. John Buckinger, of Miller Paint, and Ron Wade, of Parker Paint Manufacturing Co., will serve as Vice Chairs. Ted Hughes, of Ted Hughes and Associates, is the council's Executive Director and will lobby for the council in Oregon. Independent lobbyists Mark Gjurasic and John Woodring will lobby for the council in Washington state.

Construction Contracts Hold Steady at 103; Nonbuilding Construction Gains Two Percent

New construction contracts for January remained unchanged, according to the F.W. Dodge Division of McGraw-Hill, New York, NY. However, a modest improvement for the industry's other sectors, nonresidential building and nonbuilding construction (public works), was reported.

For January, the seasonally adjusted Dodge Index came in at 103 (1987=100), unchanged from December's revised reading. The index, after attaining its most recent peak of 109 in October, has declined to its current level, still slightly above the average rate for 1993 as a whole.

Residential construction, dropping three percent in January, fell back from the volume reported at the end of 1993. A five percent decline in the value of single-family starts pushed the residential total downward, while improvement for the depressed multifamily side of the market offered some support. Geographically, most of the contract value decline was centered in the Northeast which plunged 20%; other major regions held close to their December volume.

Nonbuilding construction advanced two percent in January. Public works remained stable as stronger totals for highways and water resource projects balanced lower contracting for bridges and sewers; meanwhile, the volatile utility segment bounced back from a low amount in the previous month.

January's nonresidential building climbed five percent, led by strengthening for the institutional structure types which were able to reverse two months of decline. Specifically, schools and public administration buildings were the primary impetus to the nonresidential upturn. Over the past two years, institutional building had lost momentum amidst growing fiscal stress at all levels of government. For the commercial categories, January witnessed a sharp gain for hotels but reduced contracting for stores, warehouses, and offices.

On an unadjusted basis, January's volume of new construction came to $17.2 billion, down one percent from the same month a year ago. Two regions started the year substantially higher than in 1993: the South Central, up 18%, and the West, up 10%; while the Midwest, up two percent, and the South Atlantic, down one percent, stayed close to their January 1993 performance. Due to the unusually cold temperatures and heavy snow, the Northeast suffered a 31% decline in the first month of 1994, relative to last year.

PPG Completes European Coatings Acquisition

PPG Industries, Pittsburgh, PA, has acquired the European automotive original equipment coatings business of Akzo NV, The Netherlands. Terms were not disclosed. Agreement on the transaction was announced last September.

The acquisition is aimed at strengthening PPG's capability to meet European customer needs, building on their electrocoat products, and Akzo's color styling and development. European technology development capability will focus on new, environmentally sound, and cost effective products.

California Paint Council Revises Strategy in Lead-Fee Lawsuit

The California Paint Council is revising its tactics in a legal challenge to a state fee on paint sales, levied to fund a lead-screening program for children.

In an attempt to speed up a ruling on whether the fee is an unconstitutional tax, the council withdrew its original suit and was preparing to file a revised action. The revised suit will focus whether the fee imposed by the state in 1993 is actually a tax that requires approval by two-thirds of the state legislature.

White Most Popular Vehicle Color Followed by Green

While the favorite vehicle color choice in 1993 remained white, green doubled in popularity during the year to more than 15% of all vehicles, as reported by the annual survey of vehicle color popularity conducted by DuPont Automotive, Troy, MI. In fact, green was the most popular color choice in the sport/compact car category.

According to the survey, nearly 20% of all vehicles purchased last year were white—down from more than 24% in 1992. Although medium red lost less than one percentage point from last year, that decline to 10.5% of the market was just enough for the color to drop out of second place and into third.

Rounding out the top five colors in 1993 were bright red, claiming 8.8% of the total market, and black, holding 7.2% of the market.

Based on research, the following trends are predicted. Purple is a new entrant this year across all four vehicle categories. Its popularity should continue, especially in dark, rich reddish hues. Gold in both light and bright tones will begin to emerge during the next two to three years. Also on the rise will be gold and yellow as an undertone, turning bluish reds to yellowish reds, for example. Bi-color effects are starting to emerge in the sport/compact and full/intermediate areas. This trend will be evident in other vehicle categories.

1993 Powder Coating Sales Soar to Record High; All Powder Market Categories Show Increase

North American sales of thermoset general decorative powder coatings reached an all-time high of 194 million pounds for 1993, according to a report published by the Powder Coating Institute, Alexandria, VA. Fourth quarter sales topped $109 million, a 20% increase over the same quarter in 1992.

All powder market categories showed strong sales increases for both the quarter and the year-to-date. Architectural finishing was up 58% for the quarter in powder material use, and 42% for the year. General metal finishing was up 13% in the fourth quarter, and 24% for the year. Lawn and garden was up 45% for the quarter and 35% for the year, followed by automotive at 24% for the quarter and 23% for the year, and appliance with a 14% quarterly growth and 13% for the year.

Dollar sales of application equipment were up nearly 19% for the year despite a 17% decrease in fourth quarter comparisons to 1992. Sales of automatic guns were up seven percent for the quarter and 27% for the year. Year-end sales of portable manual units showed a modest increase. Total sales of powder recovery booths were down one percent for the year.

Total powder coating installations each containing one or more booths, either manual or automatic/manual, increased nine percent for the quarter, and four percent for the year. The estimate of total dollar sales of powder coating application and recovery equipment reached $64 million in 1992.

Penn Color Forms Alliance With Japanese Companies

Penn Color Inc., Doylestown, PA, has formed an alliance with Toyo Ink Mfg. Co., Ltd. and Toyo Ink America, Inc. This alliance was formed to produce and market color dispersions to the automotive industry for use by both domestic and Japanese transplant automobile manufacturers in North America.

As part of the agreement, Penn will be the exclusive manufacturer in North America for Toyo Ink's automotive dispersions.

ICI Surfactants Relocates North American Operations

ICI Surfactants, Wilmington, DE, will consolidate and relocate their customer focused technical and commercial teams to a newly renovated office and laboratory complex located in suburban Wilmington's Concord Plaza. The new facility will also house the customer R&D labs. All other ICI Surfactants technical support personnel will be relocated to the company's Process Science and Technology Center, adjoining the Atlas Point Site, New Castle, DE.

Rohm and Haas to Build Biocides Plant in Texas

In response to the ongoing demand for isothiazolone biocides, Rohm and Haas Co., Philadelphia, PA, has revealed plans to build a biocides manufacturing facility at its Bayport, TX, site. Used in industrial applications and to make a new antifoulant for marine paints, isothiazolone biocides production should meet 15 million pounds per year.

Construction is scheduled to begin in late 1994, with completion planned for early 1996. The estimated cost of building the plant is $40 to $50 million.

Akzo Coatings Inc. Builds North American Distribution Center

Akzo Coatings Inc., Louisville, KY, has broken ground on an 86,000 square foot distribution center in Pontiac, MI, for their car refinishes paint products. These aftermarket paint products are sold and marketed under the trade name of Sikkens®.

The facility will have over 6,500 pallet locations with eight separate loading docks for both finished and raw material products as well as crossdocking capability from manufacturing to direct shipping. Between 1,500 and 2,000 separate paint products can be stored in pints, quarts, gallons, liters, five-gallon containers, drums, and totes. The Pontiac site also houses separate manufacturing facilities for automotive and decorative finishes products.

Union Carbide to Expand at Texas Plant

An expansion of the vinyl acetate monomer capacity to 690 million pounds annually at the Texas City, TX, petrochemicals complex has been announced by Union Carbide Corp., Danbury, CT. Slated for completion in the second quarter of 1995, this multiphase expansion is expected to take this facility to 750 million pounds per year.

The timing of the expansion coincides with recently announced plans of BP Chemicals/Sterling Chemical to expand capacity of acetic acid—a raw material for vinyl acetate—by more than 20% at Sterling's Texas City plant. Both expansions are consistent with the strategy of American Acetyls, the joint venture of Union Carbide and BP Chemicals in the vinyl acetate and acetic acid businesses.

Nalco Announces Plans to Sell Texas Plant to PPG Industries

Nalco Chemical Co., Naperville, IL, announced that it has entered a letter of intent to sell its Freeport, TX, plant and its automotive paint spray booth business to PPG Industries, Inc., Pittsburgh, PA.

The Freeport plant, which has 27 Nalco employees, produces chemical products for the oil production and refining market. It is expected that the Nalco/Exxon Energy Chemicals joint venture, announced previously, will purchase certain of its requirements for these products from PPG.

Nalco's worldwide automotive paint spray booth business, approximately $10 million in size, would be included in the sale to PPG. Nalco has agreed to sell and service the water treatment related applications for PPG in the automotive facilities associated with the business sold.

California PCA Formed to Unify Coatings Industry in California

The Golden Gate Paint and Coatings Association and the Southern California Paint and Coatings Association have announced the formation of the California Paint and Coatings Association.

This statewide organization allows paint and coatings companies throughout the state, plus concerned companies in adjoining states, to form one organization to further unify and strengthen the California coatings industry. The regional organizations will continue to exist to address the needs of the industry in specific geographic areas.

Initial committees have been formed to study and develop the association's goals and structure. In addition, plans are in progress to publish a joint yearbook in January 1995, and to hold a State Industry Fall Conference in September of this year.

Regulatory UPDATE

April 1994

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.

Consumer Product Safety Commission

March 8, 1994—59 FR 10761

Statement of Policy or Interpretation; Proposed Enforcement Policy for Art Materials

Action: Proposed statement of enforcement policy

The Consumer Product Safety Commission (CPSC) is proposing a statement of enforcement policy to more clearly inform the public of its intended enforcement focus regarding the labeling of art materials. The Labeling of Hazardous Art Materials Act, enacted by Congress in 1988, mandates a labeling standard and certain other requirements for art materials. The CPSC is proposing this statement of focus because of prior enforcement inconsistencies.

Comments will be accepted until May 9, 1994, and should be mailed to the Consumer Product Safety Commission, Office of the Secretary, Washington, D.C., 20207-0001. For further information or copies of the statement, contact Mary Toro, Div. of Regulatory Management, Office of Compliance and Enforcement, CPSC, Bethesda, MD, (301) 504-0400.

Environmental Protection Agency

March 9, 1994—59 FR 11119

Lead Hazard Information Pamphlet

Action: Notice of Availability

The U.S. Environmental Protection Agency (EPA) has released for review and comment the Lead Hazard Information Pamphlet. EPA developed the pamphlet in response to Congressional concerns relating to the lack of general public knowledge of lead paint hazards in the home. According to EPA, the pamphlet is being developed pursuant to section 460 (a) of the Toxic Substances Control Act (TSCA) and will be distributed in conjunction with the regulatory provisions set forth by the Residential Lead-Based Paint Hazard Reduction Act of 1993.

Comments on the draft pamphlet must be submitted in triplicate to: TSCA Document Receipts (7407), Room NE-G99, Office of Pollution Prevention and Toxics, U.S. EPA, 401 M St., S.W., Washington, D.C., 20460. Identify all comments on this draft with the docket number OPPTS-62133. For copies of the pamphlet, contact the office listed above at (202) 260-7099 Monday through Friday between 12 noon and 4 PM. For technical information, contact Charles Franklin, Office of Pollution Prevention and Toxics, Chemical Management Division, Program Development Branch (7404), 401 M St., S.W., Washington, D.C., 20460, (202) 260-1781; Fax: (202) 260-0700.

Interstate Commerce Commission

March 10, 1994—59 FR 11240

Implementation of Section 4 of the Negotiated Rates Act of 1993

Action: Notice of proposed rules

The Interstate Commerce Commission (ICC) has proposed regulations to implement Section 4 of the Negotiated Rates Act of 1993. The proposed regulations would establish a mechanism for obtaining ICC review and approval for motor carriers (other than household goods carriers) and shippers to resolve, by mutual consent, overcharge and undercharge claims resulting from incorrect tariff provisions or billing errors arising from inadvertent failure to properly file in a timely manner and maintain agreed-upon rates, rules, or classifications in compliance with the U.S. Code of Federal Regulations (U.S.C. 10761 and 10762).

The ICC will accept comments until April 11, 1994. Send comments (the original and 10 copies) referring to [Ex Parte No. MC-219] to: Interstate Commerce Commission, Office of the Secretary, Case Control Branch, Washington, D.C., 20423. For further information, contact Larry Herzig or James Manning at (202) 927-5180.

Department of Labor

Occupational Safety and Health Administration

March 11, 1994—59 FR 11567

Occupational Exposure to Methylene Chloride

Action: Proposed rule; limited reopening of the rulemaking record

The Occupational Safety and Health Administration (OSHA) has reopened the record for the proposed regulatory revision of methylene chloride (MC) (56 FR 57036—November 7, 1991).

The limited reopening will be to incorporate comments and information on the following: (1) engineering controls for MC exposure in the furniture stripping industry; (2) a National Cancer Institute study of occupational exposure to chlorinated aliphatic hydrocarbons and the risk of astrocytic brain cancer; and (3) information regarding the use of MC as a solvent in adhesive formulations in flexible foam manufacturing. The information generated from the NPRM subsequent hearing (57 FR 24438—June 9, 1992) raised concerns and solicited information regarding the ability of furniture stripping operations to comply with the proposed PELs through the use of engineering controls, human cancer risk from exposure to MC; and any applications of MC not addressed by OSHA's Preliminary Regulatory Impact Assessment.

OSHA is reopening the record because it has determined that the previously mentioned information is relevant to full consideration of issues raised by the MC rulemaking.

Comments are due on or before April 25, 1994 and should be submitted in quadruplicate to the Docket Office, Docket No. H-071A, U.S. Department of Labor, Room N-2634, 200 Constitution Ave., N.W., Washington, D.C., 20210, (202) 219-7894. Written comments limited to less than 10 pages may be transmitted by fax to (202) 219-5046. If comments are faxed, the original and three copies must be sent to the Docket Office thereafter. For further information, contact James Foster, Occupational Safety and Health Administration, U.S. Department of Labor, (202) 219-8148.

Pollution Prevention—Facilities subject to the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986, also known as SARA Title III, must file annual Toxic Release Inventory (TRI) data on the EPA Form R by July 1 each year. The TRI is a public database of the environmental releases and transfers of some 320 chemicals from manufacturing facilities. This information may be used by communities to assess their potential exposure risks.

With the implementation of the Pollution Prevention Act of 1990 (PPA), facilities were required to report for the first time source reduction and recycling information on Section 8 of Form R. However, the EPA has yet to finalize a rule for reporting this information as required under the PPA, leaving facilities subject to reporting with little to no guidance in the past two years on what constitutes a waste stream for collecting and reporting data.

While not guaranteed that EPA will consider users of the Pollution Prevention Waste Stream Criteria to be in legal compliance with the PPA, the guidance document appears to be fully consistent with the intent of the Pollution Prevention Act. For further information on TRI reporting or other right-to-know regulations, contact the EPCRA Hotline at (800) 535-0202.

Product Liability Reform—The Senate Judiciary Committee is scheduled to hold hearings on legislation to reform the nation's product liability laws in mid-March. The Product Liability Fairness Act (S. 687), sponsored by Sen. J. Rockefeller (D-WV), would set national standards for determining compensation for victims of faulty products and would provide incentives to settle lawsuits quickly. The bill provides no cap for punitive damage awards.

Specifics of the legislation are as follows: the bill sets forth expedited settlement procedures, including (1) the option of allowing either the claimant or the defendant to offer a judgment for a specific dollar amount as complete satisfaction of the claim; and (2) alternative dispute resolution (ADR) procedures. Penalties are established for parties who refused an offer and were awarded less at trial, or parties who refuse ADR and then lose at trial.

Under the legislation, parties seeking to recover for harm caused by a product may bring civil action against the product's manufacturer or product seller pursuant to applicable state or federal law. Uniform standards are established for product seller liability, the award of punitive damages, and time limitations on liability. The legislation bars punitive damages if the requirements of specified federal laws have been met.

The bill also entitles an employer or workers' compensation insurers to file a claim against a manufacturer or product seller to recover workers' compensation for harm caused to an employee by a product if a civil suit has been brought. It also provides that each defendant is only liable for the amount of noneconomic loss proportionally caused.

Product liability reform has been an issue before Congress for the last 14 years without ever becoming law. This year, there are more co-sponsors than ever before, and the bill was already reported favorably from one Senate committee (Commerce, Science and Transportation—Nov. 1993). Nevertheless, if the bill should pass the full Congress, it would likely be vetoed by the President. Reportedly, the Administration objects to the legislation because it favors manufacturers over consumers, and limits a victim's ability to sue.

Superfund Liability Reform Act—The Superfund Liability Reform Act (H.R. 3624), sponsored by Rep. Boucher (D-VA), amends the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) by providing that each liable party who accepts or successfully appeals the results of the allocation of responsibility process, with respect to the National Priority List (NPL), will be liable only for its assigned share of the costs.

The bill requires the orphan share of a NPL site to be paid out of the hazardous substance "Superfund" or by a liable party who unsuccessfully appeals a final binding allocation of responsibility decision. It makes potentially responsible parties (PRPs) and liable parties who fail to perform response actions at an NPL site subject to civil action and liable for all action costs, and requires PRPs who perform and pay for a response action at such a site to be reimbursed by the Superfund. H.R. 3624 also authorizes liable parties who perform and pay for such actions to recover costs as a creditor party.

Further provisions include the appointment of panels of administrative law judges to perform expedited administrative proceedings, to be known as "binding allocations of responsibility (BARs)," for purposes of determining the liability of PRPs at NPL sites; the initiation of a BAR by the filing of a petition with the EPA Office of Administrative Law judges by the EPA Administrator or a state where the site is located; the authorization of a de micromis parties (PRPs that contributed only a minuscule amount of hazardous substances to the site) to resolve liability by paying $1,000 to the Superfund; a requirement that the Administrator make firm offers of settlement to all de minimis parties (parties that contributed only one percent or less of the total quantity of hazardous substances present at the site). Makes a BAR decision binding as to all past, present, and future liability for response costs and for contributions in civil proceedings.

The bill sets forth procedures for recovery by creditor parties, and provides for stays of certain pending enforcement actions and private part litigation until a BAR is issued. It also authorizes any group of PRPs to submit a private allocation for the NPL site, to be known as a "voluntary binding allocation of responsibility," to the allocation panel.

Although not yet scheduled, both the House Committee on Energy and Commerce and the Committee on Public Works and Transportation are planning hearings on the legislation in early spring. The Senate Environment and Public Works Subcommittee on Superfund, Recycling, and Solid Waste Management is in the process of conducting hearings on the companion bill, S. 1834.

Clean Water Act Reauthorization—A bipartisan bill to reauthorize the Clean Water Act has been introduced by Rep. Mineta (D-CA) and Rep. Boehlert (R-NY).

The bill would authorize $3 billion over the next six years to finance the state revolving fund (SRF) that pays for sewage treatment construction projects and other assistance programs. Under this approach, the federal government provides funding to the states which in turn use the money to provide low-interest loans to local governments to use for water infrastructure projects. A formula for ascertaining each state's share of the SRF is still being determined.

Under the bill, an existing 20% limitation on the use of SRF loans for combined sewer overflow (CSO) controls and collector sewers will be lifted in an effort to provide states and localities more flexibility. CSOs, a mixture of domestic sewage, industrial waste water and rain water, occur when combined sewer systems overflow during heavy storms. Also included in the bill is a provision granting additional flexibility to afflicted communities.

Further provisions include: a requirement that the National Academy of Sciences conduct a study on the "current scientific knowledge" regarding certain toxic chemicals existing in U.S. waters; a requirement that penalties assessed under the CWA be no lower than the economic benefits achieved as a result of a violation; specification as to which storm water discharges would need permits; and the development by EPA of a schedule under which major nonmunicipal dischargers of pollutants and certain industries would be required to develop and submit pollution prevention plans.

The bill is in the House Public Works and Transportation Subcommittee on Water Resources and Environment. Markup of the bill could begin in that committee as early as April. The Senate Environment and Public Works Committee favorably reported a CWA bill in February.

OSHA Reform—Legislation that would overhaul OSHA was reported from the House Education and Labor Committee in March.

The bill would require each employer with 11 or more employees to establish a committee of workers and managers to review and investigate health and safety procedures and recommend any improvements. During recent hearings, members rejected a number of GOP amendments, including a substitute that would not have required employers to create a health and safety committee. That proposal also would have exempted employers from OSHA inspection if the business hired a private OSHA-approved inspector or an insurance company to ensure workplace safety.

The bill also would strengthen civil and especially criminal penalties for OSHA violations.

States Proposed Legislation and Regulations

Alabama

Lead—AL S. 379 (Lindsey) authorizes the State Board of Health to develop a program relating to indoor lead hazard reduction; authorizes the establishment of certain fee schedules and the disposition of fees levied; authorizes the State Health Officer to conduct certain investigations relating to lead hazard reduction and grants immunity from certain liability; requires the certification of persons engaged in lead hazard removal activities and the regulation of such activity. The bill passed the Senate on February 3 and was reported favorably with amendment from the House Committee on Health on February 16.

Arizona

Lead—AZ H. 2587 (E. Richardson and Soltero) creates a state program that would include warning labels for paints and goods containing lead, including a requirement for the Health Services Department to track children and pregnant women with elevated lead levels and to confiscate goods with too much lead. Introduced on February 8, the bill is in the House Committee on Environment.

Occupational Safety and Health (Regulation)—A final rule of the Arizona Industrial Commission amends construction industry and agricultural standards for occupational safety and health under R4-13-601 and -603 to adopt by reference federal OSHA standards to exposure to cadmium and to add the July 28, 1993 corrections to the incorporation of general industry safety and health standards applicable to construction work. The rule amends regulations under R4-13-602 to incorporate July 27, 1993 corrections to general industry standards for air contaminants. The rule was effective December 17, 1993. For more information, contact Derek Mullins at the Industrial Commission at (602) 542-5972.

Arkansas

Hazardous Waste (Regulation)—The Department of Pollution Control and Ecology has proposed rules under Regulation No. 23 to revise the state's hazardous waste management requirements. The proposal incorporates by reference the federal regulations promulgated through June 30, 1993, including a new schedule of fees for permits, reviews, and related activities, and revised transporter requirements. For more information, contact Rhonda Sharp at the DPCE at (501) 562-7444).

Water Quality (Regulation)—A proposed rule of the Arkansas Pollution Control and Ecology Commission amends Regulation No. 2 to specify water quality standards for certain metals. The proposed standards include both acute and chronic criteria to replace standards promulgated for the state by the federal EPA. For more information, contact Doug Szenher at the Department of Pollution Control and Ecology Commission at (501) 562-7444.

California

Lead Litigation Update—In April of 1993, the California Department of Health Services adopted emergency regulations implementing the Childhood Lead Poisoning Prevention Act of 1991, which imposed a "fee" on products manufactured by industries that have contributed to "environmental lead contamination" to fund a blood-lead screening and case management program for children under the age of six. Although the paint industry's share of the $16 million total annual assessment was reduced from 47% in the initial drafts to less than 15% in the final regulations, the California Paint Council and the National Paint and Coatings Association, along with two paint manufacturers, made the decision to challenge the validity of the "fees" in court.

Claiming that the "fees" were imposed in violation of a state constitutional provision requiring that tax legislation be enacted with a two-thirds majority vote of both houses of the legislature, CPC brought an action in California Superior Court to have the underlying statute struck down. The action also claimed that the regulations were invalid because they did not assess fees against the manufacturers of several sources of environmental lead contamination.

Soon after filing the action, CPC began discussions with the Department of Health Services and the State Board of Equalization, the two defendants in the suit, to develop a case management plan to streamline the litigation so as to minimize the time and expense for both sides. Such plans were soon subverted, however, following the intervention into the litigation of a large coalition of environmental, public interest, and child advocacy organizations. Although CPC was successful in limiting the scope of the intervenor's participation, the intervention has resulted in a dramatic increase in the time and expense of the lawsuit.

The CPC Litigation Committee, with the endorsement of the CPC Steering Committee and NPCA's Executive Committee, instructed the Council's attorneys to drop the suit. Other alternatives challenging the law are being considered.

It now appears that the dispute will not be resolved before "fees" for the second year of the program are due on April 1, 1994.

Graffiti—CA A. 3167 (Epple) regulates the sale and display of all aerosol paint, liquid dye or polish, and marker pens containing anything other than a solution that can be removed by water after it dries, and defines these products. The bill was introduced on February 23.

CA S. 1779 (Bergeson) increases the penalties for acts of vandalism resulting in defacement, damage, or destruction valued at $400 or more, but less than $50,000; authorizes a peace officer to arrest persons whom the officer has reasonable cause to believe has committed specified acts of vandalism, whether or not the acts were committed in his presence; requires minors who commit vandalism to provide restitution. The bill was introduced on February 24 and referred to the Senate Committee on Judiciary.

Hazardous Waste (Regulation)—An emergency rule of the California Department of Toxic Substances Control adopts regulations to modify requirements that implement the Hazardous Waste Source Reduction and Management Review Act of 1989. The amendments lower the threshold waste hazardous waste generation level from 12,000 kilograms of hazardous waste or 12 kilograms of extremely hazardous waste to 5,000 kilograms for specified categories of hazardous waste. New generators not previously impacted by the Act are required to prepare a compliance checklist and submit progress reports on an even-numbered year schedule. This rule was effective January 25, 1994. For more information, contact Pamela Thompson at (916) 324-9933.

Toxic Substances (Regulation)—A notice announces the addition of 1,2,3-trichloropropane and methyl bromide to the list of chemicals known to cause cancer or reproductive toxicity, as required by Proposition 65. For more information, contact Laurie Monserrat at (916) 445-6900.

Connecticut

Lead—CT H. 5560 (Committee on Housing) provides incentives and a comprehensive system of lead paint abatement and management in private multi-family residential structures containing 50 or more dwelling units. The bill was introduced on February 24 and referred to the Joint Select Committee on Housing.

CT H. 5561 (Committee on Housing) establishes a comprehensive lead risk reduction plan in housing authorities. The bill was introduced on February 24 and referred to the Joint Select Committee on Housing.

CT H. 5349 (Beals) concerns lead poisoning prevention and lead abatement; assists municipalities with meeting lead abatement mandates. The bill was introduced on February 16 and referred to the Joint Select Committee on Housing.

CT S. 192 (Looney) concerns lead abatement and lead poisoning prevention; assists municipalities with meeting lead abatement mandates. The bill was introduced on February 16 and referred to the Joint Select Committee on Housing.

CT S. 209 (Committee on Housing) concerns lead paint removal in connection with mortgage lenders; avoids further burdening of residential sellers by requiring abatement of lead paint at real estate closings in the current depressed real estate market. The bill was introduced on February 17 and referred to the Joint Committee on Banks.

Florida

Solid Waste (Advance Disposal Fee on Containers—Regulation)—The Florida Department of Revenue has approved a final rule which imposes an advance disposal fee on the retail sale of certain containers beginning October 1, 1993. The rule establishes a fee of one cent per container to be paid by dealers to distributors for containers sold in the state. The rule specifies the types of containers covered by the advance disposal fee; requires that the fee be reported monthly and paid monthly; and establishes penalties for delinquent payments. The rule was effective February 15, 1994. For more information, please call Jeff Soff at the Department of Revenue at (904) 922-4719.

Occupational Safety and Health (Regulation)—A proposed rule would adopt regulations to establish procedures for employers to obtain a workers' compensation insurance premium credit for implementing a workplace safety program. The proposal would provide a typical written program and establish procedures relevant to the credit. For more information, contact Susan Stone at the Florida Division of Safety at (904) 922-8954.

A proposed rule would adopt regulations describing the workplace safety and health compliance program, establishing procedures for filing a complaint that alleges a violation of the state's OSH Act and prescribing procedures for division investigations and for protecting the workplace from imminent danger. For more information, contact Tammy Ramsden at the Florida Division of Safety at (904) 922-8955.

Idaho

Lead—ID S. 1496 (Senate Committee on Commerce and Human Resources) relates to abatement of lead hazards. The bill was introduced on February 14 and referred to the Senate Committee on Commerce and Human Resources.

Illinois

Air Quality (Regulation)—The Illinois Pollution Control Board has adopted a final rule which adds definitions consistent with modifications to the requirements for major sources in the Chicago ozone nonattainment area, as required by the federal CAA. The modifications will ensure that all sources emitting or with the potential to emit 25 tons or more per year of volatile organic material use RACT standards. The rule was effective January 18, 1994. For more information, contact Elizabeth Harvey at (312) 814-6921.

Indiana

Household Hazardous Products—IN S. 54 (Wheeler) relocates the definition of "hazardous household product"; repeals the Household Hazardous Products Act. The bill passed the Senate in January and the House on February 23. It was sent to the Governor on March 2.

Air Quality (Regulation)—A notice of the Indiana Department of Environmental Management solicits comments on the development of a proposed rule that would control emissions of volatile organic compounds from sources for which control technology guidelines have not been issued by the federal EPA. The proposal would affect certain sources in Clark, Floyd, Lake, and Porter counties and would specify emission limits, test methods and procedures, recordkeeping and reporting requirements, and control plan procedures. For more information, contact Larry Fedor at the Office of Air Management at (317) 232-8223.

Kentucky

Hazardous Waste (Regulation)—A final rule of the Kentucky Petroleum Storage Tank Environmental Assurance Fund Commission adopts regulations to establish a certification program for contractors performing corrective action at underground storage tank sites. The rule was effective December 17, 1993. For more information, contact Morgan Kelly at (502) 564-5981.

Lead—KY S. 289 (Neal) relates to lead hazard reduction and makes an appropriation. The bill was introduced on February 28 and referred to the Senate Committee on Business Organizations and Professions.

Louisiana

Air Quality (Regulation)—The Louisiana Department of Environmental Quality, Office of Air Quality, has proposed rules requiring specified minor toxic sources to report their air toxic emissions and quantities consumed annually. The rules affect decorative chromium electroplating using chromium and chromium compounds, halogenated solvent cleaners using 1,1,1 trichloroethane, perchloroethylene, methylene chloride and trichloroethylene and hard chrome electroplating using chromium and chromium compounds. The rules also propose to assess facilities an annual fee based on emissions of air toxic chemicals including applicability, exemptions, definitions, and reporting requirement. For further information, contact David Hughes, Enforcement and Regulatory Compliance Div., Department of Environmental Quality, Baton Rouge, LA, (504) 765-0399, Fax (504) 765-0486.

Maryland

Lead—MD H. 1534 (Johnson) establishes the Lead Poisoning Remediation and Compensation Act; specifies properties subject to the act; establishes the Lead Paint Poisoning Remediation and Compensation Commission and its duties; requires the Commission to adopt specific regulations; establishes risk reduction standards for specified properties; requires specific owners to provide inspections; provides for immunity for specific individuals; authorizes specific individuals to conduct inspections. The bill was introduced on February 21 and was referred to the House Committee on Environmental Matters.

Massachusetts

Market Share Liability—MA H. 3976 (Jehlen) authorizes the use of market share liability in civil actions brought against certain producers or manufacturers of lead-based paint. This is a reintroduction of H. 2798 which died at the end of the last session of the Massachusetts legislature. It was introduced on February 8 and referred to the Joint Committee on Judiciary. The Senate companion bill (MA S. 735—Jacques) was introduced on February 15 and referred to the Joint Committee on Judiciary.

Air Quality—MA H. 4459 (Businger) prohibits the sale of certain fluorocarbons for use in aerosol cans. The bill was introduced on February 25 and was referred to the Joint Committee on Commerce and Labor.

Packaging—MA H. 4498 (Roosevelt) relates to packaging reduction and recycling. The bill was introduced on February 25 and referred to the Joint Committee on Natural Resources and Agriculture.

Lead—MA S. 1365 (Amorello and Melconian) promotes safety from lead contaminants in housing. The bill was introduced on February 18 and referred to the Joint Committee on Taxation.

MA S. 31 (Birmingham) regulates the removal of lead paint. The bill was introduced on February 11 and was referred to the Joint Committee on Commerce and Labor.

Automotive Paint—MA S. 35 (Durand) relates to illegal use of certain automotive paint and paint by-products. The bill was introduced on February 11 and referred to the Joint Committee on Commerce and Labor.

Hazardous Products—MA H.B. 3712 (Hodgkins) further regulates the sale of certain hazardous products in retail establishments. The bill was introduced on February 8 and referred to the Joint Committee on Commerce and Labor.

Toxic Substances (Lead-Regulation)—The Massachusetts Department of Public Health has announced a correction to a final rule to establish a framework for the use of a new technology (encapsulation) for lead paint abatement. The rule also establishes a third-party certification process for the laboratory testing of encapsulant product performance characteristics and provides for the establishment of a toxicological assessment process for encapsulants. The correction adds a requirement for a tape test for painted surfaces that was omitted from the final rule. For more information, contact Roy Petre of the Childhood and Lead Poisoning Prevention Program at (617) 522-3700.

Minnesota

Air Quality (Regulation)—The Minnesota Pollution Control Agency has announced its intention to regulate stationary sources with actual emissions below permit thresholds. The proposed rule would establish requirements for the use of air pollution control equipment to limit potential air emissions, grant emissions reduction credits to sources that use such equipment, require limits on the potential emissions of VOCs based upon actual use of raw material and add noncombustion stationary source emission limits based on allowing the source to document actual emissions. For more information, contact Andrew Ronchak at (612) 296-3107.

Hazardous Waste (Regulation)—A final rule of the Minnesota Pollution Control Agency simplifies the fee structure applicable to large and small generators of hazardous waste. The rule revises hazardous waste facility fees, provides an exemption for generators that produce less than 100 pounds of hazardous waste per year, and assesses a flat fee of $100 for generators of less than 2,640 pounds of hazardous waste per year. The rule was effective January 25, 1994. For more information, contact Jeanne Eggleston at (612) 297-8371.

Nebraska

Solid Waste (Regulation)—The Nebraska Department of Environmental Quality has proposed to amend the integrated solid waste management rules. The amendments would change a deadline for financial assurance and accommodate the Plastic Container Coding Act. For further information, contact Thomas Lamberson, Hearing Officer, Department of Environmental Quality, Lincoln, NE, (402) 471-2186.

New Jersey

Community Right-To-Know (Regulation)—The New Jersey Departments of Health, Environmental Protection and Energy, and Labor and the Right-to-Know Advisory Committee held a hearing on March 25 regarding the addition or deletion of substances of the state's right-to-know substance list, special health hazard substance list, and environmental hazardous substance list. For more information, contact Richard Willinger at (609) 984-2202.

Pollution Prevention (Regulation)—The New Jersey Department of Environmental Protection and Energy announced an amended final rule regarding pollution prevention programs. The rule adds use reporting ranges, allows volunteer facilities to withdraw from the pilot facility-wide permit program up to 30 days following receipt of a draft permit, and outlines penalties for failure to prepare a pollution prevention plan or for false or frivolous confidentiality claims. The rule was effective February 7, 1994, and expires on March 1, 1998. For more information, contact Janis Hoagland at the DEPE at (609) 292-0716

New Mexico

Hazardous Waste (Regulation)—A final rule amends regulations of the New Mexico Environmental Improvement Board to adopt a schedule of annual fees for hazardous waste generators and treatment, storage, and disposal facilities. The rule establishes fee calculation provisions, requires fees for waste imported into the state, specifies due dates and manner of payment, implements enforcement provisions, and requires recordkeeping. The rule was effective February 18, 1994. For more information, contact Ed Horst at (505) 827-4308.

Occupational Safety and Health (Regulation)—A final rule of the New Mexico Environmental Improvement Board amends regulations under OSHA 100 through 400 and to incorporate by reference amendments to federal OSHA standards for general industry, construction industry, and agriculture. The rule modifies posting requirements, changes requirements for permit-required confined spaces and cadmium, identifies general industry standards that are applicable to construction work. The rule was effective February 18, 1994. For more information, contact Warren Slade at the Occupational Health and Safety Bureau at (505) 827-2877.

Lead—NM S.M. 98 (Vernon) requests that the Regulation and Licensing Department develop a state certification program for lead-based paint hazard reduction. The bill passed the Senate on February 16.

New York

Graffiti—NY A. 9885 (Herbst) establishes a crime of criminal defacement of buildings and property when a person intentionally damages any building or property of another by writing, painting, or drawing on such building or property; makes such crime a Class A misdemeanor. The bill was introduced on March 1 and was referred to the Assembly Committee on Codes.

Lead (Regulation)—The New York Department of Health has proposed an outline for the basis and extent of an environmental lead investigation and describes acceptable methods for abatement of lead paint conditions conducive to lead poisoning. The comment deadline is April 22, 1994. For further information, contact Donald MacDonald, New York Department of Health, Bureau of Management Analysis, Albany, NY, (518) 474-8734.

Air Quality (Regulation)—A proposed rule of the New York Department of Environmental Conservation would adopt requirements of the federal CAA for granting permits for new sources in nonattainment areas and in the Northeast U.S. ozone transport region. Comment deadline is April 22, 1994. For more information on this proposal, contact John T. Higgins at (518) 457-3676.

Hazardous Waste (Regulation)—The New York State Department of Environmental Conservation has proposed regulations which incorporate a number of federal regulations that will permit the agency to run its own household hazardous waste program. Comment deadline is April 15, 1994. For a copy of the proposed regulations, call Margaret E. O'Neil, Department of Environmental Conservation, at (518) 485-8988.

Occupational Safety and Health (Regulation)—A proposed rule of the Department of Labor would specify employer notification requirements in the event of fatalities or multiple hospitalization injuries in the workplace under 12 NYCRR 801.9. The proposal would require employers to notify the department within eight hours of such an occurrence or awareness of the incident and allow reports to be submitted either in writing or orally. For more information, contact John Loughlin at (518) 457-4380.

Ohio

Lead—OH S. 162 (Drake) requires lead screening of certain young children, creates a tax credit for lead abatement, provides for licensure of persons performing lead abatement, and provides that it is an unlawful discriminatory practice to refuse to sell to or rent housing because it will be occupied by a young child or pregnant woman. The bill passed the Senate in January and the House on March 2. It has been sent back to the Senate for concurrence.

Oklahoma

Lead—OK H. 2497 (Hamilton) establishes the Comprehensive Childhood Lead Poisoning Prevention Program, to be administered by the State Department of Health, requires the State Board of Health to promulgate rules regarding lead toxicity screening of certain children, risk assessment, blood lead tests, health education and counseling and other requirements, and creates a nine-member Childhood Lead Poisoning Prevention Advisory Council. Introduced on February 7, the bill was released from the House Committee on Appropriations and Budget on February 24 and is expected to pass.

OK H. 2063 (Leist) relates to the Oklahoma Lead-based Paint Reduction and Regulation Act; provides that the Environmental Quality Board shall promulgate rules governing lead-based paint activities; requires the board to establish a schedule of fees for certification of abatement of contractors and training and lead-based paint activity programs. If passed, the legislation would go into effect as an emergency law on July 1, 1994. The bill passed the House on March 2 and was sent to the Senate.

Graffiti—OK S. 971 (Haney) makes it a misdemeanor to knowingly sell paint containing metallic powders dispensed from a pressurized container, or any glue, to a person under 18 years of age. The bill passed the Senate on March 1 and was referred to the House Committee on Criminal Justice.

Oregon

Hazardous Waste (Regulation)—A proposed rule of the Oregon Department of Environmental Quality adopts numerous federal hazardous waste standards, including used oil management provisions. The proposal also would revise standards for special waste management, generators, laboratories, and confidentiality, and update and revise toxics use reduction and hazardous waste reduction standards. For more information, contact Harold Sawyer at DEQ at (503) 229-5776.

Rhode Island

Lead—RI H. 9049 (Murphy) eliminates the "innocent owner" of the buildings provision in regard to lead hazard reduction. The bill was introduced on February 17 and referred to the House Committee on Judiciary.

Tennessee

Air Quality (Regulation)—A final rule amends regulations of the Tennessee Department of Environment and Conservation to revise air pollution control standards. The rule revised the total suspended particulate standard, clarifies the lead standard, adds a standard for hydrogen chloride, and requires atmospheric dispersion modeling as the method for determining compliance with the hydrogen chloride standard. The rule was effective February 13, 1994.

Texas

Hazardous Waste Spills (Regulation)—The Texas Natural Resource Conservation Commission (TNRCC) has proposed regulations that would establish a comprehensive program for reporting and responding to discharges or spills of hazardous substances. The proposed rule includes a requirement for reporting past spills upon discovery and would establish civil penalties of $10,000 a day for violations. For further information, contact Marianne Baker of the TNRCC at (512) 239-0475.

Air Quality (Regulation)—On February 23, the TNRCC extended the deadlines by which employers with 100 or more employees in the Houston/Galveston area must submit their plans to reduce the number of work-related vehicle trips. The new deadlines call for employers of 200 or more employees to submit plans by September 15, 1994 and those with 100 to 199 employees to submit plans by November 15, 1994. The deadlines were extended to allow for the establishment of a system of trainers to assist in the development of the plans. For further information, contact the TNRCC at (512) 463-8337.

Hazardous Waste (Regulation)—A proposed rule of the TNRCC would amend regulations regarding overpayment prevention in the petroleum storage tank reimbursement program. The proposal would establish procedures for the audit of money expended from the petroleum storage tank remediation fund, specify that the proposed requirements apply to all corrective actions paid for by the fund, require persons who are compensated by the fund to cooperate with audits or investigations, and authorize the executive director of the NRCC to issue a notice of overpayment in certain circumstances. For more information, contact Raymond Winter at (512) 463-8069.

Utah

Graffiti—UT H. 31 (Cannon) prohibits the sale of spray paint or broad-tipped indelible markers to minors; prohibits the possession and use of spray paint and broad-tipped indelible markers by minors; requires retailers to restrict free access (lockup) to spray paint or markers for sale. The bill was amended to remove the lockup provision and reported favorably from the House Committee on Business, Labor and Economic Development on February 15.

Containers—UT H. 339 (Davis) relates to health and environment; establishes minimum percentages of used glass to be used in containers sold or made in Utah; establishes criteria for minimum percentages of recycled plastic containers; requires reporting; provides penalties for violations; and provides procedures for waivers or reductions of percentages. Introduced on February 8, the bill was released from the House Committee on Health and Environment, as amended, on February 18. It is currently in the Committee on Rules.

Virginia

Lead—VA S.J.R. 127 (Lambert and Schewel) continues the Joint Subcommittee Studying the Abatement of Lead-based Paint. The resolution passed the Senate on February 8 and the House on February 25.

Occupational Safety and Health (Regulation)—A final rule of the Virginia Department of Labor and Industry amends regulations to incorporate clarifying language to the federal OSHA permit-required confined spaces standard for general industry promulgated on January 14, 1993. The rule clarifies certification requirements relating to pre-entry measures and various provisions contained in the appendices to the regulations. The rule was effective March 1, 1994.

Washington

Air Quality (Regulation)—A final rule of the Washington Department of Ecology adopts regulations to establish a funding mechanism for the operating permit program. The rule requires state and delegated local permitting authorities to collect fees from affected emission sources, requires the department to make public the annual fee schedule by October 31 of each year, establishes a methodology for tracking revenues and expenditures, and creates a system of fiscal and performance evaluations. The rule was effective January 30, 1994. For more information, contact Catherine O'Neill at the DOE at (206) 459-6248.

Product/Environmental Liability—WA S. 6484 (A. Smith and Nelson) regulates confidentiality claims in court settlements involving public hazards; provides that, in civil actions involving product liability/environmental damage claims, no confidentiality provision may be entered or enforced by the court absent a showing of good cause by the moving party or parties; specifies the necessary elements to determine good cause for disclosure. The bill passed the Senate on February 14. It was released from the House Committee on Judiciary on February 25 and is expected to pass.

West Virginia

Solvent Abuse—WV H. 4512 (L. White) relates to prohibiting the operation of a motor vehicle by a person under the influence of any self ingested or voluntarily ingested fume, vapor or substance derived from paint, glue, or other legal substance and provides criminal penalties for violations. The bill was introduced on February 17 and referred to the House Committee on Judiciary.

Air Quality (Regulation)—A final rule adopts regulations to establish an operating permit system, as required under the Federal Clean Air Act (CAA) Title V. The proposal would specify permit requirements and application procedures as well as procedures for permit issuance, renewal, reopening, and revision; establish monitoring and reporting procedures and describe provisions for permit review by the federal EPA and affected states. The proposal also would establish enforcement standards, and annual fees associated with the proposed program, including methods for sources to limit emission potential and become conditioned minor sources. The rule was adopted January 9. For more information, contact Dale Farley at the Department of Commerce, Labor, and Environmental Resources at (304) 558-4022.

Underground Storage Tanks (Regulation)—A proposed rule amends regulations relating to underground storage tank requirements in West Virginia. The proposal establishes certification requirements for individuals who install, repair, retrofit, upgrade, perform change in service or close underground storage tank systems. The proposal also would revise notification standards to specify procedures for tanks installed on or after January 1, 1995. The proposal was approved on January 9. For more information, contact Gail Sattler at (304) 588-0400.

Wisconsin

Chemical Reporting—WI A. 732 (Black) requires additional types of facilities to complete toxic chemical release forms and submit them to the Department of Natural Resources. The bill passed the Assembly in October 1993. It was released from the Senate Committee on Environment and Energy on February 24 and is expected to pass as amended.

Air Quality (Regulation)—The Wisconsin Department of Natural Resources has proposed rules concerning volatile organic compound emissions from molded wood parts and products, and wood door coating operations. The rules define terms, identifies wood coaters that will be regulated, establishes volatile organic compound (VOC) emission limits for wood coating facilities in nonattainment areas, establishes recordkeeping requirements, and provides compliance deadlines. For further information, contact Jim Crawford, Department of Natural Resources, Lake Michigan District Headquarters, Green Bay, WI, (414) 448-5151.

Comparison of the Effectiveness of Electric IR and Other Energy Sources To Cure Powder Coatings

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A study has been conducted to compare the effectiveness of electric IR and other energy sources to cure powder coatings. Four energy sources (high-intensity electric IR, gas IR, electric convection oven, and gas convection oven) have been employed to cure nine commercially available powders. The powders include: white epoxy, black epoxy, white acrylic, white urethane, white polyester, white polyester hybrid, white nylon, clear polyester, and fine white polyester (classified by manufacturer to less than 25-30 μ). Manufacturer's curing recommendations (time-at-peak metal temperature) were used for convection oven curing. Powder cure in electric and gas IR ovens was optimized using experimental methods. The curing conditions are presented as time-at-voltage (electric IR) and time-at-BTU expressed as water column pressure (gas IR).

Physical and performance properties of the nine coatings cured with the four different energy sources are presented. Films of each powder were deliberately under- and over-cured and evaluated to note changes in physical and performance properties with the degree of cure. These data demonstrate the efficiency of using IR curing methods to obtain optimum performance properties in powder coatings.

The mechanisms by which film formation and cure occur in powder coating materials depends on the specific means used to impart heat to the coating and the coated substrate. All of these methods of cure involve conduction, convection, and thermal radiation processes. The fundamental concepts of each of these mechanisms of heat transfer are reviewed. Special attention is given to convective and thermal radiation (IR) processes, as these two methods of heat transfer are of primary importance to the methods of powder cure evaluated in this work. Discussion is presented which defines the variables important to each process, and the effects of these variables on cure in powder coatings. Possible mechanisms for the cure process of powder coatings applied to substrate materials are presented for each of these processes, and the implications of these processes are discussed. In the case of IR cure of powder coatings, some questions are raised regarding the exact mechanism of the cure process. The advantages and disadvantages of convection and IR cure of powder coatings are addressed in detail.

The powders evaluated were examined with photoacoustic FT-IR (PA FT-IR) spectroscopy and differential scanning calorimetry (DSC). The DSC work ascertained the melting and curing temperatures of the powder coatings. Most of the coatings melted in the 160-180°C range and cured in the 220-240°C range. The PA FT-IR work illustrated the transparency of the coatings to IR in the 1-3 μm range and the infrared absorption in the 3-20 μm range. These infrared data also raised questions concerning the cure mechanism with respect to substrate conduction or coating absorption of the infrared radiation. Evidence collected during the course of this work suggests that the coatings cure through conduction with some absorption of IR by the coating. The conduction of the energy, primarily from the substrate to the coating, allows the coating from the substrate outwards to the coating surface.

A model has been developed for describing how powder particles fuse and coalesce into a continuous film structure. Parameters, such as density of the powder coating, solubility parameters, surface tension, and melt viscosity, were correlated with the ability of the powder particles to flow together and form a continuous film structure.

INTRODUCTION

Many advances in powder coatings have been made in the past few years; for example, clearcoats, low-temperature

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cures, low gloss, and thin films with greater exterior durability. Europe has taken the lead in the use of powder coatings because of environmental consciousness (powders contain ~ 0.2 lb/g VOC) and conventional epoxy resins are more expensive than in the U.S.

An impressive growth rate of 10% per year is projected for the use of powder coatings in North America through the turn of the century. If this growth rate is to be realized, it will be necessary to expand our fundamental knowledge of the chemistry (and chemical modification), manufacture, formulation, and curing of powders to a level where custom powders are readily available to meet specific physical and performance properties for demanding end-use applications. The program discussed in this report was designed as an early step in this process.

This report is divided into four areas.

(1) An introductory discussion of curing energy relative to powder coatings (electric IR is highlighted);

(2) Presentation of a new characterization technique (photoacoustic Fourier transform infrared spectroscopy) for monitoring the cure of powder coatings and discussion of data obtained using PA FT-IR in this program;

(3) A laboratory study of nine types of powders, cured with four energy sources, and evaluated for 12 physical and performance properties; and

(4) The development of a model for particle coalescence and film formation applicable to powder coatings.

Curing Energy for Powder Coatings

During the course of this work, two distinct methods, infrared (IR) irradiation and convection oven cure, were used to cure powder coatings once they had been applied by electrostatic spray. Additionally, both of these methods of cure were evaluated using electricity and gas to provide the energy necessary to drive each of the two thermal processes. The use of IR and convection to drive the curing reactions in powder coatings is discussed in the following section. Emphasis is placed on: (1) delineating the differences between the two methods of invoking cure; (2) the advantages and disadvantages of each of the two methods, particularly with regard to the characteristics of both the sample and the powder coating material; and (3) special considerations that must be given to each of the methods when using them in a powder coating cure. As heat transfer by convection and IR are fundamentally different, most of the discussion on convection versus IR cure of powder coatings is presented without delineating between gas-fueled and electric processes. Furthermore, while there are certain differences in the benefits and disadvantages in using gas-fired convection ovens and electric convection ovens, the two types of ovens still operate in the same fundamental manner. However, this is not the case between electric IR and gas-fired IR. With IR, the nature of the energy source (gas versus electricity) may determine the operating temperature of the IR emitters, and hence the energy and wavelength of the IR emitted. The differences in IR emission between the gas IR and the electric IR are significant. The reasons for these differences are discussed, as well as the implications of these differences, and the manner in which they may affect the use of IR cure for powder coatings.

Fundamentals of Heat Transfer

Before pursuing the discussion of IR irradiation and convection cure of powder coating systems, it is important that a discussion be presented on the more general aspects of heat transfer. In its simplest form, heat transfer can be defined as energy in transit due to a temperature difference.[1] There are three modes by which heat energy can be transferred to a body: conduction, convection, and thermal radiation. Each of these methods of heat transfer is fundamentally different. As such, different governing equations must be applied to quantify energy transfer. A brief discussion is presented on each of these modes of heat transfer, and the governing equations are presented. To simplify this discussion, all equations are presented in a form that governs the transfer of heat from a heat source, providing some heat flux (Watts/m^2), to a heat sink at a temperature T_s. The terms "heat" and "energy" are used synonymously throughout the remainder of this discussion.

HEAT TRANSFER BY CONDUCTION: Conduction heat transfer is defined as the transfer of energy across a stationary medium due to the existence of a temperature gradient across that medium.[1] Thus, conduction heat transfer can occur through a body (solid or liquid—gases are considered to be nonstationary), or between two bodies of different temperature if the bodies are in intimate contact with each other.

Conduction heat transfer occurs due to activity on the atomic or molecular level. Provided a material is at a temperature above absolute zero, the molecules or atoms in that material are going to possess a finite amount of thermal energy. This energy is related to the random translational motion of molecules (diffusion), or more specific rotational or vibrational modes of the molecules. It is, in fact, the movement of these molecules on the atomic level that dictates the temperature of the macroscopic system. As these molecular level perturbations occur, energy is transferred among neighboring molecules or atoms. However, the transfer of energy among the molecules is not 100% efficient, due to the existence of what may be termed "internal frictional forces" imparted by specific molecular interactions. Thus, during the transfer, some energy is lost and dissipated in the form of heat. The amount of energy dissipated as heat, dictates the temperature of the body. When a body is at equilibrium with its surroundings, the amount of energy being put into the system is exactly equal to the amount of energy being dissipated as heat. However, if the body is now subjected to an external source of energy, the level of molecular activity will increase proportionately and the temperature of the body will begin to rise until equilibrium is once again obtained.

The rate of heat transfer by conduction through a one-dimensional plane wall, is defined by Fourier's law as follows:[1]

$$q(x)'' = k\,dT/dx \tag{1}$$

The heat flux $q(x)''$ (W/m^2) is the rate of heat transfer in the x direction, per unit area perpendicular to the x direction. The rate of heat transfer is dictated by dT/dx, the temperature gradient in the x direction, and the thermal conductivity k (W/mK) of the material through which the temperature gradient exists. Since the heat flux represents the rate of heat transfer through a section of unit area, the heat rate $q(x)$ would be determined as the product of the heat flux and the surface area A of the geometry of interest: $q(x) = q(x)''A$.

The thermal conductivity k of a material describes the ability of a material to conduct heat. Thus, materials with higher values of thermal conductivity will conduct heat more readily. However, this value does not describe the rate at which a material will heat up (rise in temperature) when exposed to a given heat flux $q(x)''$. The rate at which a material is able to heat up is defined by the ability of the material to store energy, not conduct it. The ability of a material to store energy is described by the specific heat c_p (J/kgK) of the material. For transient conduction processes, a value α (m^2/s), for thermal diffusivity, has been defined as $k/\rho c_p$. Typically, metallic solids, which are better conductors, have a higher value of α than nonmetallic solids, which are better insulators, and hence have better energy storage properties.

Heat Transfer by Convection: Convection refers to heat transfer between a surface and a moving fluid of a different temperature.[1] During convective heat transfer, heat is being exchanged due to the same type of random molecular motion driving conductive heat transfer, but there is also energy being transferred by the bulk, macroscopic motion of the fluid itself, a process termed advection.[1] Convective heat transfer can occur by forced convection, in which the fluid flow is controlled by some external means, such as a fan, or free convection, in which the fluid flow is dictated by naturally induced buoyancy forces in the fluid.[1] Forced convection is a more effective means of heat transfer, and is the method of convective heat transfer used in industrial convection ovens.

The rate equation for the heat transfer by convection is defined as follows:

$$q'' = h\,(T_s - T_f) \tag{2}$$

where q'' is the convective heat flux (W/m^2), h is the convective heat transfer coefficient (W/m^2K), T_s is the surface temperature of the object of interest, and T_f is the temperature of the fluid forcing the heat transfer process. As with conductive heat transfer, the heat rate $q(x)$ is determined as the product of the heat flux and the surface area A of the geometry of interest, perpendicular to the x direction, so $q(x) = q(x)''\,A$. The convective heat transfer coefficient h is a proportionality constant that dictates the rate of heat transfer that occurs due to the difference in temperature between the surface and the fluid. The determination of h is no trivial matter, since the value used for the convection heat transfer coefficient is a complex function of the surface geometry, the nature of the fluid motion, and a number of thermodynamic and transport properties of the fluid.[1] Typical values of h for forced convection by a gas medium may range from 25 to 250 (W/m^2K).[1]

Note that for a given value of h, the rate of heat transfer from the convective fluid to the surface is dictated solely by the difference in temperature between the fluid and the surface temperature of the part. Assuming the convective fluid is maintained at a constant temperature T_f, the rate of heat transfer will decrease as the surface temperature of the part increases. Consequently, the rate of increase in the surface temperature of the part is dependent on the ability of the part to store the energy (a function of c_p) that is being conducted away from the surface of the part to the interior (a function of k).

Heat Transfer by Thermal Radiation: Heat transfer by thermal radiation occurs between two bodies of different temperature, as a consequence of the fact that all surfaces at a finite temperature (above absolute zero) emit energy in the form of electromagnetic radiation (photons).[1] The emission of electromagnetic energy is a result of the manner in which electrons in matter naturally oscillate or translate from one energetic state to another. The natural vibration of the electrons is a result of their thermal energy and, therefore, is a direct function of temperature. Thus, even in the absence of direct contact, or some other medium for heat transfer by conduction or convection, heat transfer will occur between two objects of different temperature due to a thermal gradient set up between the objects as a result of the different amount of electromagnetic radiation emitted by each object. As the net result is a transfer of heat from one object to another, the transfer of electromagnetic energy between two bodies at different temperatures is termed thermal irradiation, or simply thermal radiation.

The maximum heat flux q'' (W/m^2) that may be emitted from a surface is defined by the Stefan-Boltzman law:

$$q'' = \sigma T_s^4 \tag{3}$$

σ is the Stefan-Boltzman constant ($\sigma = 5.67 \times 10^{-8}\ W/m^2K^4$), and T_s is the absolute temperature of the surface of the part. Equation (3) defines the maximum heat flux that may be emitted from a body at temperature T_s. Such a body is called a black body radiator. In actuality, real surfaces are not 100% efficient at radiating the electromagnetic energy being generated internally. A finite amount of this energy will be dissipated internally, so some of the potential radiant energy will be lost or transferred via conductive or convective processes. The efficiency at which a given material radiates energy from its surface, relative to a black body radiator, is dictated by the surface emissivity ε. Thus, the heat flux radiated from a surface is actually defined by equation (4):

$$q'' = \varepsilon\sigma T_s^4 \tag{4}$$

For radiant heating, it is necessary to define the net rate at which radiant energy is exchanged between two bodies at different temperatures. For radiant heat ovens, the surface area of the radiant heat source is assumed to be large compared to the surface area of the part being heated; i.e., the oven is able to supply radiant heat to the entire surface of the part at a constant heat flux. Thus, the net exchange in radiant energy between the surface of the part being heated and the source of radiant energy can be defined as:

$$q'' = \varepsilon\sigma\,(T_s^4 - T_{sur}^4) \tag{5}$$

where T_{sur} is the surface temperature of the radiant heat source. Since the heat flux provided by the radiant source is such a strong function of the difference in temperature (fourth power dependence) between the source and the part, any convective heat transfer, which occurs between the source and the part, may be neglected for the purpose of discussion,

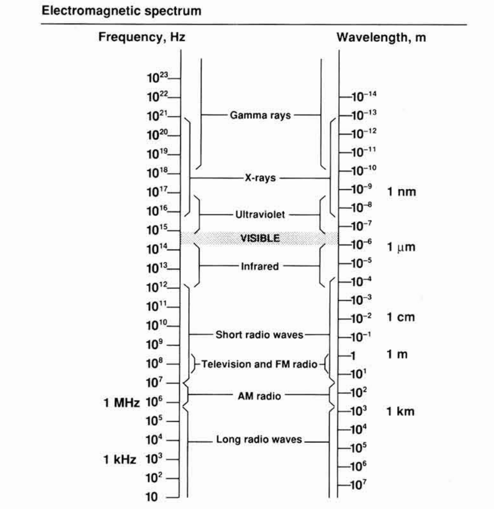

Figure 1—Electromagnetic spectrum

i.e., assume that the radiant heat transfer occurs in a vacuum. However, when calculating heat transfer rates, the convective component should be included for completeness.

Thermal energy transferred by electromagnetic radiation is typically confined to a portion of the UV, and the visible and infrared portions of the electromagnetic spectrum (0.1 to 100 µm wavelength range).[1] As the wavelength of radiant emission is inversely proportional to the vibrational frequency of the electrons, and more energetic electrons vibrate faster, electromagnetic radiation at shorter wavelengths will be more energetic. Thus, objects possessing more thermal energy and having higher frequency vibrational modes, will emit more energetic forms of electromagnetic radiation. The relationship between energy E, wavelength λ, and frequency ϑ is expressed as follows:

$$E = h\vartheta = hc/\lambda \qquad (6)$$

where h is Plank's constant ($h = 6.63 \times 10^{-34}$Js) and c is the speed of light in vacuum ($c = 3 \times 10^{8}$ m/s).

Infrared Radiation

Under the current program, electric and gas-fired IR ovens were used to cure powder coatings. The mechanism by which electric IR and gas IR cure powder coatings is essentially the same regardless of the source of IR. However, there are some subtle, yet significant, differences between the two IR systems studied in this program which can be attributed to the differences in the wavelength and energy of the IR emitted from each of the ovens.

As depicted in *Figure* 1, the infrared portion of the electromagnetic spectra is located at wavelengths just longer than that of visible light.[2] For coating applications, the IR spectra can be further broken down into three categories: the near or short wavelength IR, intermediate or medium wavelength IR, and the far or long wavelength IR (*Figure* 2).[3] Electric IR ovens typically operate in the near-to-mid IR range, depending on the operating temperature of the oven and the type of IR emitter used. Gas-fired IR ovens typically operate in part of the intermediate and the long wavelength regions of the IR spectrum.

Because of the number of different emitter sources available for electric IR and the range of operating temperatures of the electric IR ovens, electric IR ovens are more versatile than gas. The most efficient and versatile IR emitters are sealed quartz lamps with tungsten filaments. Quartz lamps have the capacity to operate at temperatures up to 4000°F, and are the most efficient type of IR emitters, capable of converting up to 86% (at the maximum operating temperature) of the power input to radiant heat energy (*Figure* 3).[4,6] The rest of the energy is lost or transmitted via conduction or convection. Other IR emitters, such as quartz tubes or metal sheath sources with nickel-chrome filaments, operate at lower temperatures, and produce longer wavelength radiation. These sources are not as efficient as the quartz lamps at emitting radiant energy (*Figure* 3), but offer some advantages in service life and mechanical integrity. Since gas-fired IR ovens operate at lower temperatures, gas-fired IR ovens are typically less efficient at transmitting radiant energy than electric IR ovens. However, this IR efficiency is not always advantageous. For instance, when curing powders on complex geometries, less efficient IR converters may be better because the heat "lost" provides a means of heating the portions of the substrate not in the line-of-sight of the IR. Thus, in these instances, the use of gas IR, or electric IR operating at lower temperatures, may be more favorable.

The peak wavelength of the IR emitted from the quartz lamp, at their maximum operating temperature, is about 1.2 µm. Gas-IR ovens typically operate at a peak wavelength of 4 µm or greater. As depicted in *Figure* 4, the peak wavelength of emission increases with decreasing operating temperature of the emitter.[5] Also note that the distribution of the IR wavelengths emitted broadens as the operating temperature of the emitter decreases. As discussed earlier, the wavelength of IR emission is solely a function of the temperature of the emitter source. Different IR sources have been configured to operate at a particular peak wavelength. This wave-

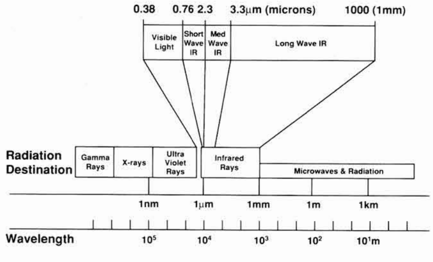

Figure 2—Infrared and the electromagnet spectrum

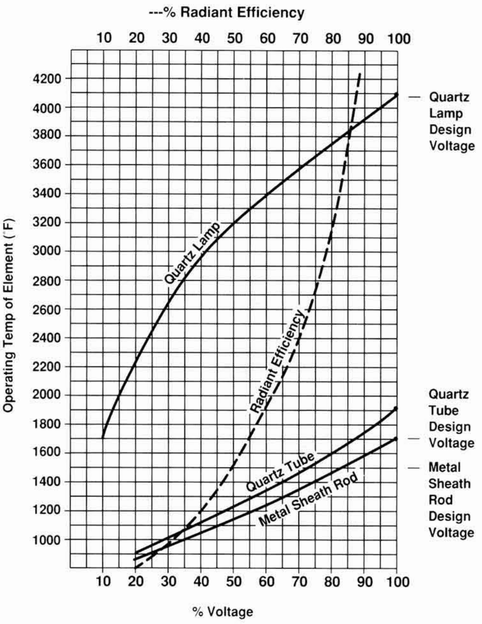

Figure 3—Distribution of infrared heat sources

length dictates the maximum operating temperature needed for the source. It is important to note, however, that the quartz lamps, for instance, can be operated at lower temperatures where the emission of IR radiation will shift in wavelength and distribution, simply due to the change in operating temperature. Thus, the IR distributions depicted at the maximum operating temperature of the lower intensity sources can be duplicated using the high intensity IR quartz lamps, simply by decreasing the operating temperature of the lamp. This flexibility is one of the biggest advantages of electric IR ovens. Because of the number of sources that can be used in electric IR ovens, and the ability to vary the emitting temperature of these sources, electric IR ovens can be "tuned" to emit IR energy at any desired peak wavelength less than the maximum operating peak wavelength of the emitter being used. Because of this, electric IR ovens can be made to mimic the IR distribution patterns of gas-fired IR ovens. Gas-fired IR ovens do not offer this type of flexibility.

The response of IR ovens offer a great advantage over convection ovens. This is particularly true with electric IR ovens equipped with high efficiency IR emitters. High intensity IR ovens, using quartz lamps, respond almost instantly to programmed changes in radiant heat output.[4] Other IR sources, which are not as efficient at converting input energy into radiant energy, respond more slowly. The increase in response time is a result of the time required to bring the IR emitter up to the temperature desired for appropriate energy output. Again, this is a result of the efficiency of the emitter, since the lag time noted can be attributed to the fraction of heating that must occur by conduction rather than by thermal radiation.

Thermal Cure of Powder Coatings

Two methods of heat transfer were used to provide the thermal energy needed to drive the curing reactions in the powder coating materials evaluated: forced convection and thermal radiation by IR. Each of these methods provides heat energy to the coated part using two distinct mechanisms. Regardless of the vehicle used to provide the heat energy to the powder coating, conductive heat transfer, from within the powder coating itself, or from the substrate to the powder coating, plays an important role in driving the curing process to completion.

CONVECTION CURE OF POWDER COATINGS: Convection oven cure of powder coatings is the most commonly used method to cure powder coatings in industry. As such, a great deal of information is available to aid powder coating users in selecting cure temperatures and oven cycle times that will result in a product with the appearance and physical properties desired. Typically, the powder coating manufacturer will provide the user with a range of temperatures and the corresponding cycle times that will allow complete cure at the selected temperature. The temperatures provided are typically "peak metal temperatures."

For a powder coating to cure using convective heat transfer, the powder coating would have to be heated, throughout its thickness, up to or above this temperature, and the temperature of the coating would have to be maintained for a sufficient amount of time to allow the coating to fully cure. Peak metal temperature may be difficult to obtain in some instances, particularly when coating large parts or parts with high specific heat values. In such cases, energy is wasted heating up the substrate material which is serving as a heat sink.

Ideally, when using forced convection to cure a powder coating, the temperature of the substrate should be sufficient to initiate cure in the powder coating material. This would minimize the occurrence of one of the primary problems associated with convection cure of powder coatings: orange peel effect, or in the more severe cases, poor adhesion of the coating to the substrate. These problems may be incurred when using convection cure because the heat has to be transferred from the convective fluid, through the coating,

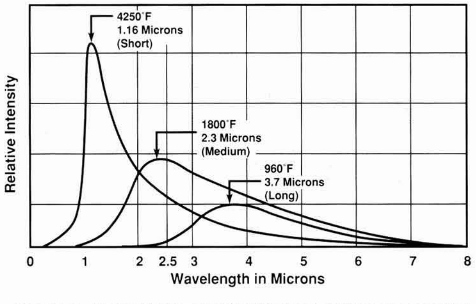

Figure 4—Energy intensity distribution of three types of IR emitters

Table 1—MEK Double Rubs

Powder Coating	Electric Convection Oven Cure	Gas Convection Oven Cure	Electric IR Cure		Gas IR Cure	
			Steel Panel	Aluminum Panel	Steel Panel	Aluminum Panel
White epoxy (No. 1)	5	5	5	5	5	—[a]
Black epoxy (No. 2)	5	5	4	4	5	5
White acrylic (No. 3)	5	5	5	5	4	5
White polyurethane (No. 4)	4	4	4	4	3	4
White polyester (No. 5)	4	4	4	3	3	3
White polyester hybrid (No. 6)	2	2	2	2	1	2
White nylon (No. 7)	5	5	5	5	5	5
Clear polyester (No. 8)	2	2	2	2	2	2
Fine white polyurethane (No. 9)	2	2	2	2	2	2

(a) Value not obtained.

and then to the coating substrate interface. Since the outer surface of the coating is at the highest temperature, the coating is most likely to begin curing from the outer surface inward. If cure proceeds rapidly and the coating begins to set on the outer surface, the coating may skin, making it difficult for gaseous by-products (from subsequent curing reactions occurring in the inner portion of the coating) to escape without damaging the appearance or integrity of the coating. Most often, this situation results in the orange peel effect, but may cause blistering or popping, depending on the reaction process and the thickness of the coating.

ELECTRIC- AND GAS-FIRED IR CURE OF POWDER COATINGS: One of the advantages of using IR ovens to cure powder coatings is that IR ovens allow better control over the manner in which heat is transferred to the powder coated parts. In a forced convection oven, the oven temperature is set, and the parts are moved in to cure. Only the thermal properties of the coating and the substrate material (of which the applicator has no control), the oven temperature, and the air circulation rate in the oven will dictate the rate of heat transfer through the coating. With an IR oven, additional means of control are provided. The intensity of the incident IR on the part being heated, and hence the rate of heat transfer to the part, can be controlled easily by varying the source temperature of the emitter, or by changing the distance of the part from the source of IR. The ability to vary source temperature is only available with electric IR ovens. Part distance can be varied in both electric- and gas-fired IR ovens. One major advantage of the electric IR oven is the almost instantaneous response that the ovens exhibit when the emitter temperature, and hence the heating rate of the part, is changed. Thus, for electric IR, if a change in heating rate is desired, the user need only adjust the voltage being supplied to the emitters. No lag time is required for the oven to reach thermal equilibrium before its use can be continued. It is worth noting that the response of the oven is inversely proportional to the efficiency of the IR-emitting source, with faster response exhibited by source converting a larger portion of energy to IR radiation. The response of electric IR ovens makes them better suited for applications in which multistage heating processes are required to achieve optimum cure, especially when computer control methods are used to set up the heat treatment program. The quick response of the electric IR oven also makes it possible to use an IR oven more efficiently when there are breaks in the production process, since the electric IR oven can be turned off when it is not in use. For this reason, electric IR ovens can provide economic benefits in a number of industrial processes.

Electric IR ovens offer one strong advantage of being able to vary the penetration depth of the IR radiation through the coating by varying the temperature of the IR emitter. Varying the voltage to the emitter changes the temperature of the emitter; hence, the wavelength and energy of the IR radiation produced. Increasing the temperature of the emitter will shift the peak wavelength of emission to shorter wavelengths. Since the energy of the radiation is inversely proportional to its wavelength, the resultant emission has a higher energy and, consequently, the ability to penetrate deeper into the applied powder coatings. Thus, when thicker coatings are being applied, the energy of the IR can be adjusted to ensure the penetration of the IR into the interior of the coating.[3] The ability of IR to cure a powder coating in this manner is one of the major reasons IR curing methods are gaining popularity. Because IR penetration can be controlled, emitter temperatures can be selected that will ensure transmission of a significant portion of the incident IR to the substrate, thus increasing the temperature of the substrate prior to increasing the temperature of the coating. Because of this, the coating will begin to cure at the coating-substrate interface first. As a result, some of the problems associated with using convection cure methods are alleviated: film adhesion is enhanced, and the appearance of the coating is less apt to exhibit the orange peel effect.

IR ovens offer time and space saving advantages over convection methods.[7] Since IR ovens are more capable of transferring energy to the coating in a given amount of time, powder cure in IR ovens occurs more rapidly. Powders that require 12 to 15 min at cure temperature in convection system may cure in as little as 2 to 4 min in an IR oven.[7] For a given rate of production, faster curing times in IR translate into shorter oven dwell times and shorter ovens.

One problem typically associated with the use of IR ovens is the fact that, since IR ovens use electromagnetic energy to drive the heating process, the radiant energy supplied is very directional in nature, i.e., IR ovens transfer energy in a "line-of-sight" type manner.[7] This is true of the radiant energy emitted by IR sources. This problem is more prevalent in electric IR ovens using high efficiency IR sources since there is a smaller percentage of energy "lost" to conductive heating processes. However, like visible light, IR radiation can be redirected to "hidden" areas of a substrate using reflective materials. The use of highly reflective materials to redirect IR radiation from the IR emitters is a common practice used by IR oven manufacturers to redirect IR towards the center of the oven.

New Characterization Tool for Monitoring the Cure of Powder Coatings

Photoacoustic Fourier transform infrared (PA FT-IR) spectroscopy is becoming a popular technique for the analysis of polymeric powder coatings. In contrast to transmission FT-IR experiments where a clear sample is needed, PA FT-IR measures absorption and decay of the infrared radiation in the form of a pressure wave, thus eliminating the problem of detector saturation caused by strong absorption bands in the sample. PA FT-IR also has the advantage of requiring little or no sample preparation.

In a typical PA FT-IR spectroscopic experiment of this program, each infrared spectrum consisted of 400 co-added scans recorded at a 4 cm^{-1} resolution utilizing a mirror speed of 0.3 cm/sec corresponding to a modulation frequency of 5 kHz. All PA FT-IR spectra were recorded on a Digilab FTS-10M FT-IR spectrometer using a Digilab photoacoustic cell purged with helium. The co-added sample scans were ratioed against a carbon black reference spectrum. All spectra were then transferred to an IBM compatible computer for further spectral manipulation using Spectra Calc software (Galactic Industries).

RESULTS AND DISCUSSION

The goal of this work was to determine the relative efficiencies of the powder coatings in various curing situations such as the gas IR oven, the electric IR oven, and the electric and gas convection ovens with an eye toward powder coating modifications that might lend themselves to IR curing. Electric IR is usually considered to be more efficient than gas IR. As such, it was believed that coatings which cured optimally at a specific IR frequency might be more amenable to this type of a curing study. It should be noted that all powder coatings will cure in any of the mentioned ovens. If, for instance, one could obtain or design a powder coating that would cure instantaneously when exposed to a certain wavelength of infrared radiation, than a potentially more useful coating would be in hand. This increased usefulness would be in the form of the coating shelf-life and also in the coating's efficiency in converting the IR energy into the curing reaction.

To address the previously mentioned optimization of cure, PA FT-IR spectra were collected with all of the powder coatings. The spectra would conceivably allow the functional group identification which might be later used for the cure optimization. For instance, the polyester powder coatings cure through hydroxyl groups which absorb in the 2.5-3.5 μm range. After the coatings melt and begin to flow out into a continuous film, the curing agent is dissolved as a result of this melting action and begins to cure the coating. The powder coating must form an even, continuous film during this melt process and before the coating has crosslinked, or adequate surface coverage of the substrate may not be attained. Given the temperatures found in an IR oven, it is anticipated that the coatings would flow out into a film and cure very quickly.

In the case of a coating which simply has to melt and flow over the substrate (a thermal plastic system), no real benefit would likely be realized by altering the frequency of infrared radiation. In other words, the hotter the system, the better the flow out of the coating, as long as there is no thermal degradation. The Nylon powder coating is just such a thermoplastic coating.

There were also several epoxy powder coatings investigated for this study. All of the powder coatings are listed in in the following with respect to powder type, melt temperature (°C), and cure temperature (°C). All but the first two epoxy coatings generally fall into the same range for melting and curing temperatures. The melting temperature is related to the glass transition temperature of the base resin system, while the cure temperature is related to the chemistry of the specific functional groups in the powder coating.

Powder Type	Melt Temp.[a] °C	Cure Temp.[b] °C
White epoxy	88	210
Black epoxy	115	210
White acrylic	170	241
White polyurethane	160	220
White polyester	162	236
White polyester hybrid	125	222
White thermoplastic nylon	150	198[b]
Clear polyester	152	240
Fine white polyurethane	163	236

(a) Melt and cure temperatures determined from differential scanning calorimetry (DSC).
(b) Optimum melt temperature.

If a coating that absorbed a certain frequency of light which, in turn, caused it to cure rapidly were employed, then the coating might not have an opportunity to flow out into the continuous film required for substrate protection in a typical coatings application. However, the exact converse could also happen if the coating's melting process were affected such that the coating melted and flowed quickly, followed by cure. The exact nature of the melting process would be controlled by the chemical structure of the powder coating materials.

The frequency of the infrared radiation used in IR ovens is usually no higher than 1.2 μm where a typical organic coating will have very little absorption. That is not to say that the coating has no absorption as some powder coatings have hydroxyl groups which will absorb infrared radiation in this 1.2 μm frequency range. These coatings might be expected to cure more efficiently with high frequency IR. However, most powder coatings are clear or have low absorptions in this range and no real benefit would be realized by curing with this longer IR wavelength light. The only real benefit is that the substrate heats faster and will begin the cure reaction from the substrate outward to the coating surface.

The benefits of utilizing materials that will selectively absorb IR radiation include: more efficient conversion of the

Table 2—Impact Resistance (in.-lbs)

Powder Coating	Electric Convection Oven Cure	Gas Convection Oven Cure	Electric IR Cure		Gas IR Cure	
			Steel Panel	Aluminum Panel	Steel Panel	Aluminum Panel
White epoxy (No. 1)	76	72	70	10	60	—[a]
Black epoxy (No. 2)	> 160	> 160	148	6	136	> 60
White acrylic (No. 3)	22	22	16	2	14	3
White polyurethane (No. 4)	> 160	50	> 160	2	38	6
White polyester (No. 5)	48	40	24	6	30	6
White polyester hybrid (No. 6)	44	56	42	2	12	2
White nylon (No. 7)	> 160	> 160	> 160	> 60[b]	> 160	> 60[b]
Clear polyester (No. 8)	> 160	76	116	1.5	2	8
Fine white polyurethane (No. 9)	52	104	104	22	16	4

(a) Value not obtained.
(b) Panel failed (not coating).

energy to obtain a faster cure response; and IR ovens can be zoned with different emitters to provide substrate heating in zone 1, coating curing in zone 2, and another heating (substrate) in zone 3.

Physical Properties of Powder Coatings

Nine powder coatings were applied to steel and aluminum substrates and cured by four different heat sources (electric convection, gas convection, electric IR, and gas IR).

The physical properties and other characteristics evaluated in this study are: MEK double rubs; direct impact resistance; adhesion; smoothness; flexibility; pencil hardness; gloss (60°); gloss after Weather-Ometer exposure; color stability after Weather-Ometer exposure; effect of color on IR response of powder coatings; effects of overcuring and undercuring; and application and curing considerations for bent panels.

The nine powders selected for study were: white epoxy—No. 1; black epoxy—No. 2; white acrylic—No. 3; white polyurethane—No. 4; white polyester—No. 5; white polyester hybrid—No. 6; white nylon—No. 7; clear polyester—No. 8; and fine white polyurethane—No. 9 (screened by manufacturer to 25-30 µ).

The six curing conditions selected were: (1) electric convection oven; (2) gas convection oven; (3) electric IR oven, steel panel; (4) electric IR oven, aluminum panel; (5) gas IR oven, steel panel; and (6) gas IR oven, aluminum panel.

Data are discussed by physical property in the following.

MEK Double Rubs: It is generally accepted that the MEK double rubs test (ASTM D 4751-87) offers a reliable index of cure of a coating. After 50 double rubs, film condition is rated on a scale of 5 to 0, where 5 = no effect, 4 = burnished appearance, 3 = some marring, 2 = heavy marring, 1 = heavy depression, and 0 = penetration to substrate. As can be seen in *Table* 1, ratings for the nine coatings ranged from 2 to 5 for the different types of coatings but were generally consistent for a specific coating type throughout the six curing conditions previously cited. For example, all white epoxy coatings were rated 5 regardless of curing condition. Panels cured with gas IR rated slightly lower for the white polyurethane (No. 4) and the white polyester hybrid (No. 6) than did other panels in their respective groups. These data confirm that the electric and gas IR curing conditions selected in this study to match manufacturers curing recommendations for convection ovens (time-at-peak metal temperature) were acceptably close. However, it is obvious that the sensitivity of the MEK double rubs test is not sufficient to discriminate subtle differences in degree of cure among the six curing conditions. A more sensitive index is provided by the other physical property testing described in the following sections.

Impact Resistance: Direct impact resistance was measured in inch-pounds by dropping a falling weight onto an impactor in contact with the painted surface (ASTM D 2794-84). Results of these evaluations are provided in *Table* 2. The general pattern of similar performance for a single coating representing all six cure conditions can be observed throughout these measurements. The gas IR-cured panels are generally lower, indicating that more definitive information is required to establish a cure profile relative to that of convection ovens. It is interesting to note that the impact resistance of the white nylon coating (No. 7) on thin aluminum panels exceeded the integrity of the panel. The failure mechanism did not involve the extensibility of the coating but that of the aluminum substrate (measured on an uncoated 4 × 12 × 0.125 in. aluminum panel as 30 in.-lb). The impact resistance of all other coatings on the aluminum was significantly less than

Table 3—Adhesion

Coating	Adhesion Rating[b]	Rating on Gas IR-Cured Panel
White epoxy (No. 1)	5B	—
Black epoxy (No. 2)	5B	—
White acrylic (No. 3)	5B	1B
White polyurethane (No. 4)	5B	—
White polyester (No. 5)	5B	—
White polyester hybrid (No. 6)	5B	—
White nylon (No. 7)	5B	—
Clear polyester (No. 8)	5B	4B
Fine white polyurethane (No. 9)	5B	—

(b) Highest rating is 5B. Adhesion ratings were the same for all curing conditions with the exception of the values in the second column.

that of the same coatings on steel panels. This indicates that the powders cured faster on aluminum panels than on steel and were over-cured and brittle. No significant differences in performance between electric IR-cured or convection oven-cured coatings were observed. Differences with respect to resin types were seen as, for example, lower impact resistance values for the coatings of the harder, more brittle acrylic powder.

ADHESION: Adhesion of the powder coatings to the steel and aluminum panels was measured by crosshatch tape pull (ASTM D 3359 Method B) (see *Table* 3). With few exceptions, the adhesion of all coatings was measured as excellent (ratings 5B). The gas IR-cured panel of the white acrylic powder (No. 3) was an exception and rated only 1B. This poor rating probably reflects the difficulty of translating convection oven curing conditions to gas IR.

SMOOTHNESS: Coating smoothness provides a good index of flow during film formation. Smoothness was evaluated according to Powder Coatings Institute (PCI) visual standards and rated on a scale of 1 to 10, where 1 = textured, and 10 = mirror-like. In general, values for different classes of coatings ranged from 4 to 8 with only small deviations within a single coating group. No significant differences in smoothness were observed between the electric IR-cured and convection oven-cured panels of the same coating. Panels of four of the nine coatings were less smooth when cured with electric convection than when cured with electric IR or gas convection. These small differences of one rating number can probably be attributed to air circulation patterns in the electric oven. The white nylon on an aluminum panel heated with electric IR was rated 3, the poorest performance in the study. It would be expected that the aluminum panel would provide greater heat of conduction and, therefore, greater melt flow. No explanation of this unusual performance is apparent.

FLEXIBILITY: Flexibility of the powder coatings was measured by bending the coated panels over a conical mandrel according to ASTM D 522-85. Flexibility values expressed in inches (mandrel diameter successfully passed without cracking) are listed in *Table* 5. A rating of "pass 1/8 inch" equals an elongation of approximately 32%, whereas a rating of "fail 1 inch" equals an elongation of approximately 4.5%.

HARDNESS: Pencil hardness was evaluated according to ASTM D 3363-74 using the Gardner HA336 Scratch Hardness Tester. The same pattern of similar group performance according to powder type was observed. Results of these evaluations are provided in *Table* 6. The higher hardness of the white acrylic panels cured with gas IR (2H/3H) is consistent with flexibility data reported above (panels failed 1 in. mandrel).

GLOSS: Gloss was measured at 60° according to ASTM D 523-89. Again, values for each coating, irrespective of heat source used for cure, fell within a relatively narrow range. As can be seen in *Table* 7, there was no heat source that produced consistently higher or lower gloss values.

GLOSS AFTER WEATHER-OMETER EXPOSURE: After 300 hr exposure in the Weather-Ometer, it was observed that major differences in performance existed between resin types and minor differences existed between films cured with different energy sources. The percent loss is listed in *Table* 8 for the 54 evaluations (9 coatings × 6 energy/panel conditions). There is a noticeable difference between the percent loss of the black epoxy powder cured with electric IR (40% loss) versus similar films cured in an electric convection oven (67% loss).

Effect on Color on IR Response of Powder Coatings. The black epoxy was included in the program to demonstrate that color is unimportant to IR energy. Most pigments are transparent to IR in certain wavelength. As can be seen in the following, MEK double rubs and impact resistance values of the black epoxy coatings are acceptably close. The loss of flexibility could indicate overcuring but that effect is not duplicated in the impact resistance properties.

Black Epoxy Film Properties on Steel Panels

Cure Method	MEK Double Rubs	Flexibility	Impact Resistance
Electric IR	4	fail 1"	148 in. lb
Gas convection oven	5	pass 1/8"	> 160 in. lb

EFFECTS OF OVERCURING AND UNDERCURING: Manufacturer's recommendations for convection curing (time at peak metal temperature) were used as target cure conditions for all powders. Additional steel panels cured with electric IR were deliberately undercured and overcured. This was accomplished by (1) developing a temperature profile for the electric IR oven, (2) identifying the time/voltage conditions for the IR oven that corresponded to the manufacturer's recommendation for convection oven of time at peak metal temperature, and (3) selecting electric IR curing conditions (and, in some cases, gas-IR conditions) that were below target, on target, and above target. For example, it was determined that the electric IR condition that approximated the white epoxy (No. 1) recommended cure condition of 15 min at 323°F was 4 min at 280V (see *Table* 10). Undercure was achieved by 3 min at 280V and overcure was achieved by 5 min at 280V. Over and undercuring conditions were determined by monitoring the MEK rub test data. It should be pointed out that MEK rub data obtained immediately after curing (used to determine under and overcure) and data obtained after 14 days aging vary because cure apparently proceeded with aging (also see "MEK Double Rubs" tabulation).

Physical properties examined on coatings representing under target, on target, and over target curing conditions included: (1) MEK double rubs; (2) direct impact resistance; (3) adhesion; (4) smoothness; (5) flexibility; (6) pencil hardness; (7) gloss; and (8) gloss after Weather-Ometer exposure.

Comments relative to each powder type are presented in the following:

White Epoxy Powder (No.1) Coatings. Most physical properties of the cured white epoxy powder coatings on steel panels cured with electric IR were similar, indicating a broad curing range for the epoxy. However, direct impact resistance data illustrated the expected improvement in properties progressing with cure. These data illustrate the sensitivity of impact resistance in indicating the degree of cure. No other physical property offered these small differences.

Table 4—Smoothness

Powder Coating	Electric Convection Oven Cure	Gas Convection Oven Cure	Electric IR Cure		Gas IR Cure	
			Steel Panel	Aluminum Panel	Steel Panel	Aluminum Panel
White epoxy (No. 1)	4	5	4	4	4	—[a]
Black epoxy (No. 2)	7	8	8	8	7	7
White acrylic (No. 3)	6	6	6	6	6	5
White polyurethane (No. 4)	5	5	6	6	7	6
White polyester (No. 5)	8	9	9	8	8	8
White polyester hybrid (No. 6)	6	8	8	6	6	6
White nylon (No. 7)	5	6	5	3	5	6
Clear polyester (No. 8)	9	9	9	8	8	8
Fine white polyurethane (No. 9)	8	8	8	7	7	7

(a) Value not obtained.

Table 5—Flexibility

Powder Coating	Electric Convection Oven Cure	Gas Convection Oven Cure	Electric IR Cure		Gas IR Cure	
			Steel Panel	Aluminum Panel	Steel Panel	Aluminum Panel
White epoxy (No. 1)	pass 1/8	pass 1/8	pass 1/8	pass 1/8	pass 1/8	pass 1/8
Black epoxy (No. 2)	pass 1/8	pass 1/8	fail 1	fail 1	pass 1/8	pass 1/8
White acrylic (No. 3)	fail 1	fail 1	fail 1	fail 1	fail 1	fail 1
White polyurethane (No. 4)	pass 1/8	pass 1/8	pass 1/8	pass 1/8	fail 1	pass 1/8
White polyester (No. 5)	fail 1	fail 1	pass 1/8	fail 1	fail 1	fail 1
White polyester hybrid (No. 6)	fail 1	pass 1/8	pass 1/8	pass 1/8	fail 1	fail 1
White nylon (No. 7)	pass 1/8	pass 1/8	pass 1/8	pass 1/8	pass 1/8	pass 1/8
Clear polyester (No. 8)	pass 1/8	pass 1/8	pass 1/8	fail 1	pass 1/8	fail 1
Fine white polyurethane (No. 9)	pass 1/8	pass 1/8	pass 1/8	pass 1/8	pass 1/8	pass 1/8

Table 6—Hardness[a]

Powder Coating	Electric Convection Oven Cure	Gas Convection Oven Cure	Electric IR Cure		Gas IR Cure	
			Steel Panel	Aluminum Panel	Steel Panel	Aluminum Panel
White epoxy (No. 1)	H	H	H	H	H	—[b]
Black epoxy (No. 2)	H	H	H	H	F	F
White acrylic (No. 3)	H	H	F	F	2H	3H
White polyurethane (No. 4)	H	H	F	H	F	F
White polyester (No. 5)	F	F	F	F	H	H
White polyester hybrid (No. 6)	H	H	2H	3H	H	2H
White nylon (No. 7)	2B	2B	2B	2B	B	B
Clear polyester (No. 8)	F	HB	HB	HB	HB	HB
Fine white polyurethane (No. 9)	F	H	H	H	H	H

(a) Pencils range from soft (6B) to very hard (9H). Where no number is used in the rating, it is a "1."
(b) Value not obtained.

Impact Resistance of White Epoxy Powder on Steel Panels Cured with Electric IR

Undercure (3 min/280V)	42 in.-lbs
Target cure (4 min/280V)	70 in.-lbs
Overcure (5 min/280V)	78 in.-lbs

Black Epoxy Powder (No. 2) Coatings. All properties of the black epoxy powder coatings on steel panels cured with electric IR were comparable. An exception was the direct impact resistance of the overcured panel (rated at 74 in.-lbs) which is undoubtedly reflecting its degree of overcure and brittleness. The impact resistance of the target cure panel was 148 in.-lbs.

White Acrylic Powder (No. 3) Coatings. White acrylic powder coatings were cured using both electric IR and gas IR under conditions considered "less than target", "target", and "over target." No significant differences were seen between the electric IR- and gas IR-cured panels. This verifies that the selected electric IR conditions (time at voltage) and gas-IR conditions (time at BTUs measured as height of water column) reasonably approximated the manufacturer's recommended "time-at-peak metal temperature."

Most performance properties observed in the undercured panels improved when "target cured" conditions were obtained. For example, impact and adhesion values were as follows:

Electric IR Cure	Impact	Adhesion
Undercure (2 min/300V)	0.5 in.-lbs	0B
Target cure (3 min/300V)	16 in.-lbs	5B
Overcure (4 min/300V)	24 in.-lbs	5B

Gas IR Cure	Impact	Adhesion
Undercure (3.5 min)	1 in.-lbs	0B
Target cure (5 min)	14 in.-lbs	1B
Overcure (6 min)	16 in.-lbs	5B

White Polyurethane Powder (No. 4) Coatings. Most properties of the white polyurethane powder coatings on steel panels undercured, target cured, and overcured using electric IR were comparable. From direct impact data, it can be seen that undercure is apparent (impact resistance of only 20 in.-lbs), whereas the point of overcuring is more forgiving (impact resistance of >160 in.-lbs for both target cure and overcure).

Impact Resistance of White Polyurethane Powder on Steel Panels Cured with Electric IR

Undercure (3 min/300V)	20 in.-lbs
Target cure (4 min/300V)	> 160 in.-lbs
Overcure (5 min/300V)	> 160 in.-lbs

White Polyester Powder (No. 5) Coatings. Physical properties of under-, target-, and over-cured coatings of the white polyester powder on steel panels cured with electric IR were generally comparable. Again, the more sensitive indicator of cure appears to be impact resistance.

	MEK Double Rubs	Impact Resistance
Undercured (4 min/320V)	4	16 in.-lbs
Target cure (5 min/320V)	4	24 in.-lbs
Overcured (6 min/320V)	5	48 in.-lbs

White Polyester Hybrid Powder (No. 6) Coatings. Most physical properties of the white polyester hybrid powder coatings on steel panels cured with electric IR are comparable, regardless of over-, target-, and under-curing. This indicated that the "cure window" is quite wide. Direct impact resistance data again provide the most sensitive index of cure.

	MEK Double Rubs	Impact Resistance
Undercure (3 min/280V)	2	12 in.-lbs
Target cure (4 min/280V)	2	42 in.-lbs
Overcure (5 min/280V)	2	68 in.-lbs

White Nylon Powder (No. 7) Coatings. The electric IR target conditions identified for the nylon powder that produced good melt flow (nylon is thermoplastic and no "cure" is obtained) were 2.25 min at 400V. It was not possible to produce a true under-heated condition because the nylon powder simply did not flow below heating conditions of 2 min at 400V. This condition (2 min/400V) was used to represent under-heated films even though physical properties were equal to those of the target-heated films.

The over-heated condition was difficult to understand because films heated for 2.5 min at 400V resulted in poor appearance (smoothness rating of 3). Target heated films (2.25 min/400V) rated 5 for smoothness, as would be expected.

Clear Polyester Powder (No. 8) Coatings. The impact resistance of clear polyester coatings on steel panels cured with electric IR were dramatically different after under-, target-, and overcuring. All other properties were comparable.

Impact Resistance of Clear Polyester Powder on Steel Panel Cured with Electric IR

Undercure (4 min/280V)	60 in.-lbs
Target cure (5 min/280V)	116 in.-lbs
Overcure (6 min/280V)	>160 in.-lbs

It is interesting to note that, at the time the panels were prepared, there were slight differences in the MEK rub data. These differences, which influenced under-, target-, and overcure condition selections were not apparent after two weeks aging.

	MEK Double Rubs	
	30 Min after Curing	After Two Weeks Aging
Undercure (4 min/280V)	1+	2
Target cure (5 min/280V)	2-	2
Overcure (6 min/280V)	2	2

The case can be made that target curing conditions for the clear polyester powder are probably closer to 6 than 5 min. Nevertheless, it is important to understand that, within the "cure window," it is possible to optimize curing conditions to key on the physical properties of choice. This situation appears to be true for most coatings in the present study. Electric IR is well-suited to this fine tuning by subtle adjustment of time, voltage, and/or distance from lamp.

Table 7—Gloss

Powder Coating	Electric Convection Oven Cure	Gas Convection Oven Cure	Electric IR Cure Steel Panel	Electric IR Cure Aluminum Panel	Gas IR Cure Steel Panel	Gas IR Cure Aluminum Panel
White epoxy (No. 1)	100.2	101.4	96.6	99.7	99.1	—[a]
Black epoxy (No. 2)	97.4	99.9	86.1	94.1	101.4	99.8
White acrylic (No. 3)	88.5	86.1	89.3	89.8	90.8	90.2
White polyurethane (No. 4)	91.0	91.9	91.0	92.4	92.0	92.3
White polyester (No. 5)	92.5	92.4	92.2	92.4	91.3	92.9
White polyester hybrid (No. 6)	77.1	75.6	65.3	73.2	77.0	81.1
White nylon (No. 7)	75.1	61.4	67.2	76.6	67.6	68.6
Clear polyester (No. 8)	107.5	103.2	107.7	166.0	109.5	162.2
Fine white polyurethane (No. 9)	88.4	90.2	86.1	92.7	89.5	93.1

(a) Value not obtained.

Table 8—Loss in Gloss (Percent) After 300 Hours Exposure in Weather-Ometer

Powder Coating	Electric Convection Oven	Gas Convection Oven	Electric IR Steel Panel	Electric IR Aluminum Panel	Gas IR Steel Panel	Gas IR Aluminum Panel
White epoxy (No. 1)	81	89	83	74	82	—[a]
Black epoxy (No. 2)	67	51	40	63	43	3
White acrylic (No. 3)	0	1	0	0	0	0
White polyurethane (No. 4)	0	0	0	0	0	0
White polyester (No. 5)	3	0	0	0	0	0
White polyester hybrid (No. 6)	53	45	51	52	61	52
White nylon (No. 7)	0	3	0	0	0	0
Clear polyester (No. 8)	3	5	3	0	4	4
Fine white polyurethane (No. 9)	0	0	0	0	0	0

(a) Value not obtained.

Table 9—Properties of Powder Coatings

Powder Type[a]	Powder Coating Slopes of the Area Vs $(\text{Temperature})^{1/2}$ Curves $(dA/dT^{1/2}) \times 10^{-5}$	Density (g/cm^3) (Measured)	Polymer Surface Tension (dyne/cm) (Calculated)	Solubility Parameter $(cal/cc)^{1/2}$ (Calculated)
White nylon	(3.83)	0.710	46	31
White polyester	(8.5)	0.990	35	30
White polyester/polyurethane hybrid	(14.4)	0.970	35	28
Fine white polyurethane	(121)	0.990	30	25
Clear polyester	(217)	0.660	35	30
Black epoxy	(267)	0.780	40	27
White polyurethane	(361)	0.980	30	21

(a) Note the white acrylic and white epoxy powders were not available at the time of modulus effect.

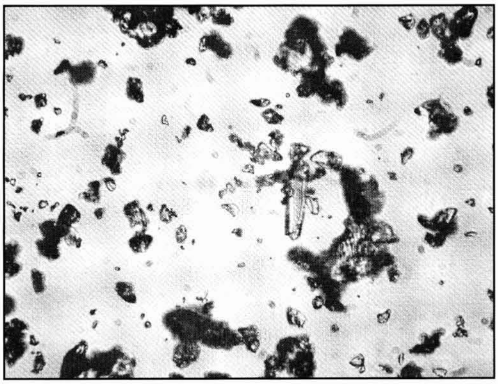

Figure 5—Powder particles before fusing (irregular shapes)

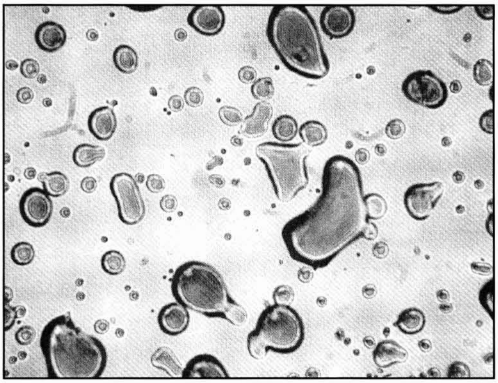

Figure 6—Powder particles after fusing (spherical shapes)

Fine White Polyurethane Powder (No. 9) Coatings. Again, impact resistance data appear to provide a sensitive index of cure while other properties are comparable.

Impact Resistance of Fine White Polyurethane Powder on Steel Panel Cured with Electric IR

Undercure (5 min/320V)	124 in.-lbs
Target cure (5.5 min/320V)	104 in.-lbs
Overcure (6 min/320V)	>160 in.-lbs

The 5 and 5.5-min cured impact values average 114 in.-lbs. This average should be considered to be the undercured condition, the 6-min impact value (>160 in.-lbs) should be considered to be the target value. A true overcured condition apparently was not achieved. The sensitivity of electric IR curing is apparent from these data.

Color Stability After 300 Hours Exposure in Weather-Ometer: Color stability was evaluated on panels cured with electric IR. All powder types with the exception of the black epoxy demonstrated good color stability. The Delta E of the black epoxy powder coatings lost 23% after 300 hr exposure (see the following tabulation).

Color Stability After 300 Hours Weather-Ometer

Powder	Delta E (percent change)
White epoxy	1.74
Black epoxy	-23.00
White acrylic	-0.10
White urethane	-0.23
White polyester	0.07
White polyester hybrid	-0.40
White nylon	1.10
Clear polyester	0.04
Fine white polyester	-0.12

Application and Curing Considerations for Bent Panels: Concern has been expressed over possible problems in using electric IR to cure powders on items with complex geometry. These problems included questioning the effectiveness of using a line of sight cure mechanism and of the possibility of overcuring that portion of the part which was closer to the lamp.

To study this condition, 4 × 8-in. steel panels were bent into an L shape and coated on the inside angle face of the panel. All nine powders were included in this investigation. No problems were encountered in applying the powder. Film thickness and appearance were uniform over the entire panel. Color and gloss changes are a good indicator of overcuring on surfaces closer to the lamp. Since no changes were observed, it was concluded that the bent panel did not present problems to electric IR curing. However, parts with more complex geometries and greater masses than flat Q-panels would have to be studied before firm conclusions can be made.

Modeling the Fusion of Powder Particles

The objective of this preliminary modeling study on powder fusion is to develop a better understanding on what controls the ability of the powder to flow and coalesce into a single continuous film structure. The ultimate performance properties of any coating system strongly depends on the initial and final stages of the film formation process.

Each of the powders examined in this study formed irregular patterns or clusters (*Figure* 5) that tended to become spherical (*Figure* 6) upon heating and fusing together to form a continuous film.

The fusion or deformation of pure spherical particles (*Figure* 7) can be represented by the following equation:

$$a^2 = \frac{3\,\upsilon\,R\,t}{2\,\pi\,\eta} \tag{9}$$

where, a is the radius of the circle of contact as shown in *Figure* 7, υ is the polymer surface tension (polymer/air interfacial tension), t is the elapsed time, R is the particle radius, and η is the polymer viscosity.[8]

The surface tension (υ) of polymers is a function of temperature (T)

$$\upsilon = \upsilon^\circ\,(1 - T/Tc)^{11/9 \cong 1} \tag{10}$$

where υ° is a constant and Tc is the critical temperature.[9] In these studies, the temperatures are far below the critical temperatures of the polymers, thus Tc can be neglected and

Table 10—Relationship between Manufacturer's Curing Recommendations (Time at Peak Metal Temperature) and Electric IR Curing Conditions

		Manufacturer's Recommendations (Time at Peak Metal Temp.)		Comparable Conditions for Electric IR[a]		
No.	Powder	Temp. (°F)	Time (min)	Electric IR Setting (V)	Emitter Temp. (°F)	Exposure Time (min) Undercure/Optimum/ Overcure
1	White epoxy	323	15	280	3280	3/4/5
2	Black epoxy	340	15	280	3280	3/4/5
3	White acrylic	400	10	300	3380	2/3/4
4	White polyurethane	400	10	300	3380	3/4/5
5	White polyester	400	17	320	3470	4/5/6
6	White polyester hybrid	350	10	280	3280	3/4/5
7	White nylon	430	20	400	3750	2/2.25/2.5
8	Clear polyester	380	20	280	3280	4/5/6
9	Fine white polyurethane	400	17	320	3470	5/5.5/6

(a) Panels are 7 inches from T-3 emitter during IR exposure.

the dominant temperatures are those at which the polymers melt and flow. Simplification of equation (10) ($\upsilon = \upsilon^\circ T$), and substitution into equation (9) results in an expression [equation (11)] that relates the surface area of two polymer particles undergoing a fusion process as a function of temperature.

$$a^2 = K\,(T) \qquad (11)$$

where $K = 3\,R\,t\,\upsilon^\circ / 2\,\pi\,\eta$.

It should be noted that an analyses expressed for equation (11) could also be derived using melt viscosity [$\eta = f(1/T)$] as a parameter for describing the fusion of polymer particles.

Plots of "a" versus $(T)^{1/2}$ increase with increasing temperature in a linear manner (*Figure* 8). The change in the surface area of the powders with temperature (slopes of the curves) are significantly different for each of the powder samples examined. The reasons for these differences are related to the pigment loading effects (density of the powder particles), and to the surface energies, the solubility parameters, the melt viscosities, and the molecular weights of the polymers.

In these particular studies, an initial correlation was found between the change in area as a function of temperature (slopes of the curves in *Figure* 8) and the density of the powders, the surface energies of the polymers and their associated solubility parameters (*Table* 9). The results of this correlation are represented by equation (12).

$$\left.\begin{array}{l}\text{change in powder particle}\\ \text{surface area with temperature}\end{array}\right\} da/dT = [-803\,(\text{density}) - 7\,(\text{surface tension}) - 39\,(\text{solubility parameter}) + 2181] \times 10^{-5}$$

Multiple correlation R value = 0.94
Standard of error estimate of 72 (12)

The degree of flow or ability of the polymer particles to flow together can also influence the chemical resistance of a film structure. Partial coalescence or undercure of a powder coating would result in a poor performance rating for stain resistance of the film. The stain resistance of an undercured film should have some relationship to the ability of the powder coating to flow together and cure. Thus, it would be expected that powder coatings that have large changes in their areas as a function of temperature (*Figure* 8) would coalesce and react faster and have improved stain resistance capabilities over those powder coating systems that exhibit a lower tendency (lower d area/d temperature slope values) to flow together to form a continuous film structure. *Figure* 9 shows an approximate trend toward a decrease in stain resistance for a series of powder coatings (*Table* 9) as a function of their change in surface area versus temperature (slope values from *Figure* 8) properties. Those powder coatings that exhibited high flow rates or large changes in their particle surface areas as a function of temperature had improved stain resistant properties over those powder coating systems with lower tendencies to flow together under temperature stress conditions.

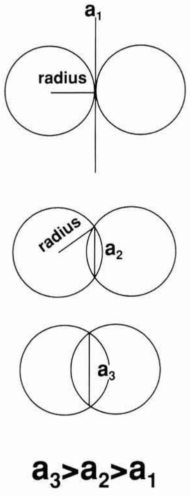

Figure 7—Model of two polymer particles fusing together

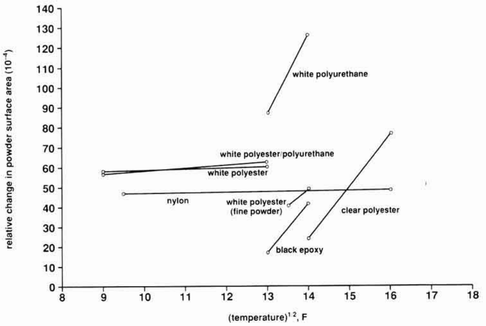

Figure 8—Relationship between relative change in powder particle surface area with temperature

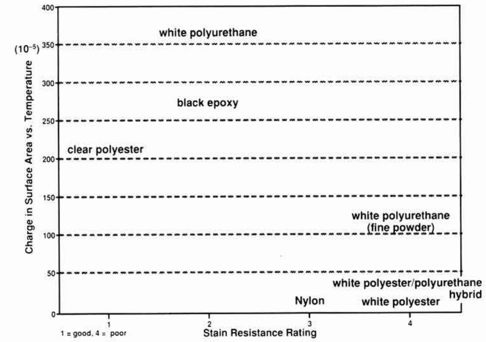

Figure 9—Relationship between the flow of polymer powder particles and the stain resistance of their undercured films

These data can be used by both the powder manufacturer and the formulator to provide better powder coating systems for improved flow-out and cure properties that will result in higher performance film structures.

CONCLUSIONS

The first exhaustive study to compare physical and performance properties of nine different types of powder coatings cured with four different energy sources has been completed. These data prove conclusively that premium quality coatings can be obtained when using high-intensity electric IR as the energy source. The physical and performance properties of electric IR-cured powder coatings are equal in every respect to comparable coatings cured with electric convection, gas convection, or gas IR. In addition, the electric IR energy source is more thermally efficient, significantly faster, and therefore, more economical.

An opportunity exists for designing powders for specific physical and performance properties by (1) modifying the powder, and (2) fine tuning the source of curing energy. To date, powder coatings are generally not optimized for specific curing scenarios. The cure information available from the powder manufacturers is recommended only as "time-at-peak metal temperature."

Electric IR curing presents a unique opportunity for fine tuning the cure process so that specific advantages in targeted physical and performance properties can be obtained. This opportunity exists because electric IR curing can accommodate minor changes in cure conditions easier and can hold the changes constant better than convection ovens or gas IR. Further, electric and gas IR curing are significantly faster than electric or gas convection oven curing. Electric IR curing offers crisp control of curing conditions with instant on/off for maximum economy. Gas IR must be left on and is not as easy to adjust accurately or to gage the energy level being used.

Miscellaneous conclusions that can be drawn from data in hand indicate:

(1) It is possible to achieve premium quality coatings at thicknesses less than 1 mil if the powder is screened to a small diameter particle size range. Even though acceptable appearance and smoothness can be obtained, it still will be vitally important to design a particular powder and tune the energy source if higher performance is desired.

(2) The MEK double rubs test commonly used in industry is not sufficiently sensitive to monitor subtle differences in degrees of curing. A battery of characterization and physical performance tests must be identified to identify the cure conditions that yield the desired performance level in cured powder coatings.

(3) Differences in pigmented coatings are generally unimportant to electric IR because most pigments are invisible to IR.

Photoacoustic Fourier Transform infrared spectra indicate that the short wavelength T-3 emitter, an electric IR energy source, cures powder coatings by conduction of energy from the substrate to the outside surface of the coating. These spectra show that powder coatings are virtually transparent in the 1-3 μm range, the short wavelength of electric IR. Thus, as presently used, curing occurs principally from conduction of heat from the substrate and not by absorption of IR energy by the powder, as is commonly believed.

Information obtained from PA FT-IR spectra generated in this program will facilitate the industry trend to shorter electric IR cure times (seconds as opposed to minutes). To obtain these extremely fast cures, electric IR ovens must be front-zoned to obtain optimum melt flow (using an IR wavelength of 1.2 μm), followed by back-zoning for cure (using an IR wavelength of 5-10 μm). The purpose of this tuning is primarily to improve throughput, but the overall quality and final properties of the powder coatings may be improved as well. To meet the increasing speed requirements for using electric IR to cure powders in special applications, such as coil coatings, the substrate may also be preheated.

Powders absorb IR in the range of 3-20 μm but, to date, electric IR ovens generally have not been tuned to these wavelengths. Major opportunities exist for optimizing cure of powders by adjusting the output of electric IR ovens.

A general approach has been identified for translating manufacturer's recommendations for curing in convection ovens (time-at-peak metal temperature) to electric IR ovens. In this study, the following tabulated relationships have been established (*Table* 10).

A model has been developed that provides critical information on understanding melt and flow out of powders during cure. This information is key to obtaining optimum physical and performance properties of the cured powders. The information derived from this model is of importance to the powder manufacturer in designing products optimized for specific properties that can be obtained from specific cure conditions. The information derived from this model should be of most importance to the user in demanding powders that have been optimized/tuned to meet their specific application criteria.

ACKNOWLEDGMENT

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Chemical Reactivity of Sulphur Dioxide With Unsaturated Drying Oils

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Differential scanning calorimetry (DSC) and Fourier transform infrared spectroscopy (FTIR) were used to characterize the chemical reaction occurring between sulphur dioxide (SO_2) and unsaturated drying oils present in typical alkyd paints. Specifically, linolenic acid, linoleic acid, and oleic acid were studied. It was found that prior exposure of linolenic and linoleic acids to SO_2 would suppress the DSC exotherm associated with the autooxidative crosslinking reaction. Similar behavior had been noted previously when a fully formulated alkyd paint was exposed to SO_2 and then scanned in the DSC. Oleic acid was unreactive toward SO_2, due to the lack of any doubly activated allylic hydrogen atoms. FTIR spectra of linolenic and linoleic acids exposed to SO_2, air, or both showed loss of allylic hydrogen atoms, a configurational change from *cis*- to *trans*- about the double bonds, and incorporation of $—SO_2—$ groups when SO_2 was present. A reaction scheme is proposed that involves reaction at doubly activated allylic sites, and subsequent incorporation of $—SO_2—$ groups into the crosslinks.

INTRODUCTION

Increasing levels of atmospheric sulphur dioxide (SO_2) have prompted a desire to know the rate at which gaseous SO_2 may diffuse through various paint coatings. Rapid diffusion of SO_2 through the paint film could result in substantial corrosion of the underlying substrate. We conducted a series of sorption/desorption experiments in order to determine the diffusion coefficient of SO_2 in alkyd paint films. During the course of this investigation, we observed that a significant fraction of the diffusing SO_2 remained in the paint film after desorption.[1] We assumed that this residual SO_2 had chemically reacted with some component of the alkyd paint. Experiments which measured the residual as a function of the degree of crosslinking determined that the residual decreased as the degree of crosslinking increased. Sol-gel analysis showed that the SO_2 crosslinked the alkyd paint with almost the same efficiency as air, and DSC experiments showed that the exotherm associated with the curing reaction was suppressed in samples that were previously exposed to SO_2. It was concluded that the unsaturated drying oils were the most likely paint components to undergo reaction with SO_2.

Previous work by Holbrow has shown that SO_2 can react with drying oils. He exposed alkyd paints to atmospheric levels of pollutant gases in industrial and suburban sites, and noted that exposure to SO_2 at concentrations of 7-10 ppb can cause delays in drying (curing) time up to two to three days.[2]

Drying oils have been used for centuries in the formulation of protective coatings. These oils are extracted from vegetable matter such as linseed or soybeans and consist of an unsaturated linear alkene chain, usually with 18 carbon atoms, and a carboxylic acid group on one end. Drying properties are controlled by the number of double bonds along the chain. Generally, the more double bonds the better the drying properties.[3,4]

The reaction mechanism responsible for crosslinking the oils was not completely understood until the 1940s. Farmer has been credited with developing the true mechanism of autooxidation.[5] He showed that oxygen reacts with a free radical formed due to the abstraction of hydrogen at the methylene group adjacent to the double bond (i.e., allylic sites) in the drying oils. A hydroperoxide group is formed which then decomposes to form more free radicals and propagate the reaction. He also suggested the formation of six-membered cyclic peroxides and showed how a conjugated structure could be obtained by the rearrangement of the double bonds after the allylic hydrogen has been abstracted.[6-10]

The autooxidative reactivity of drying oils containing multiple double bonds is also affected by the positions of the double bonds. When two double bonds are separated by two

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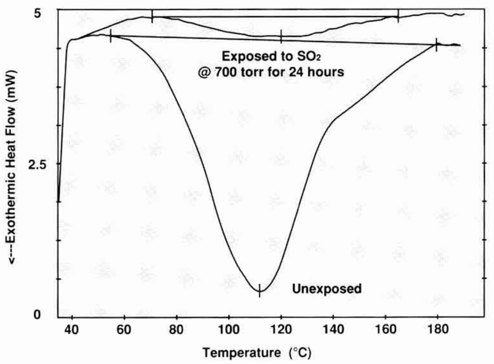

Figure 1—DSC plot of alkyd paint samples cured at 25°C for one hour. Note the large exothermic peak associated with the crosslinking reaction for the sample that has had no exposure to SO_2. The sample exposed to SO_2 at 700 torr for 24 hr displays no noticeable exotherm

single bonds, the allylic hydrogens on the central singly-bonded carbon atom are "doubly activated." This makes these hydrogens even easier to abstract, and can increase the reactivity of the molecule by as much as 20 times.[11]

In this paper, we show that SO_2 does indeed react with the pure drying oils, especially those containing doubly activated allylic hydrogen atoms. Differential scanning calorimetry (DSC) and Fourier transform infrared spectroscopy (FTIR) were used to characterize the chemical reaction with SO_2.

EXPERIMENTAL

Preparation of Alkyd Paint Films for DSC Experiments: The alkyd paint was generously supplied by The Sherwin-Williams Co.; the composition of the paint and binder is given in *Table* 1. Films were cast on glass plates using a doctor blade to ensure a uniform thickness. After casting, the films were allowed to dry in air for 48 hr. Samples were cured in a drying oven for one hour at 100°C. The paint films were then removed from the glass and the film thickness was measured, and found to be approximately 105 μm. The DSC experiments were performed using a Perkin-Elmer DSC 7. Samples were scanned over the temperature range of 35-195°C at a rate of 10°C per min.

The one-hour cure at 100°C was performed on all samples throughout this study to ensure uniformity in starting material and to avoid artifacts due to slow continuation of the curing reaction during subsequent experimentation. We have shown previously[1] that increasing the curing temperature from 25°C to 150°C (at a constant curing time of one hour) serves only to decrease the reactivity of the paint toward SO_2, presumably through increased crosslinking and reduction of the number of sites available for the SO_2 reaction. There is no evidence for a change in the fundamental reaction mechanism with SO_2 after curing at elevated temperatures.

Preparation of the Drying Oils for DSC Experiments: Linolenic acid, linoleic acid, or oleic acid were prepared for DSC studies by dispersing approximately 20 wt% of the respective fatty acid in an inert latex binder. Dispersion of the oils in a latex binder prevented extensive evaporation during the DSC scan. The fatty acid/latex suspension was then cast on glass using a doctor blade and allowed to dry for two hours in air. After drying in air, the glass plate containing the film was then placed in a vacuum chamber and evacuated for 24 hr. Samples were then removed as needed, and the remaining film was returned to a vacuum chamber to prevent premature oxidation of the drying oil. A Perkin-Elmer DSC 2 was used, and samples were scanned over the temperature range of 310-500 K (37-227°C) using a heating rate of 10°C per min.

Preparation of the Drying Oils for FTIR Experiments: Thin films of the drying oils were obtained by smearing the respective fatty acid on a sodium chloride (NaCl) crystal. The NaCl substrates were then placed in a vacuum chamber, evacuated, and backfilled with SO_2 to a pressure of 150 torr at 80°C for one week. After exposure to SO_2, the linolenic and linoleic acid samples had formed a thin solid film on the surface of the NaCl crystal. Oleic acid, however, did not form a solid film and was still a liquid. The NaCl substrates were then removed and placed directly into the FTIR beam path to obtain transmission FTIR spectra.

Drying oil samples were also oxidized in air by smearing the respective fatty acid on a zinc selenide (ZnSe) crystal. The ZnSe crystal was then placed in an oven and held at 80°C in air for one week. After this time, linolenic and linoleic acid had formed solid films; however, oleic acid did not form a solid film and was still a liquid. The ZnSe crystal substrates were then placed in an attenuated total reflectance (ATR) cell and FTIR spectra were recorded using an Analect Model FX-6260 infrared spectrometer at a resolution of 4 cm^{-1}.

Table 1—Alkyd Paint and Binder Composition

Component	Wt%	Function
Overall Paint		
Cargil 5070	48.8	binder
Mineral spirits	12.1	binder solvent
Bentonite clay	0.5	filler
Ethanol	0.3	coupling solvent
Zinc oxide	2.5	hiding pigment/mildewcide
Calcium carbonate	7.5	extender
Titanium dioxide	25.0	pigment
Butyl cellosolve	2.5	organic solvent
12% cabalt drier	0.2	naphthenate drier
10% calcium drier	0.2	naphthenate drier
18% zirconium drier	0.2	naphthenate drier
Methyl ethyl ketoxime	0.1	blocked crosslinker
Rabo anti sag	0.4	clay filler
Binder (70% solids)		
Soya (fatty acids)	63.0	crosslinking agent
Palmitic acid	10.0	$CH_3(CH_2)_{14}COOH$
Stearic acid	3.0	$CH_3(CH_2)_{16}COOH$
Oleic acid	25-30	$CH_3(CH_2)_7CH=CH(CH_2)_7COOH$
Linoleic acid	50-55	$CH_3(CH_2)_4(CH=CHCH_2)_2(CH_2)_6COOH$
Linolenic acid	4-8	$CH_3(CH_2CH=CH)_3(CH_2)_7COOH$
Phthalic anhydride	23.0	binder A
Polyol[a]	14.0	binder B

(a) The actual polyol used was not identified by or available from The Sherwin-Williams Co.

RESULTS AND DISCUSSION

DSC Studies of the Alkyd Paint: The primary motivation for the drying oil investigation is displayed in *Figure* 1. These are DSC scans of an alkyd paint sample cured at 25°C with no exposure to SO_2 and another alkyd sample cured at 25°C but exposed to SO_2 at 700 torr for 24 hr prior to being placed in the DSC. The exothermic peak for the unexposed sample in *Figure* 1 can be associated with the autooxidative crosslinking reaction that occurs in the sample due to the presence of oxygen. Consequently, the absence of this peak in the sample exposed to SO_2 indicates that the reaction is not occurring during the DSC scan even though oxygen is present. Samples cured at 100°C displayed the same behavior, except that the exotherm was smaller. Samples cured at 150°C displayed no exothermic peak, indicating that the crosslinking reaction had been driven to completion during the oven cure. Second scans revealed no exotherms for all samples, indicating that the chemical reaction had gone to completion during the first scan.

The reduction in the magnitude of this exotherm can be attributed to SO_2 either promoting or preventing the crosslinking reaction. In either case, a reduction in the exotherm would be expected. Sol-gel analysis, however, showed that crosslinking is predominant, indicating that the reduction in the exotherm is due to the occurrence of crosslinking during exposure of the sample to SO_2 prior to placement in the DSC. These results have been reported previously.[1]

Previous studies on latex paints containing the same inorganic components as this alkyd paint showed no sign of chemical reaction with SO_2.[12] Consequently, we concentrated on the components of the Cargil 5070 organic binder, specifically, the unsaturated drying oils, including oleic, linoleic, and linolenic acid. These acids all consist of a straight chain of 18 carbon atoms with a carboxylic acid group at one end. They differ primarily in the number of double bonds they contain; oleic, linoleic, and linolenic acid having 1, 2, and 3 double bonds, respectively. Crosslinking of the paint film during drying occurs via an autooxidative chemical reaction, which takes place at the allylic hydrogens of the drying oils.[3-5] Linolenic acid has two doubly-activated allylic sites, whereas linoleic acid has one and oleic acid has none; therefore, we expect the reactivity of these compounds to decrease in the same order as well.

DSC Studies of Drying Oils: DSC experiments were conducted using the alkyd paint drying oils suspended in inert latex films to determine if the thermal behavior of the drying oils alone would be similar to the thermal behavior of the alkyd paint film. *Figure* 2 is a DSC plot of a sample containing approximately 20% by weight of linolenic acid in latex. Here a large exothermic peak is present for the sample which has had no exposure to SO_2. This peak can be attributed to the autooxidative reaction of the linolenic acid. Also shown is a sample that has been exposed to SO_2 at 700 torr for 24 hr prior to placement in the DSC. No exothermic peak is evident in this scan. This is the same behavior seen for the alkyd paint samples. *Figure* 3 is a DSC plot of pure latex with no drying oil dispersed in the sample. No exothermic peak is present, indicating that the latex binder does not react, and does not affect the thermal behavior of the linolenic acid.

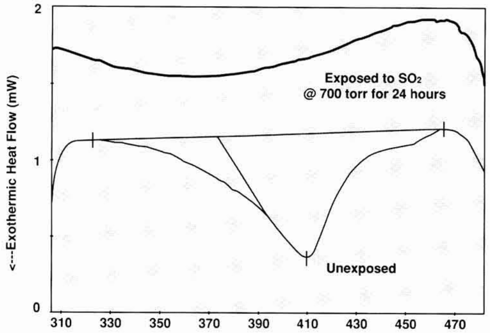

Figure 2—DSC plot of 20 wt% linolenic acid in the latex binder. Note the exothermic peak associated with autooxidation of the drying oil for the sample that has had no exposure to SO_2. The sample exposed to SO_2 at 700 torr for 24 hr displays no evidence of the autooxidation reaction

Table 2—Infrared Peak Assignments for Linolenic, Linoleic, and Oleic Acids

Peak #	Wavenumber, cm^{-1}	Structural Group
1	3012	allylic hydrogen
2	2928	asymmetric vibration of CH_2
3	2855	symmetrical vibration of CH_2
4	2500-3000	OH group vibration
5	1711	C=O group vibration
6	1463	CH_2 scissoring
7	1413	COOH dimeric
8	1284	COOH dimeric
9	936	COOH dimeric
10	721	=CH out of plane deformation (*cis*-configuration)

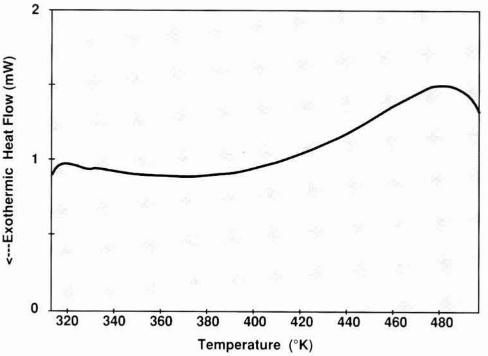

Figure 3—DSC plot of pure latex binder, showing that the latex does not react with SO_2 and has no other thermal transitions in this temperature range

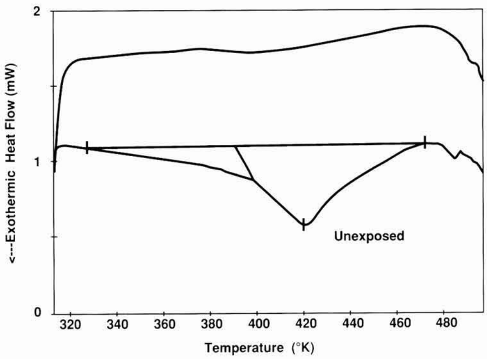

Figure 4—DSC plot of 20 wt% linoleic acid in the latex binder. Note the exothermic peak associated with autooxidation of the drying oil for the sample that has had no exposure to SO_2. The sample exposed to SO_2 at 700 torr for 24 hr displays no evidence of the autooxidation reaction

Figure 4 is a DSC plot for 20 wt% linoleic acid in latex with no exposure to SO_2 and linoleic acid exposed to SO_2 at 700 torr for 24 hr prior to the DSC experiment. The same behavior is obtained as previously described for the linolenic acid, except that the magnitude of the exotherm in *Figure* 4 is less than that seen in *Figure* 2. The reduction in the magnitude of the exotherm in *Figure* 4 is consistent with the fact that linoleic acid has only one doubly activated allylic site, as opposed to two for linolenic acid; consequently, linolenic acid has a higher reactivity.

The important information that can be gathered from the DSC experiments of the drying oil/latex samples is that the SO_2 is chemically reacting with the drying oils, and the normal autooxidative reaction is not observed when samples have had a previous exposure to SO_2. This behavior is exactly the same as that seen during the DSC studies of the alkyd paint. This provides a great deal of evidence supporting the SO_2/drying oil chemical reaction.

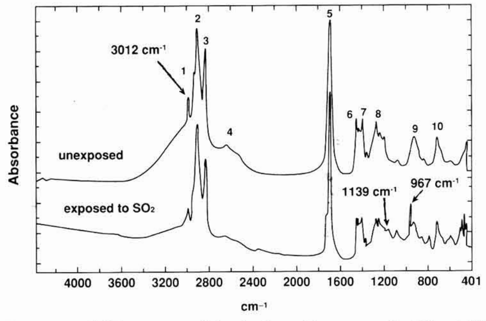

Figure 5—FTIR spectra of linolenic acid exposed to SO_2 at 150 torr and 80°C for one week, and linolenic acid with no exposure to SO_2. The new peak at 967 cm^{-1} results from the change from a *cis*- to a *trans*-structure due to the chemical reaction with SO_2. Also, note the reduction in the intensity of the allylic hydrogen peak at 3012 cm^{-1}, consistent with abstraction of these hydrogens during the chemical reaction. A complete list of the numbered peaks is given in *Table* 2

DSC studies of oleic acid displayed no noticeable exotherm for samples exposed or unexposed to SO_2 in the same manner as the other drying oils. This presumably occurs because oleic acid has no doubly activated allylic hydrogens and thus is less reactive.

FTIR Studies of Drying Oils: FTIR experiments were conducted with linolenic acid, linoleic acid, and oleic acid which were exposed to SO_2, air, or consecutive exposures to SO_2 and air. The FTIR studies were conducted for the purpose of elucidating the chemical structure of the crosslink site. In these studies the drying oils were not dispersed in latex, but were exposed to the experimental gases in their normal liquid state. All of the major peaks were assigned for the linolenic acid sample (*Figure* 5) and a complete list is given in *Table* 2.[13-17] Because linolenic, linoleic, and oleic acid only differ in structure by the number of double bonds along the carbon backbone, their infrared spectra are very similar, and *Table* 2 may also be used to identify peaks for linoleic and oleic acid.

Drying Oils Exposed to SO_2: *Figure* 5 contains the FTIR spectra for linolenic acid unexposed and exposed to SO_2 in the manner described previously. It should be noted that unexposed linolenic acid is a liquid, whereas the exposed sample is a dry film. A prominent feature in the exposed spectrum is a new peak at 967 cm^{-1}. This reveals several important pieces of information pertaining to the chemical reaction of SO_2 with linolenic acid. In their natural state, linolenic, linoleic, and oleic acid have *cis*-configuration about all of the double bonds in the molecule, which is characterized by a peak at 721 cm^{-1} in the infrared spectrum (peak #10 in *Figure* 5). During the autooxidation reaction at the allylic sites, the configuration changes to *trans*-, which produces a new infrared peak at 967 cm^{-1} and loss of intensity in the 721 cm^{-1} peak. These changes are precisely what we see after exposure to SO_2, suggesting that the SO_2 reaction occurs at the allylic carbon atoms as well. The 967 cm^{-1} peak also indicates that the double bond is still present after the reaction, and that the SO_2 does not react at the double bond.

Two additional subtle features also arise in the exposed sample spectrum. These include the decrease in intensity of the allylic hydrogen peak at 3012 cm^{-1}, and an indication of a weak new peak at 1139 cm^{-1}. The decrease in the allylic hydrogen peak is expected because the allylic hydrogens are being removed during the chemical reaction. The new peak at 1139 cm^{-1} has been assigned to the presence of a sulfone group which is what we would expect for a reaction forming sulfone crosslinks.[17] This peak is weak presumably because the crosslink density is low. It will be shown later that a much stronger sulfone peak results when linolenic acid is exposed to SO_2 and air, which increases the extent of reaction considerably.

Figure 6 is the FTIR spectra for linoleic acid exposed to SO_2 and linoleic acid which has had no exposure to SO_2 and is still a liquid. The same changes are observed as for linolenic acid. These same experiments were conducted for oleic acid; however, no changes in the FTIR spectra were observed due to the lower reactivity of oleic acid.

Table 3—Infrared Peak Assignments for Linolenic and Linoleic Acids Exposed to Air

Peak #	Wavenumber, cm^{-1}	Structural Group
1	3200-3600	-OH group vibration
2	2928	asymmetric CH_2
3	2855	symmetric CH_2
4	1733	new C=O vibration
5	1711	original C=O vibration
6	1550	C=C conjugated stretch
7	1460	CH_2 scissoring
8	1412	dimeric COOH
9	1173	C-O stretch (ester)
10	1090	C-O-O-C peroxide
11	972	disubstituted *trans*-C=C
12	724	=CH out of plane deformation (*trans*-configuration) and CH_2 in plane rocking

Table 4—Infrared Peak Assignments for Linolenic Acid Exposed to SO_2 and Air

Peak #	Wavenumber, cm^{-1}	Structural Group
1	3000-3600	OH group vibration
2	2928	asymmetric CH_2
3	2855	symmertic CH_2
4	1734	new C=O
5	1711	previous C=O
6	1540	C=C conjugated
7	1462	CH_2 scissoring
8	1413	dimeric COOH
9	1139	$-SO_2-$ symmetrical vibration
10	1022	S=O stretching
11	880	tertiary carbon
12	724	=CH out of plane deformation (*cis*-configuration)
13	666	sulfonic acid, S-O stretch

DRYING OILS EXPOSED TO AIR ONLY: *Figure* 7 contains an FTIR spectrum of linolenic acid exposed to air by the method described earlier. A complete list of peak assignments is given in *Table* 3.[16] Peak #1 is very broad and covers the range of 3200-3600 cm^{-1} and has been assigned to the vibration of the -OH group associated with the formation of hydroperoxides. Peak #4 at 1733 cm^{-1} is assigned to the carbonyl group in an ester, and is significantly more intense as compared with the unexposed sample in *Figure* 5. This suggests an increase in the number of ester groups for the air exposed sample, which is supported by peak #9 at 1173 cm^{-1}, which results from the ester C-O stretch. Peak #6 at 1550 cm^{-1} is important because it falls in the range usually associated with aromatic compounds, and has been assigned to conjugated carbon-carbon double bonds. Peak #10 occurs due to the presence of a peroxide. Finally, peak #11 at 972 cm^{-1} occurs due to the *trans*-configuration about the double bonds.

FTIR studies of linoleic acid exposed to air in the same way demonstrated essentially the same FTIR spectrum as that observed for linolenic acid. However, oleic acid did not show any evidence of a chemical reaction; this, again, can be attributed to its lower reactivity.

DRYING OILS EXPOSED TO SO_2 AND AIR: Linolenic acid was exposed to SO_2 and air by exposing the fatty acid to SO_2 only in a vacuum chamber. The dissolved SO_2 was then evacuated from the sample and the sample was removed from the vacuum chamber. After removal from the vacuum chamber, the linolenic acid was then smeared on a zinc selenide crystal and placed in an oven at 80°C in air until dry. The FTIR-ATR spectrum obtained for linolenic acid exposed in this way is compared with the sample exposed to air only in *Figure* 7. A complete list of the assigned peaks is given in *Table* 4.[16] Additional -OH absorbance is evident (peak #1) at 3000-3600 cm^{-1}, this could result from the presence of sulfonic acid groups, which is consistent with the reaction scheme presented in the following. Peaks 10 and 13 are also consistent with formation of a sulfonic acid structure. Peak #9 at 1139 cm^{-1} is characteristic of the sulfone group,[16] and is much stronger in this sample compared to the sample exposed to SO_2 alone (*Figure* 5). Peak #6 at 1540 cm^{-1} is from the conjugated double bond structure. Finally, peak #11 was difficult to assign; it falls around 880 cm^{-1}. This could correspond to a trisubstituted alkene, or it could result from the formation of a tertiary carbon atom resulting from 1:2 or 1:4 addition.[10] Based on the fact that the vinylic hydrogen is the most difficult hydrogen atom to abstract from an alkene, it would seem that the reaction at the allylic carbon would be favored.[18] However, it has been proposed that during the oxidation of drying oils, reactions at the double bond can occur.[5,11,19]

PROPOSED REACTION SCHEME: The data presented suggests the following reaction scheme, in which SO_2 is incor-

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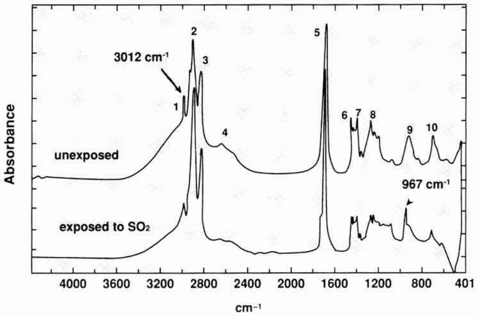


Figure 6—FTIR spectra of linolenic acid exposed to SO_2 at 150 torr and 80°C for one week, and linolenic acid with no exposure to SO_2. The new peak at 967 cm^{-1} results from the change from a *cis*- to a *trans*-structure due to the chemical reaction with SO_2. Also, note the reduction in the intensity of the allylic hydrogen peak at 3012 cm^{-1}, consistent with abstraction of these hydrogens during the chemical reaction. A complete list of the numbered peaks is given in *Table* 2

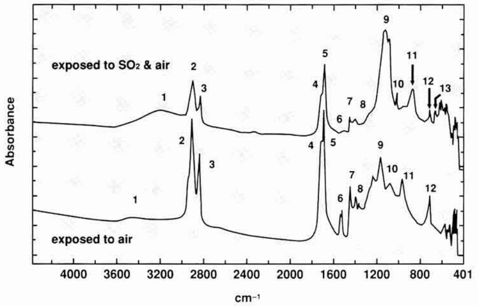
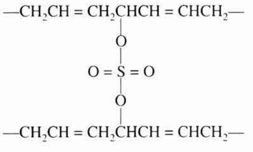


Figure 7—FTIR spectrum of linolenic acid dried in air at 80°C for one week, compared with the spectrum of linolenic acid exposed to SO_2 and air consecutively. Note that the allylic hydrogen peak at 3012 cm^{-1} has almost completely disappeared, and the large sulfone peak at 1139 cm^{-1} (#9 in the upper spectrum). A complete list of the numbered peaks is given in *Table* 3 for the lower spectrum, and in *Table* 4 for the upper spectrum

porated in the crosslinks as a sulfate ester. To do so, it must react with pre-existing hydroperoxide groups, as shown in the following:

$$\mathrm{R(R')\text{-}CH\text{-}OOH + SO_2 \longrightarrow R(R')\text{-}CH\text{-}OSO_3H}$$
$$\mathrm{R(R')\text{-}CH\text{-}OOH \longrightarrow R(R')\text{-}CH\text{-}O\bullet + \bullet OH}$$
$$\mathrm{R(R')\text{-}CH\text{-}OSO_3H + R(R')\text{-}CH\text{-}O\bullet \longrightarrow R(R')\text{-}CH\text{-}OSO_3\text{-}CH\text{-}R(R') + \bullet OH}$$

The hydroperoxide groups would be expected to be present in small concentrations due to incidental air exposure before the acids are exposed to SO_2. They would exist in larger concentrations when the acids are deliberately cured in air for an extended period. Note that a sulfonic acid is formed as an intermediate product, for which we have infrared evidence as discussed previously. The final structure of the crosslink would be:



$$\begin{array}{c}\mathrm{—CH_2CH = CH_2CHCH = CHCH_2—}\\ |\\ \mathrm{O}\\ |\\ \mathrm{O = S = O}\\ |\\ \mathrm{O}\\ |\\ \mathrm{—CH_2CH = CH_2CHCH = CHCH_2—}\end{array}$$

Another possible reaction could be copolymerization of SO_2 with the double bonds in the drying oils. Copolymerization of SO_2 with alkenes has been reported.[20-23] However, the presence of the peak at 967 cm^{-1} indicates that the double bond is still intact after exposure to SO_2. This information leads to the conclusion that the SO_2 forms a sulfate ester at the allylic carbons leaving the double bond intact.

CONCLUSIONS

DSC and FTIR experiments were conducted in order to determine the nature of the chemical reaction of SO_2 with drying oils present in alkyd paints. Specifically, linoleic, linolenic, and oleic acids were studied. DSC results showed that prior exposure of the drying oils to SO_2 suppresses the exotherm associated with the autooxidation reaction, just as it does with the formulated alkyd paint containing these oils. The reaction with SO_2 was most pronounced with linoleic and linolenic acids, which is consistent with the higher reactivity of these compounds. No reaction was observed with oleic acid under the conditions of these experiments. We attribute this to the lack of any doubly activated allylic hydrogen atoms, which significantly lowers the reactivity of oleic acid.

Thin films of linolenic and linoleic acid became solid when exposed to SO_2 alone. FTIR spectra of these samples showed a new peak at 967 cm^{-1}, which indicates a configurational change from *cis*- to *trans*-about the double bonds resulting from a substitution reaction at the allylic carbon. The peak at 3012 cm^{-1}, which is due to the allylic hydrogen, also decreases in intensity after exposure to SO_2, which is consistent with removal of this hydrogen during the reaction. No reaction could be discerned for SO_2 and oleic acid.

FTIR spectra of linoleic and linolenic acids exposed to air showed additional changes, including formation of peroxides, hydroperoxides, and double bond conjugation. The formation of these reaction products and the formation of the conjugated structure has been well-documented in the literature, and our results seem to agree with this information.[18-23]

FTIR spectra of the linoleic and linolenic acids exposed to SO_2 and then allowed to completely dry in air showed essentially the same reaction products as samples dried only in air. However, there were also new peaks which could be assigned to sulfonic acid structures and sulfate ester groups. It is believed that the sulfate ester group is present in the crosslinks between drying oil molecules. This structure is, of course, different from the crosslink structure that is obtained from the normal autooxidation reaction in the absence of SO_2.

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REVIEW ARTICLE

Cost-Effective Pigmentation in Alkyd Primers for Steel: Barrier Anti-Corrosion Mechanism

William C. Johnson
KTA-Tator, Inc.*

A major cost of alkyd primers for the protection of steel is the chemically active pigment. A low concentration of a pigment sufficient to just neutralize the acids that are formed during the drying process produces soaps and salts and eliminates chemically active acids and alkalis. Thus, barrier properties of the binder are secured. This reduces the raw material cost and increases the protection.

A review of collected literature on the chemistry of alkyd primers and on exposure studies provides an understanding of barrier protection as related to alkyd primers. Formulating practices for alkyd primers to obtain superior protection at low cost are explained.

INTRODUCTION

Definitions

Barrier Mechanism—A process for protection of steel from corrosion through "lowering the permeability to corrosive agents" and through "enhancing resistance to disbondment."[1]

Barrier Formulation (for alkyd and oil coatings)—Preparation which includes: (1) stoichiometric neutralization of acids produced during the cure to form soaps and salts having low solubility in water; and (2) minimizing the amount of water-soluble, water-sensitive, or chemically active materials in the cured coating.

Passivation—The formation or repair of metal oxides at defects of the natural oxide layer.[1]

Resistance to Disbondment—Resistance to creepback from a scribe is used to measure this.

Salts—Organic salts: azelate, suberate, formate, etc., are neutralization products. Inorganic salts: chlorides, sulfates, nitrates, etc., are contamination products.

Scission (acids)—Those acids that are formed during the drying process.

Stoichiometric—"In a broader sense it signifies the weight relations in chemical formulas and chemical equations."[2] [Because the chemistry of drying, neutralizing, and exposure are complex and variable, an exact stoichiometric amount (equal chemical equivalents of reactants, acid, and alkali) is difficult to identify. Nevertheless, it should be a formulating goal.]

Background

For a century, the principles of passivation by an "inhibitive" pigment was the prevalent theory. This belief for synthetic resin systems (vinyls, epoxies, etc.) was eroded in the late 1970s when inert (barrier) pigments were shown[3] to be superior. Barrier principles have now displaced the passivation theory for synthetic resin systems. Floyd[4] has reported superior performance with a barrier waterborne system. Funke[1] has stated "the future of corrosion by organic coatings more likely lies in developing the barrier principle." These advances in barrier technology with synthetic resins are applied to alkyd primers. Thus, as background for barrier formulation of alkyd primers, the following are explained: the chemistry of drying; the neutralizing of the scission acids (acids that are formed during the drying of linseed oil or alkyd resins); the solubility of the resulting soaps and salts; the determination of optimum concentrations by exposure studies; and barrier formulation principles.

The report is divided into two parts:

- Part I—Exposure results from four separate programs on alkyd primers formulated with low optimum concentrations of neutralizing pigment are reviewed.

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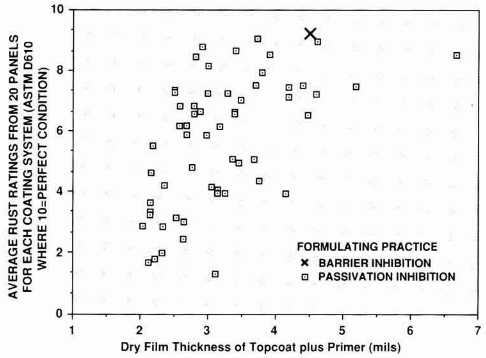


Figure 1—Corrosion protection vs film thickness for 30 month exposure

- Part II—Barrier chemistry, formulating principles, and cost savings are explained. (Mechanisms are compared in the Discussion section.)

PART I—COMPARATIVE EXPOSURE RESULTS

Part I is a review of four stages of development to include the exposure work regarding barrier protection from corrosion with alkyd primers. Johnson[5-7] developed the compositions and conducted two of the exposure studies. The other two exposure studies were comprehensive programs conducted by the Steel Structures Painting Council (SSPC) and reported by Keane,[3,8] Bruno,[9] and Appleman.[10] Johnson[11] analyzed lead pigment compositions for ratios of lead to linseed oil versus exposure results. They are reviewed in the following with respect to composition and its development and to exposure programs.

Earliest Alkyd Barrier Formulation

Compositions—Attention to the soaps and salts of the acids formed during the drying process (scission acids) prompted exposure studies. In 1958, Johnson[5] evaluated a primer composition having a low concentration of French process zinc oxide aimed at stoiciometrically neutralizing the acidic scission products to form beneficial soaps and salts. The zinc oxide was fine in particle size to facilitate neutralization by scission acids. The binder was 20/80 long oil alkyd/linseed oil. This early alkyd/oil primer was formulated for minimum sensitivity to water using barrier formulating principles. ASTM D 2448, "Water-Soluble Salts in Pigments by Measuring the Specific Resistance of the Leachate of the Pigment" was used for selecting pigments that were minimally contaminated with water-soluble salts. The equation for neutralizing scission acids (represented by azelaic acid) is as follows:

$$\overset{\text{zinc oxide}}{ZnO} + \overset{\text{azelaic acid}}{HOOC(CH_2)_7\,COOH} \text{—>} \overset{\text{zinc azelate}}{Zn[OCO(CH_2)_7COO]_2} + \overset{\text{water}}{H_2O}$$

An agent, a barium soap of fatty acids derived from lanolin (barium oleate), was added to sequester sulfate ions, a common contamination. The solubility product for barium sulfate is 1.08×10^{-10} at 25°C. The equation for sequestering sulfates is as follows (barium oleate is used to represent barium lanolate):

$$\overset{\text{barium oleate}}{3(C_{17}H_{33}COO)_2Ba} + \overset{\text{iron sulfate}}{Fe_2(SO_4)_3} + \overset{\text{zinc oxide}}{3ZnO} \text{—>} \overset{\text{barium sulfate}}{3BaSO_4} + \overset{\text{zinc oleate}}{3(C_{17}H_{33}COO)_2Zn} + \overset{\text{rust}}{Fe_20_3}$$

Lampblack was added to provide protection from UV light, and magnesium silicate was used as an extender.

The composition, with respect to zinc oxide and linseed oil, is expressed as a ratio of the units of zinc metal to 100 units of total linseed oil (limpid plus combined). Thus, the concentration in this barrier composition was 0.21 lb of zinc metal from French process zinc oxide per pound of linseed oil. Lead pigmented primers in this study, that were less protective, contained from 0.8 to 4.8 lb of lead metal as red lead or basic lead silico chromate per pound of linseed oil. The obvious raw material cost of these primers would have been from several to many times as much as the barrier formulation cost. Solid ingredients in the optimum composition were as follows:

Zinc oxide, French process	8.8%
Barium lanolate	3.0%
Magnesium silicate	44.7%
Lampblack	2.9%
Raw linseed oil	32.4%
Long oil alkyd resin solids	8.2%
Total	100.0%

Exposures—In the late 1950s, the early, barrier-formulated alkyd/oil primer was entered into the comprehensive exposure study,[8] "Painting of Hand-Cleaned Steel," conducted by SSPC. After 54 months, this early composition provided protection superior to the 60 other coatings, which included 26 red lead and chromate coatings. Ratings of all coatings plotted against film thickness are shown in *Figure* 1. Code 59 is at the top of the chart. The composite protective rating, an average for each coating, represented 20 hot-rolled steel specimens of various surface preparations and exposure sites.

Code 59, the primer having a low concentration of neutralizing pigment, offered outstanding protection and, since it is much lower in cost than the other coatings, it was the most cost effective. On the basis of success in this study, barrier principles were pursued in further studies and a specification[12] on this composition was adopted as Paint 26 by SSPC in 1982.

Zinc Oxide and Red Lead Concentration Ladders

To follow-up the successful results with the low concentration of the early primer, Johnson,[6,7] in 1970, began studies of neutralizing pigments in concentration ladders to search, empirically, for the necessary amount to provide optimum protection. Non-lead zinc oxide pigment was studied in one; red lead was studied in another.

From each ladder, the composition providing superior protection with a low concentration of the neutralizing pigment, red lead or zinc oxide, was entered into the comprehensive PACE[3,9,10] (Performance of Alternative Coatings in the Environment) exposure program conducted by SSPC.

ZINC OXIDE CONCENTRATION LADDER:

Compositions—Because the low concentration of 0.21 lb of zinc oxide per pound of linseed oil in Code 59 of the early study showed outstanding protection and was low in raw material cost (RMC), a ladder of zinc oxide was studied[6] to confirm or fine tune the earlier estimate for neutralizing pigment concentration.

In the zinc oxide study, concentration ladders were prepared in two binders, 50/50 and 33/67, alkyd/oil. Compositions were identical except that French process zinc oxide replaced talc at equal pigment volume. Primers were prepared at ratios of 0, 0.08, 0.15, 0.19, 0.23, 0.27, 0.54, and 1.08 pounds of Zn++ per pound of total linseed oil. Percentages of solid ingredients in the 0.27 ratio composition were as follows:

Zinc oxide, French process	10.4%
Red iron oxide	25.4%
Magnesium silicate	21.1%
Mica	7.1%
Raw linseed oil	18.0%
Long oil alkyd resin solids	18.0%
Total	100.0%

Exposures—Primers were applied to rusted panels of hot-rolled steel and to blast cleaned, 4 in. x 12 in. x $^3/8$ in. hot-rolled flat panels and exposed at a general industrial site.

Figure 2 is a redraft of exposure data which shows one curve from a figure in reference (6). It shows the curve of the results from the 50/50 alkyd/oil composition ladder exposed on blast cleaned panels. A peak for the optimum concentration range is evident. The 0.27 ratio was judged to be the optimum and was very low in cost. The 33/67 oil/alkyd compositions show a similar pattern. The two curves are shown together in reference (6).

A composition of a red oxide color with a 0.27 ratio of neutralizing pigment was entered into the SSPC PACE program where it was assigned Code 52. This composition was also adopted as Paint 25[12] by SSPC in 1982.

Another zinc oxide composition that used a straight medium oil alkyd was also entered. It was assigned Code 50 in the PACE program.

As shown in *Figure* 2, acidic scission products that are present below a ratio of about 0.27, are detrimental to protection of steel surfaces. They make an acidic environment and soften the film.

RED LEAD CONCENTRATION LADDER:

Compositions—Health concerns about lead-pigmented primers were being raised in 1970. Johnson[7] studied low concentrations of red lead in search of one that would be less hazardous. In this lead pigment study, concentrations of fine particle and coarse particle red lead were prepared in a ladder at 0.06, 0.23, 0.60, and 1.7 lb of Pb^{++} per pound of linseed oil. Percentages of solid ingredients in the optimum composition were as follows:

Red lead	8.5%
Red iron oxide	14.5%
Magnesium silicate	31.6%
Mica	4.7%
Bentone	0.3%
Raw linseed oil	20.2%
Long oil alkyd resin solids	20.2%
Total	100.0%

Exposures—In reference (7), curves for the fine and for the coarse particle size red lead were plotted. The curves have similar patterns and show an optimum concentration of 0.23 lb of lead per pound of linseed oil. Both optimums were very low in raw material cost. In *Figure* 3, the data was plotted for the fine particle size only. Fewer data points were obtained.

The optimum of the fine particle red lead ladder study was entered in the SSPC PACE 1 Exposure Program. Code 49 was assigned to this primer in PACE 1.

A specification on this composition was considered for adoption as Paint 28 by SSPC in 1982. It was ruled out because of the health hazard from lead pigments.

SSPC PACE Program 1

This SSPC comprehensive primer study covered lead and chromate-free pigmentations. It was conducted with the objective of developing substitutes for protective coatings that cause health, environmental, and safety problems. The project was aptly named, "Performance of Alternative Coatings in the Environment" (PACE 1, Branch A).

Compositions—Primers for 56 coating systems,[8] of which 45 were oil, alkyd/oil or alkyd systems, were obtained from the coatings industry. For the outdoor exposures, a total of 14 prerusted and new specimens of structural angles and flats in 4 in. x 12 in. size were prepared for each system. In 1978, specimens were exposed at severe industrial, mild industrial, marine seacoast, and urban sites. In addition, accelerated tests were run in salt fog, fresh, and salt water immersion.

Barrier inhibition was also tested in a faster drying medium oil alkyd (TT-R-266 Type III) primer. The control primer was Federal Specification TT-P-636, containing zinc yellow and zinc oxide. To formulate the experimental (x) primer, the zinc yellow was omitted from the TT-P-636 composition and replaced with extender. The American process zinc oxide was replaced with French process zinc oxide. The result was a barrier inhibition formulation having longer life. It was Code 50 in the PACE Program.

Code 49, Code 52, and Code 50, formulated in accordance with barrier principles, were compared with various

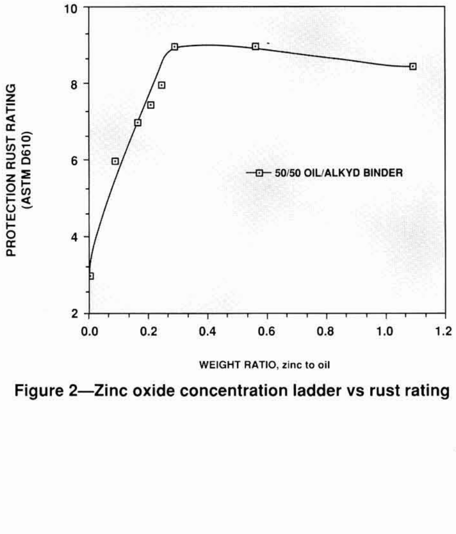


Figure 2—Zinc oxide concentration ladder vs rust rating

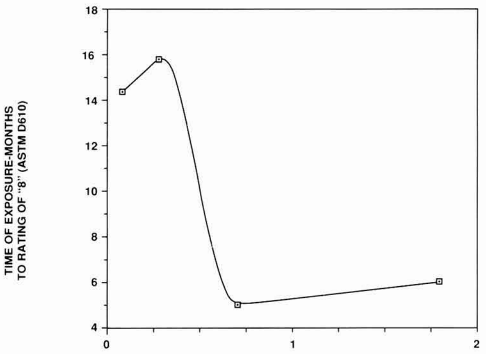


Figure 3—Protection time vs lead content

new and experimental and control primers. Compositions, comparisons, and 10-year results are listed in *Table* 1. *Table* 1 is divided into three sections:

- Section 1 covers comparisons of the red lead, barrier-formulated, 50/50 alkyd/oil primer, Code 49, with eight red lead, passivation-formulated controls.
- Section 2 covers a comparison of a zinc oxide, barrier-formulated, 50/50 alkyd/oil primer, Code 52, with a zinc yellow, passivation-formulated control.
- Section 3 covers a comparison of a medium oil alkyd, zinc oxide, barrier-formulated primer with a zinc yellow, passivation-formulated control.

Exposures—At the end of a year's exposure of the barrier primer (Code 49 of PACE), which was formulated with 0.23 lb of lead as red lead pigment per pound of oil, X-ray diffraction analysis of the bulk showed only amorphous lead and no lead oxides remaining. Results of analyzing the surface, like the bulk, showed only amorphous oxides and no lead oxides which indicated penetration of the X-rays through materials on the surface. Moreover, the analysis detected no sulfates or carbonates on the surface. This absence of red lead within the film and of sulfates or carbonates on the surface indicated that lead oxides had been consumed in the neutralization during the cure leaving amorphous lead compounds. Therefore, because lead compounds emit strongly in X-ray diffraction analysis, the finding of no lead oxide, lead sulfate, or lead carbonate being present was definite. On the other hand, X-ray diffraction analysis of a primer containing 0.60 lead as red lead per pound of oil showed a very strong presence of red lead in the bulk after exposure and showed dominating amounts of lead sulfate and lead carbonate on the surface.

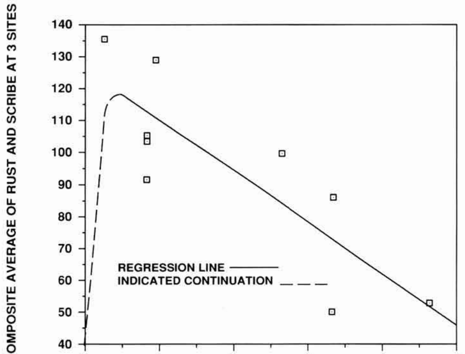


Figure 4—Ten-year performance rating vs lead

Results were reported by Keane[3] in 1979, by Bruno[9] in 1984, and by Appleman[10] in 1989. Data from the 10-year results listed in the 1989 report were studied. Johnson[11] compared results for the barrier formulated primers and relevant controls. The controls were government or SSPC specifications so compositions were known. He determined the ratios for active pigments to limpid and combined (total) linseed oil. These were plotted against protective life in reference (11). This data was replotted in *Figure* 4 where an optimum concentration is apparent. A dashed line represents data from the two ladder studies which showed a very sharp drop from the optimum to 0.

In 1989, after 10 years of exposure, a composite rating for each coating was obtained from six blast descaled panels for each primer. The rating for each system appears in column E of *Table* 1.

On the basis of outstanding protection from the primer containing the low concentration of red lead, Johnson[11] calculated ratios of neutralizing pigment to oil for red lead containing primers in the PACE program. He also compared ratios from empirically determined exposure optimums with a calculation of ratios from data by Merzbacher[13] in order to estimate potential agreement in stoichiometry between empirical values and values calculated from chemical data.

PART II—CHEMISTRY, FORMULATION, AND COSTS

Part II covers a review of the special chemistry involved, formulation practices, and cost savings of barrier drying oil primers. The formulation of barrier primers takes advantage of the unique chemistry of alkyd and drying oil which form acids during the cure. The exposure studies referenced in Part I confirmed that to aim for the stoichiometric neutralization of these acids by a pigment that produces insoluble soaps and salts is an essential formulating principle. To calculate the amount of neutralization pigment needed is difficult with the complex alkyd primer chemistry. However, the effort to obtain an empirical approximation of an optimum level is rewarding. Information on the electrolytic resistivity of saturated azelate salt solutions (and thus the insolubility which will provide longer corrosion protection) is given to guide the selection and concentration of the neutralizing pigment. Information is summarized on the barrier formulation details and costs.

Unique Chemistry of Alkyd and Drying Oil Cure

Interest in the chemistry of the cure of linseed oil was intense during the first half of the 20th century. The cure

Table 1—Compositions and 10-Year Results

Pace Code No.[a]	Specification[b]	Pigment[c]	#Cation/Oil[d]	1989 Rating[e]	F.T.[f]
Section 1—Alkyd/Oil Binder—Lead Pigments					
49	SSPC Ref. 7.11	Red lead	0.23	136	4.7
15	TT-P-615 Type I	BLSC (c)	0.80	104	4.3
54	SSPC Ref. 11	Red lead	0.90	130	4.6
3	TT-P-615 Type IV	BLSC (c)	0.80	106	4.0
14	SSPC Paint 1	Red lead	3.30	86	4.0
7	TT-P-86 Type II	Red lead	2.60	100	4.1
16	TT-P-615 Type II	BLSC (c)	0.80	92	3.7
10	SSPC Paint 2	Red lead	3.30	50	3.3
1	TT-P-86 Type I	Red lead	4.60	53	3.6
Section 2—Alkyd/Oil Binder—Zinc Oxide vs Zinc Chromate					
Zinc oxide primer—Barrier formulation					
52	SSPC Paint 25	Zinc oxide	0.27	136	4.7
Zinc yellow primer—Passivation formulation					
5	SSPC Paint 11	Zinc yellow	NA	100	4.2
Section 3—Medium Oil Alkyd Binder—Zinc Oxide vs Zinc Chromate					
Zinc oxide primer—Barrier formulation					
50	Paint X636X	Zinc oxide	0.27	116	4.3
Zinc yellow primer—Passivation formulation					
11	TT-P-636	Zinc yellow Zinc oxide	NA	100	4.2

(a) The original code from the exposure [ref. (3)].
(b) The Federal or SSPC specification number.
(c) The neutralizing pigment.
(d) The ratio of active cation to oil.
(e) *A composite rating in months for the 1989 (10 year) data(1) was determined by totaling the months to failure for* rust and scribe at the marine and the two industrial sites. The highest possible score was 136 which was only obtained by Code 49 and Code 52, barrier formulation primers.
(f) The Film Thickness: Thickness is given for the primer plus topcoat in mils.

begins when oxygen is absorbed at the double bonds of component fatty acids. In 1928, D'Ans[14] reported that a large quantity of oxygen, 11.5 moles, is absorbed by one mole of linseed oil.

RELEASED (SCISSION) FATTY ACIDS DURING THE CURE: In 1928, Merzbacher[13] determined the mono- and di-basic acids which were released during the oxidative decomposition (scission) of double bonds on the linseed oil fatty acids as well as the resulting acid number. He reported increases in acid number as linseed oil films aged to acid numbers of 73 after 60 days, and 191 after two years. This is very much more acid than the original fatty acids in oil and alkyd, which are controlled to an acid number of 10 or lower.

In curing for 60 days, each gram of linseed oil that developed an acid number of 73 would have produced 0.0013 g *equivalents of scission acids which, to be neutralized, would* have needed 0.0013 equivalents of cation. Likewise, in curing for two years, each gram of linseed oil that developed an acid number of 191 would have produced 0.0034 g equivalents of scission acids which, to be neutralized, would have needed 0.0034 equivalents of cation. When evaluating cations, a more convenient relationship for a formulator to use will be gram equivalents of cation per 100 g of linseed oil. A low value and a high value are 0.13 and 0.34, respectively. This ratio is used throughout the report.

The volume of film occupied by a scission acid number of 191 (or of the fatty zinc salts and zinc soaps) is estimated to be 10 to 15%. This relatively large volume of soaps is present even though the amount of cation required seems small.

DRYING/DEGRADATION CHEMISTRY: Elm[15] theorized that the oxidation drying reaction is the same as the degradation reaction that occurs after cure; however, the degradation reaction is very much slower than the drying reaction. After exposure for 12 years in direct sunlight in the PACE program, the low concentration of red lead obviously stabilized the coating compared to the normal fast degradation of red lead paints.

ALKYD: Hartshorn[16] reported that acids have formed when soya alkyds dry. He has also reported that other chemicals are released.

NEUTRALIZING CONCENTRATIONS OF ACIDS AND ALKALI—RATIOS: Concentrations of neutralizing pigments are conveniently expressed in a ratio of the cation to the limpid and combined linseed oils [see reference (11)]. They may be expressed either as the chemical equivalent of cation per 100 weights of component oil when different cations are being compared or as simple weight ratios of cation (or of pigment) to component oil when concentrations are being evaluated. Ratios for Merzbacher's acid numbers and empirical ratios determined from the primer compositions are shown in *Table* 2.

For the purpose of calculating ratios of alkaline pigments to scission acids, the chemistry of oxidation cure of double bonds in alkyd resins is assumed to give scission acids exactly as they occur in linseed oil. Long oil alkyds contain more double bonds on a weight of solids basis than medium oil alkyds contain. Linseed oil contains more than either alkyd.

SOLUBILITY DETERMINATIONS BY ELECTROLYTIC RESISTIVITY: Pursuing the scission acid idea, Mayne[17] selected azelaic acid (the predominant scission acid found by Merzbacher[13]). He prepared soaps and salts of these acids which would result from neutralization with basic pigments. From his evaluation of efficiency in protection from corrosion by the soaps and salts, he reported that lead azelate was many times as efficient as calcium azelate. His data showed that the threshold concentration for calcium azelate to protect from corrosion was 10 to 25 times as great as the threshold concentration for lead. This data indicated that not only was lead azelate more protective but that lead azelate was very insoluble. Mayne's[17] data indicated that insolubility of the azelate salt is related to resistance against corrosion.

On the basis of Mayne's data on insolubility, Johnson[18] undertook a project to determine the electrolytic resistance of saturated solutions (and thus the insolubility) of various azelate salts. Its purpose was to reveal the most promising cations for neutralizing. Accordingly, cations of the familiar pigments—lead, zinc, calcium, and barium—were selected for evaluation.

In preparing azelate salts from lead, zinc, barium, and calcium, Johnson[18] reacted the oxide or hydroxide of these elements in a solution of azelaic acid to form the salt. He then rinsed the precipitate in deionized water. Precipitate or cloudiness was noted as an indication of saturation. A resistance reading was taken and recorded. The resistivity was calculated.

ELECTRICAL RESISTIVITY READINGS: In *Table* 3, the resistivity of zinc azelate is next to lead azelate and seven times higher than calcium. At this time, zinc oxide is the only pigment with extensive background at a fine tuned concentration. At the present state of technology, zinc oxide is the obvious choice. Barium and calcium are relatively soluble and should not be used.

(Of incidental interest is the very high resistivity shown by nonleafing aluminum when Johnson[18] also included aluminum, iron, zirconium, magnesium, and chromium. Of these, he found that nonleafing aluminum formed an azelate salt which had a very high resistivity. This indicates that the barrier principle and the azelate salt could account for the superior protection that Hare[19] reported from an aluminum-pigmented alkyd primer.)

Formulating Principles and Practices

Formulating principles are explained thoroughly for the barrier composition of SSPC Paint 25 in reference (6). Only one alkyd/oil binder is covered by that reference whereas general principles for starting compositions using faster drying alkyds are presented in the following.

For long protective life, alkyds must be barrier formulated. Soluble materials must be excluded because they become a pathway to weaken barrier properties. Formulating principles to obtain barrier protection are as follows:

—French process zinc oxide pigment at 0.27 lb per pound of limpid plus combined linseed oil is incorporated.

—Ionic contaminants[20] are excluded from the composition in accordance with ASTM Standard D-2448, Water-Soluble Salts in Pigments by Measuring the Specific Resistance of the Leachate of the Pigment. A minimum resistance (maximum salt) at 5,000 ohms/cm was established for the composite pigmentation of SSPC Paint 25 based on measured levels for its development composition.

—Auxiliary pigments that are water resistant, lamellar[21] in shape, chemically inert, and/or minimally contaminated[5,20] are commonly selected.

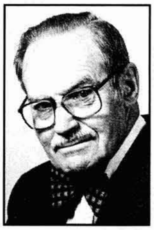
Savings in Cost with Barrier Formulation

With these technical reviews as a background, barrier formulating principles (particularly a low-concentration, neutralizing-pigment goal) of alkyd primers are itemized and cost comparisons are made.

Dollars will be saved by incorporating the optimum quantity of chemically active pigment into alkyd compositions. Any excess will shorten the protective life of the primer. The optimum quantity of zinc oxide (0.27 lb of zinc oxide per pound of linseed oil) was one pound per gallon of Paint 25. The cost of primers containing commercial chemically active pigments based on vendor recommended compositions are compared with the cost based on the zinc oxide composition primer given in the following:

—Barrier formulation, French process zinc oxide, one pound of pigment per gallon, SSPC Paint 25: Cost* of active pigment per gallon $0.70

—Passivation concept, commercial calcium pigment, five pound of pigment per gallon: Cost** of active calcium pigment per gallon $3.25



WILLIAM C. JOHNSON graduated from the University of North Dakota with the Bachelor of Science Degree in Chemical Engineering in 1941. He worked at the DuPont Marshall Laboratory in the Organic Coatings Department, at the Homer Research Laboratory of Bethlehem Steel Corporation, and at KTA-Tator, Inc., Protective Coating Consultants.

Mr. Johnson became interested in the subject of alkyd primers for steel in the late 1940s, and continued his studies through the years when time from regular work allowed. In 1970 he followed leads from the early studies with concentration ladders of red lead and zinc oxide in alkyd/oil binders. He was committee chairman for the Alkyd Branch of the PACE I (Performance of Alternative Coatings in the Environment) Project at the Steel Structures Painting Council. This paper is the culmination of this half-century of effort.

Table 2—Concentrations of Acid or Alkalinity

Source of Data	Ratios to Component Linseed Oil Weight[a]	 Gram Equivalent[b]
Merzbacher		
Acid number of scission acids for linseed oil		
After two months AN 73	NA	0.13
After two years AN 191	NA	0.34
Estimated from Oil Content		
For TT-R-266 Type I or Type II solids	NA	0.25
For TT-R-266 Type III solids	NA	0.17
Barrier Formulated Primers (See Part I)—Empirical Stoichiometric Values		
Code 59 SSPC Ref. 1	0.21	0.70
ZnO optimum code 52 SSPC PACE 1	0.27	0.83
Zinc oxide, medium oil alkyd code 50	0.21	0.70
Lead, optimum code 49 SSPC PACE 1	0.23	—
Pb++	NA	0.42
Pb+++	NA	0.28
Specification primers SSPC PACE 1		
Passivation formulation concentrations		
Basic silico lead chromate, range	0.75-0.81	NA
Red lead, linseed oil, range	0.93-4.65	NA
Red lead, alkyd oil, range	0.93-3.29	NA

Starting ratios for cations other than zinc oxide.

(a) The weight of neutralizing pigment consumed per weight of component linseed oil.

(b) The gram equivalents of neutralizing cation consumed per 100 grams of component linseed oil. In the case of the acid numbers it is the gram equivalents corresponding to the acid number.

—Passivation concept, commercial zinc pigment, five pounds of pigment per gallon: Cost** of active zinc pigment per gallon $7.00

DISCUSSION

The barrier mechanism for alkyd/oil binders involves the additional concept of aiming at stiochiometric neutralization of the scission acids. Mechanisms and neutralization are reviewed and discussed.

Funke[1] asserted, "barrier .... and passivation .... cannot be reconciled in the same coating layer." In other words, the formulating principles are diametrically opposed. Funke[21] affirmed that passivation .... needs water; on the other hand, barrier .... excludes water. Only one can be the true mechanism.

Mayne[22] referred to high electrolytic resistance as resistance "inhibition." In a review, Leidheiser[23] found papers that support this conclusion. The resistance mechanism is another approach to the barrier mechanism. The exposure studies reviewed for this report affirm that test fence and field experience with long protection from primers based on various cations correlates with high electrolytic resistance of saturated solutions of azelate salts.

Uhlig[24] noted that "For optimum (passivation) ...., concentration of the passivator must exceed a certain critical value. Below this concentration, passivators behave as active depolarizers and increase the corrosion rate at localized areas (pits)." Accordingly, scribes, damage areas, and pinholes in a coating are sites where moisture from rain, dew, condensation, etc., can leach or rinse away soluble passivator to reduce the concentration below critical values and cause corrosion as admonished by Uhlig. Funke[21] reported that a far-reaching action of the dissolved fraction of passivating pigment at a defect is not possible.

Cited exposure programs showed that low concentrations of neutralizing pigment in barrier compositions, characteristically provided superior resistance to creepback at a scribe. Floyd,[4] in his barrier-designed, waterborne system, reported no creepback from a scribe after 10,000 hr in salt fog. Funke[1] asserted that the barrier mechanism protects by "enhancing the resistance against water disbondment."

Conversely, passivation is explained[21,25] as needing water which dissolves passivator and permeates through the film to the steel/primer interface. Here, the solution in an electrochemical cell establishes or repairs an insoluble monomolecular layer on the metal. Unfortunately, a passivator that is one percent soluble in water would arrive at the primer/steel interface in solution along with 99% of water. This solution at the interface would displace primer from the steel resulting in weak wet-adhesion and undercorrosion at the scribe.

A monomolecular passivation-repair coating cannot be sufficiently stable on steel; especially under exposure variations of wetting/drying, freezing/thawing, flushing by rain, differing oxidation/reduction potentials, presence of holidays, or thick and thin coatings.

Water-soluble material will lower the vapor pressure, will provide pathways for water, and will draw water through the film.[20]

Neutralization

For alkyd primers, the major distinction between barrier formulation and passivation formulation is the stoichiometric-neutralization goal to obtain barrier properties. Chemical similarities are inherent in the fact that, in both of these formulation systems, the active pigment neutralizes the scission acids and indicates electrolytic passivation in a beaker test.

The stoichiometric concentration goal was met in the superior primers and was indicated by the following three results:

(1) The existence, in the concentration ladders, of optimum levels that coincide roughly with the estimation of the amount of alkali needed to just neutralize the acids formed.

(2) The X-ray diffraction of Code 49 in the PACE program, after one year of exposure, showed that the low concentration of red lead, the neutralizing pigment, had been

Table 3—Electrolytic Resistivity of Saturated Azelate Salt Solutions

Azelate	77°F Resistivity, ohms/cm at pH 6
Aluminum	57,000 to 81,000
Lead	11,000
Zinc	5,500
Barium	900
Calcium	700

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* The weight of active pigment that has been specified in SSPC Paint 25 for 14 years is one pound per gallon.

** Suppliers recommend five pounds per gallon.

consumed. In its absence, no credit for passivation can be directly assigned to red lead for the superior protection provided by this barrier composition.

(3) Code 49 also showed no visual surface chalk of lead sulfate and/or lead carbonate that normally forms on red lead primers. Moreover, the absence of sulfates and carbonates was confirmed by X-ray diffraction analysis. This evidence indicates that the red lead has been consumed. A primer, on the other hand, formulated with 0.60 lb of lead as red lead pigment per pound of oil, showed visible amounts of chalk. The chalking with the higher amount of red lead shows that amounts of red lead greater than the small quantity needed for optimum protection are not consumed.

Selection of the neutralization cation and its resulting azelate salt is important for formulation. Although the comparison between empirically determined equivalents of lead and of zinc indicates a wide range, it is still small compared to the differences between barrier formulated quantities and those for passivation. These differences for the lead and zinc ratios may be due to (1) a difference in scission products formed by drier action of the cation involved, (2) the formation of a lead acid azelate salt with some azelate acid groups remaining unreacted, or (3) a characteristic that Jacobsen[26] reported regarding the absorption of greater than equal neutralizing amounts of zinc molecules by fatty acids, or (4) being broader than actual which may be determined by fine tuning of the concentration. Calcium azelate and barium azelate are too soluble to formulate into barrier primers. Aluminum needs more development work.

After a report by Appleby[27] in 1967, describing protection using lead azelate, James foresaw a future for low concentrations and Mayne concurred.

Bruno,[9] in reporting results of the SSPC PACE exposure studies found zinc oxide to be "the leading candidate for replacement of lead and chromate pigments." SSPC adopted two zinc oxide specifications[12] aimed at stoichiometric neutralization.

Golden and Mayne[28] reported from tests in aqueous azelate solutions that zinc azelate provided both anodic and cathodic protection to mild steel. Potassium and magnesium azelates did not provide cathodic protection to mild steel.

CONCLUSIONS

A formulation goal to stoichiometrically neutralize the scission acids is a means for substantial enhancement of the corrosion resistance and the film properties of alkyd coatings.

Three to seven dollars in raw material costs can be saved by aiming for stoichiometric neutralization of the scission acids. Moreover, recent exposure results have established that barrier properties are the significant mechanism for protection of steel with alkyd primers.

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A Critique of the Taguchi Approach—Part II: An Alternative that is More Efficient

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Part I of this paper (JCT, March 1994, page 65) showed that the Taguchi approach to experimental design and analysis has some serious deficiencies. A more efficient and powerful approach, which is free of these defects, is presented in this paper and is illustrated by re-examining a paper which recently appeared in this Journal in which the Taguchi approach was employed.

INTRODUCTION

The Taguchi approach to experimentation has been used with increasing frequency in many industries in recent years in order to improve the quality and performance of a variety of products and processes.[1-3] Although it has resulted in various degrees of improvement in many areas in which it has been applied, alternative approaches have been demonstrated to be more beneficial.[4] In this era of increasingly intense competition, with our industries facing encroachments into their markets from firms around the globe, the use of the best available methods of operation by all the functional areas of a business is of paramount importance, if the owners and managers of an enterprise intend to not only survive but flourish in the new global market. The research and development (R&D) departments in the coatings industry can best contribute to the efficiency and profitability of their enterprise by using the most productive methods of experimentation.

The objective of this paper is to describe an approach to the design and analysis of experiments that is simpler, more efficient, and more powerful than the Taguchi approach. This method is illustrated by reanalyzing the results of a paper that appeared recently in this Journal in which the Taguchi approach was used.

RECOMMENDED ALTERNATIVE TO THE TAGUCHI APPROACH

Many statistical experts have high praise for Taguchi's emphasis in quality engineering on choosing the factor settings so the distribution of the quality characteristic of interest has the smallest possible variance around a target value. They think it is unwise, however, to combine location and dispersion effects in a single statistic as Taguchi does in his S/N statistics. They prefer to estimate the location and dispersion effects separately to gain insight into the behavior of the factors and then use this information to optimize the performance measure of interest. These experts recommend that the laudable engineering aims of Taguchi be achieved by using the following approach:[5-10]

(1) Use two-level fractional factorial designs with known alias structure in initial exploratory work instead of the more complicated and expensive three-level designs.

(2) Use simple, valid graphical techniques to identify which factors affect the mean level and which affect the variance.

(3) Use a sequential approach. Completion of the analysis of the first design usually results in increased understanding of the system under study. These results often suggest the subsequent direction in which to proceed to realize further gains and understanding.

TWO-LEVEL FRACTIONAL FACTORIALS

In the initial stage of industrial experimentation, it is often true that most of the process variation is due to just a few of the process variables or factors. Box and Meyer call this "factor sparsity."[11] In circumstances of factor sparsity, unreplicated fractional factorial designs have frequently been effective in detecting the "vital few" factors that account for the preponderance of the variation in the response data. Consider an experimenter who wishes to screen eight fac-

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Table 1—Taguchi Orthogonal Array L8[a]

Trial No.	1	2	3	4	5	6	7	$\overline{y}_k$	s_k
1	-	-	-	-	-	-	-	15.85	0.152
2	-	-	-	+	+	+	+	18.57	0.030
3	-	+	+	-	-	+	+	20.84	0.176
4	-	+	+	+	+	-	-	17.73	0.115
5	+	-	+	-	+	-	+	16.53	0.209
6	+	-	+	+	-	+	-	13.25	0.179
7	+	+	-	-	+	+	-	13.82	0.139
8	+	+	-	+	-	-	+	17.44	0.216

(a) The - and the + indicate the low and high level of each factor.

tors, believing that no more than three actually have an effect on the response of interest. He might choose a 1/16th fraction of a 2^8 design of resolution IV (a two-level design with 16 trials). This design avoids confounding main effects with two-factor interactions and provides a duplicated 2^3 factorial in any set of three of the factors.

As described in reference (4), the three-level designs advocated by Taguchi suffer from several deficiencies.

These designs confound main effects with two-factor interaction (2-fi's) effects; the analyst cannot separate the estimates of the factor main effects from the estimates of the 2-fi's. Taguchi recommends the three-level designs to allow the experimenter to examine possible quadratic effects while ignoring the estimation of interaction effects. However, George Box[12,13] pointed out that this is illogical if one is attempting to maximize or minimize a response, since the expression for such an extremum usually involves both quadratic (x_i^2) and product (x_ix_j) terms. For a given number of trials, there is generally a two-level design available that will have less confounding of factor main effects with 2-fi's than the three-level designs with the same number of runs. Two-level, resolution IV designs, for example, have no confounding of main effects with 2-fi's.[14]

The three-level designs also require more trials and so are more expensive to run than two-level designs. Taguchi recommends reducing the greater costs entailed by use of three-level designs by conducting the experiment in the split-plot mode. He suggests replicating only within-runs[4]; but, if the trials in an experiment are not genuinely replicated by complete randomization of the run order, then insignificant effects may well be declared significant.

Furthermore, Taguchi practitioners generally ignore the pattern of confounding (i.e., the alias structure) of their designs. Thus, they are often unaware that there are a number of alternative explanations of their experimental results and sometimes miss opportunities for realizing better results, which could be achieved by clarifying these ambiguities by further experimentation. This is illustrated by the authors of reference (1), who used the Taguchi approach to analyze the effects of variations in paint composition on hiding power.

GRAPHICAL ANALYSIS

The general goal of parameter design in Taguchi's strategy is to choose the settings of the design factors so the distribution of the quality characteristic has the smallest possible variance at the target value. This focuses our attention on the first two moments of the distribution of the quality characteristic. To clarify which factors have location effects (a change in response with a change in factor level) and which have dispersion effects (a change in the variance of the response with a change in factor level), it is necessary to separate the dependence of the latter on the former.[6,9]

If the treatments in an experiment are genuinely replicated, then a line plot displaying the sample mean of results at each factor level combination, a one-standard deviation about the mean, and all responses outside this central interval, shows immediately if there are differences in both mean and variance due to the different factor level combinations.[6] Another plot recommended by the same authors is a graph of $\ln \overline{y}_i$ versus $\ln s_i^2$ for each replicated treatment. This latter plot is designed to indicate the form of the dependence of the variance on the mean. These plots are illustrated below in the section on the alternative analysis of the experiment reported in reference (1). Reference (15) demonstrates other graphical methods that have been proposed to show which factors affect location and which affect dispersion.

The efficiency of analyses in terms of t or F statistics and analysis of variance (ANOVA) depends on how closely the data conform to the following assumptions: independently and normally distributed observations with constant error variance and expected values of the responses given by a model linear in a set of parameters θ. If these assumptions are not approximately satisfied by the original data, then a transformation of the observations may improve matters.

A graphical method of doing this is the lambda plot of Box and Cox.[9,16] If the original response values y_i are not (approximately) independent and normally distributed with constant error variance, then a non-linear transformation from y_i to y_i^γ, where λ is a parameter in the transformation, may help. For each value of lambda (λ), the t or F values of the location and the dispersion effects calculated from the transformed data are plotted versus λ. As the value of λ is changed, the t or F values of each effect describes a curve on the plot. By examining the resulting plots, we can identify a transformation (a value of λ) which gives the maximum number of effects with t or F values close to zero. In this metric, these effects are insignificant. One lambda plot may be made for the location effects and another for the dispersion effects from a design. In this way, we can determine a transformation which will produce as simple a model form as possible (one with the fewest significant effects) and which will remove as much transformable dependence be-

Table 2—Alias Pattern of L8 Design in *Table* 1

1 = -45 = -23 = -67
2 = -46 = -13 = -57
3 = -47 = -12 = -56
4 = -26 = -15 = -37
5 = -14 = -27 = -36
6 = -24 = -17 = -35
7 = -34 = -25 = -16

tween the mean and standard deviation as possible. In reference (9), Box illustrates these plots using an artificial example to demonstrate how they indicate the transformation that eliminates unnecessary complication in the model form and removes what he refers to as crosstalk between location and dispersion effects.

When an estimate of the experimental error variance is available from genuinely replicated runs from current or past experiments, ANOVA methods may be used to judge the reality or significance of estimated effects.

For unreplicated experiments, contrasts of higher-order interactions are often assumed to be insignificant and are pooled to produce an estimate of the error variance. This method can sometimes be inapplicable, because the required insignificant contrasts may be impossible to identify.[11]

A valuable graphical technique to use in identifying significant effects in unreplicated experiments was introduced by Daniel in 1959.[17] It does not require prior identification of insignificant effects. In this method, the absolute value of each effect is plotted on half-normal probability paper. Daniel subsequently came to prefer a full normal plot for this purpose, citing its greater ability to reveal violations of assumptions.[18]

In normal plotting, the empirical cumulative distribution of the estimated effects is plotted on normal probability paper. If the data in the experiment occur simply as random variation about some fixed mean and changes in the levels of the factors have no real effect on the response, then the effects should plot reasonably well as a straight line on the graph. This occurs because the effects in this case tend to be normally distributed about zero. (Each effect is a difference of two averages which contain different halves of the data and is exactly normally distributed if the data is normally distributed. If the data is not normally distributed, the effects will still be approximately normally distributed due to the central limit theorem in statistics.) An estimate of the standard error of the effects can be made from the plot by taking the difference of the abscissae of the points on the straight line on the graph which have probability values of 0.5000 and 0.8413, respectively.[18]

A half-normal probability graph may be prepared from a normal graph by deleting the probability scale with values below 0.500 and by renumbering the probability (P) values above 0.500 according to $P' = 2P - 100$. The abscissae are the absolute values of the effects. The ordinate of each effect is given by $P' = (i - 1/2)/n$, where i is the relative size or rank of the absolute value of an effect, and n is the number of factors. In a null experiment (i.e., no real effects), the effect points should plot on a reasonably straight line through the origin, and an estimate of the standard error of the effects is the absolute value of the effect whose value of P′ is most nearly 0.683.[17]

Those effects which do not fall on the straight lines on these two graphs are not readily explained as chance occurrences and are deemed "significant." The normal and half-normal plots are only useful in circumstances when a small proportion of the factors account for a large proportion of the response variation; these large effects may be called "active" effects, and the rest "inert." If a considerable proportion of the effects are active, then the estimate of the standard error from the remaining points which fall on a line will not be reliable, and an independent estimate of the error is necessary.[14,17]

When the active effects in an experiment have been identified, the next step is to attempt to identify which factors or factor interactions have given rise to the active effects. In fractionated designs, a particular effect may estimate an "alias string"—a combination of different factor main and interaction effects. The ambiguity presented by such alias strings requires further experimentation to resolve. Since unreplicated or partially replicated designs are frequently used in industrial experimentation in order to limit the number of trials which must be run (and thus to contain costs), it is evident that in such cases, a sequence of experiments and experimental designs will be required in order to obtain unambiguous results.[4,11,14] The results from the first experiment often suggest the subsequent direction in which to proceed to realize further gains and understanding. The first results might, for example, indicate that one of the following approaches should be explored[19]: (1) move to a new location because there appears to be a desirable trend in that direction; (2) one or more factors should be added or dropped; (3) addition of more design points to resolve some ambiguities in the first design; and (4) augmentation of the initial two-level design with "star" points to form a composite design in order to study possible curvature in the response. Such curvature is strongly indicated by the presence of large two-factor interactions. Large quadratic and/or two-factor effects occur in the neighborhood of a maximum or minimum in the response.[13,14] These possibilities illustrate the concept of the sequential assembly of designs.

SEQUENTIAL APPROACH

The results from any experiment depend upon careful planning and require judgment from the designers. They must decide which factors to study, the range over which the

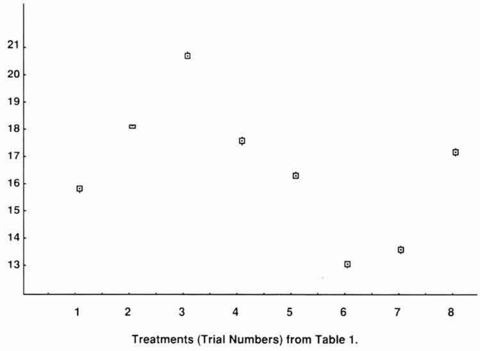


Figure 1—Line plot of data in *Table* 1

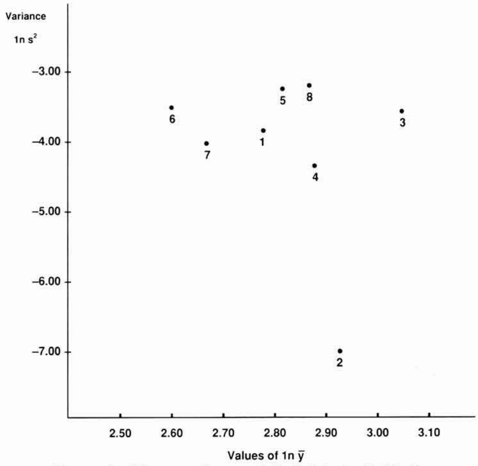


Figure 2—Mean-variance plot of data in *Table* 3

factors should be varied, the number of trials to conduct, how the response will be measured, the degree of fractionation to use, the design resolution desired, an appropriate alias pattern, and other related issues. At the beginning, we have the least knowledge about the system or process under study. Instead of attempting a one-shot experiment where we learn everything that could conceivably result in some improvement, we should employ an initial design, which requires fewer trials or runs, but provides clues [(1) and (4) in previous paragraph] which we may exploit.

When a number of factor effects have been identified as significant by either the normal (or half-normal) plot or by ANOVA, the estimates of the factor effects may be used to produce a least squares regression equation in which the regression coefficients are proportional to these factor effects, and the factor levels are the variables (see reference (14) and alternative analysis in this paper). This equation is the mathematical expression of a tentative model which purports to explain (hopefully) most of the variation observed in the response of interest. The differences between the values predicted by this equation at the various factor levels specified by the experimental design and the observed values are called the residuals. The adequacy of the assumed model may be checked by plotting these residuals on a normal probability graph. If the model is good approximation to the actual functional relationship between the various factors and the response, the insignificant factor effects are actually just random variation or noise, therefore, the residuals should reflect this by plotting on a reasonably straight line on the normal graph. The residuals may also be plotted in the order they were run to check for any time trend in the results and versus the predicted value to detect any dependence of the size of the residuals on the response level.[14]

There are also ways of checking for some specific types of lack of fit of first- and second-order polynomial models associated with certain frequently used designs. In the case of two-level factorial and fractional factorial designs of resolution III or more, the addition of a number of center points to the design permits a test for second-order curvature to be made by calculation of the contrast between the average response at the factorial points and the average response at the center points (this quantity estimates the sum of the quadratic coefficients). If this quantity is large relative to the absolute values of the estimated linear coefficients, the response surface has some curvature and a good estimate of it will require fitting of the full second-order model. Second-order designs appropriate for fitting an equation containing quadratic and second-order interaction terms are central composite designs consisting of a two-level factorial or fraction of resolution greater than four (referred to as the "cube") augmented by a "star" design with points on each predictor variable axis a distance $\pm \alpha$ from the center ($\alpha > 1$) and some replicated center points. Ways of checking for lack of fit of second-order models may be found in references (20) and (21).

These recommendations are an embodiment of the scientific method. The scientific method may be characterized as an iterative procedure in which each iteration involves the sequence of hypothesis formation, deduction of consequences implied by the hypothesis (i.e., predictions of the assumed model), and comparison of the predictions with experimental results (existing as well as new results). The checking of the predictions versus observations illuminates the inadequacies of the model assumptions, and refinement of the model in ways possibly indicated by the initial results will hopefully result in a better approximation of the behavior of the system under study. In the field of design of experiments in statistics, the scientific method takes the form of the sequential assembly of experimental designs, in which each iteration involves: (1) identification of the potentially applicable model; (2) estimation of the parameters of the assumed model; (3) checking of the fit of the estimated model to the response data by analysis of residuals; and (4) refinement of the model, if necessary, in a manner suggested by the lack of fit: i.e., back to step 1 in this sequence.[22]

ALTERNATIVE ANALYSIS OF EXPERIMENT IN REFERENCE (1)

The authors of reference (1) used an L8 Taguchi Orthogonal Array to study the effect of seven factors on the hiding powder of a coating. This design, shown in *Table* 1, is a 1/16th fraction of a 2^7 factorial. It is a design of resolution III,

Table 3—Data for Mean-Variance Plot

Trials	1	2	3	4	5	6	7	8
ln $\bar{y}_i$	2.76	2.92	3.03	2.87	2.81	2.58	2.63	2.86
ln s_i^2	-3.77	-7.01	-3.47	-4.33	-3.13	-3.44	-3.95	-3.06

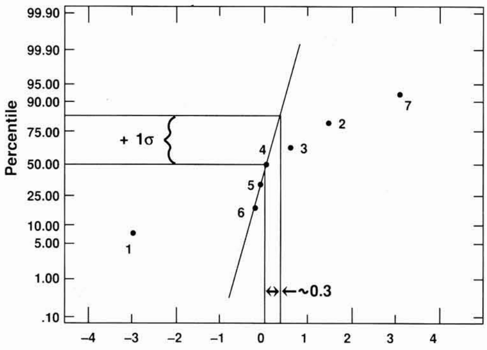
since the main effect of each factor is aliased with some two-factor interactions. This alias pattern is given in *Table* 2. Factors 1-7 were pigment content, dispersion space index (the ratio of vehicle solids volume to pigment volume), micronized extender content, dispersing agent content, calcium naphthenate content, rheological agent content, and toner content, respectively. Sixteen separate coatings were prepared, two at each of the eight different compositions dictated by the L8 design, and the hiding power was measured on two drawdowns from each, for a total of 32 hiding measurements. The 16 paint compositions were prepared in random order. ANOVA of the hiding measurements was conducted by the authors, and they found that all of the factors had a significant effect on the hiding power except for their factor 4 (see their *Table* 7, remarks column, and their Discussion section).

These results are ambiguous because of the alias pattern of the design shown in *Table* 2. This table shows that the main effect of factor 1 is confounded with the two-factor interactions of factors 2 and 3, 4 and 5, and 6 and 7. (If the factor columns are viewed as column vectors and denoted x_i where x_{ij} is the entry in row j of this vector and is +1 or -1, then the interaction of factors 2 and 3 is the vector with element $x_{2j}\ x_{3j}$ in row j, and inspection of the L8 design shows that the entry in each row of this vector is the negative of the entry in the same row of column one. The other aliases in *Table* 2 may be calculated in the same fashion.) Similarly, all the other main effects are aliased with a number of two-factor interactions. Because of this alias pattern, we could reach the following three different but (possibly) equally plausible conclusions concerning why the effects of all the factors but that of factor 4 were found to be significant: (1) factors 1, 2, and 7 and their respective two-factor interactions (2-fi's) 12, 17, and 27 are significant; (2) factors 1, 3, and 6 and their 2-fi's 13, 16, and 36 are significant; or perhaps (3) factors 1, 2, 5, and 6 and some of their 2-fi's are significant. Now, all of these alternative possibilities involve some 2-fi's, and, as previously indicated, the presence of large 2-fi's suggests some curvature in the hiding power data. The presence of curvature might indicate that we are in the neighborhood of a relative maximum in the hiding power in the PVC domain covered by the design points. This would seem to be worth investigating, and this could be accomplished by adding star points to the L8 design to form a composite design in a subsequent experiment.[13,14,20,21] The authors of reference (1) completely ignore the ambiguity caused by the alias pattern of the design they used. This tendency by Taguchi practitioners to ignore the alternative possible explanations of their experimental results has been pointed out by numerous experts in the statistics field. This is patently an unwise strategy, since in some experiments one of the ignored alternative possibilities will be a better approximation of the system under study, but will not be explored, and an opportunity for greater understanding and improvement will be missed.

The ambiguities caused by this confounding would have been less problematic if the authors of reference (1) had chosen a 16-run, resolution IV design instead of the L8 design. Such a design may be constructed from the L8 design in *Table* 1 by switching all the signs in *Table* 1 and adding the resulting runs to the runs in *Table* 1. This design does not

Table 4—Location Effects of Factors in *Table* 1

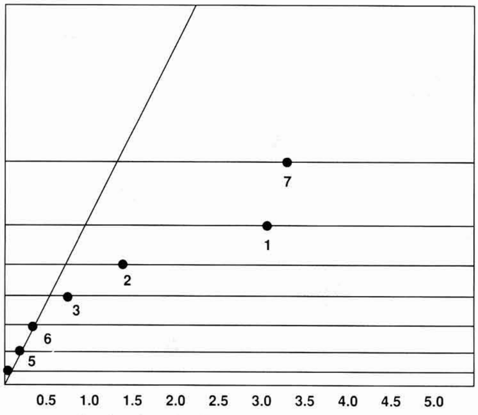
Factor	1	2	3	4	5	6	7
Effect	-2.99	1.41	0.67	-0.01	-0.18	-0.27	3.18



Location Effects (Line drawn by eye)
Figure 3—Normal probability plot

Table 5—Residuals from Equations (1) and (2)

1. -0.25	8. -0.11	13. 0.01	20. 0.13
2. -0.23	8. -0.11	14. 0.02	21. 0.14
3. -0.20	9. -0.10	14. 0.02	22. 0.16
4. -0.17	9. -0.10	15. 0.04	23. 0.17
4. -0.17	9. -0.10	16. 0.06	24. 0.20
5. -0.15	10. -0.04	17. 0.07	24. 0.20
6. -0.13	11. -0.02	18. 0.11	25. 0.21
7. -0.12	.12. -0.01	19. 0.12	26. 0.25



Absolute Location Effects (Line drawn by eye)
Figure 4—Half-normal probability plot

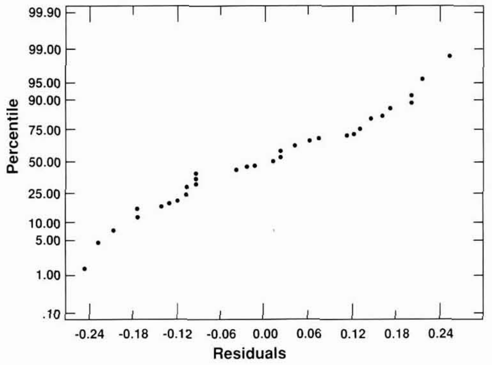


Figure 5—Normal probability plot of residuals

confound the seven main effects with each other or with 2-fi's, but the 2-fi's are confounded with each other. This design, like all resolution IV designs, has the further potentially useful property that, if only three of the factors happen to be significant, regardless of which three, then we may unambiguously estimate the main effects of these three factors and their three 2-fi's; i.e., it provides a twice-replicated 2^3 factorial in any three of the factors.[19,23,24]

The hiding power experiment in reference (1) was reanalyzed using the alternative methods described in this paper to illustrate some of the elements of this approach and to show how it indicates a direction to proceed in a subsequent experiment in order to more accurately characterize the factors that govern the hiding power.

The mean ($\bar{y}_k$) and standard deviation (s_k) of each trial are given in *Table* 1 and are plotted in *Figure* 1. The data for the mean-variance ($\ln \bar{y}_i$ vs $\ln s_i^2$) plot is given in *Table* 3 and plotted in *Figure* 2. It is clear from these plots that the variance is not a function of the mean and there are evident location effects. So, there is no need indicated to transform the data.

Table 6—Addition of Star Points to Design in *Table* 1

Factor	1	2	3	4	5	6	7
Runs							
9	0	0	0	0	0	0	0
10	2	0	0	0	0	0	0
11	-2	0	0	0	0	0	0
12	0	2	0	0	0	0	0
13	0	-2	0	0	0	0	0
14	0	0	2	0	0	0	0
15	0	0	-2	0	0	0	0
16	0	0	0	2	0	0	0
17	0	0	0	-2	0	0	0
18	0	0	0	0	2	0	0
19	0	0	0	0	-2	0	0
20	0	0	0	0	0	2	0
21	0	0	0	0	0	-2	0
23	0	0	0	0	0	0	2
24	0	0	0	0	0	0	-2

The location effects of the factors in *Table* 1 are given in *Table* 4, and the normal and half-normal plots of these effects are shown in *Figures* 3 and 4, respectively. (Either plot could be used alone; both are shown for the purpose of illustration.) These figures indicate that only the effects of factors 1, 2, and 7 are clearly significant, and perhaps that of factor 3 also. The standard deviation of these effects, estimated from the normal plot, is about 0.3. Since the error variance σ^2 is (N/4) times as large as the variance of the effects σ_e^2, where N is the total number of response measurements, then these plots indicate that the error variance is eight times the effect variance or 0.72. This is much larger than the error variance of 0.02 calculated in the ANOVA in reference (1). Since the authors of reference (1) randomized the order the paints were prepared, their calculated error variance incorporates both within-run and between-run variance. The normal and half-normal plots indicate an inflated error variance because the smallest three effects appear to fall on straight line on both plots. The fact that this is a circumstance when the plots clearly indicate the invalidity of the hypothesis of factor sparsity, and because the trials were genuinely replicated, indicates that the results of the ANOVA should be relied upon in this situation.

The least squares equation for hiding power (HP) as a function of all of the factors except for factor 4 is:

$$HP = 16.75 - 1.50X_1 + 0.71X_2 + 0.34X_3 - 0.09X_5 - 0.14X_6 + 1.59X_7 \quad (1)$$

where each X_j is the level of factor J, each coefficient is 1/2 the value of the corresponding effect, and 16.75 is the grand mean of all hiding power observations.[14] Because of the alias pattern of the L8 design, we may also write a least squares equation involving factors 1, 2, and 7 and their respective 2-fi's as follows:

$$HP = 16.75 - 1.50X_1 + 0.71X_2 + 1.59X_7 - 0.34X_{12} + 0.14X_{17} + 0.09X_{27} \quad (2)$$

where X_{ij} is the 2-fi of factors I and J. Note that the coefficient of X_{12} is the negative of that of X_3 in equation (1). From *Table* 2, it may be seen that factor 3 is confounded with the 2-fi of factors 1 and 2 (as well as with two other 2-fi's), and that the effect of the former is the negative of the effect of the latter; this accounts for the different signs of these factors.

Equations (1) and (2) predict exactly the same value at each factor level combination given in *Table* 1. The residuals (predicted value—actual hiding power) are given in order of magnitude in *Table* 5, and a normal probability plot of these residuals is given in *Figure* 5. There appears to be some deviation from linearity at both extremes of this plot; an observation that suggests some inadequacy in the model assumed to explain the hiding measurements. It is possible that the addition of some so-called star points to the design, as shown in *Table* 6, in order to permit the estimation of quadratic terms to include in equation 2, would provide a more adequate model. This possibility was not recognized by the authors of reference (1) because they, like many practitioners of Taguchi's approach, ignore the alias structure of the designs which are employed. In this case, the possibility that the compositions of the paints may be in the proximity of one possessing maximum hiding power was not recognized or explored.

CONCLUSIONS

The authors of reference (1) assert in their conclusion that their results show that Taguchi's strategy provides considerable economy of experimental effort, that its use could lead to better optimization of products and processes and to increased productivity of research laboratories, and that these attributes should encourage its wider application in coatings research. They also state that the use of this technique would bring about a "quantum increase in productivity" in R&D departments in the coatings industry. I would agree with these assertions, but I also believe that coatings researchers should use the most productive methods of experimentation available. Taguchi's methods have been demonstrated to be less efficient than other existing methods of design and analysis, and it is these more powerful methods which should be more widely used in the coatings industry.[4]

Vaidya and Natu[1] point out that Taguchi's technique yielded key information about the seven factors studied in just 16 experiments versus the 256 that would be required to examine all possible combinations of the seven factors (a 2^7 factorial experiment). Even though this statement is true, they go on to suggest in their conclusion that this major reduction in experimental effort was not possible before the introduction of Taguchi's methods, which is incorrect. Fractional factorial experiments have been conducted frequently in many industries for decades.[11,14,17,18,25]

As a final caveat about the use of Taguchi's methods and an authoritative opinion concerning the appropriate topics for courses in engineering statistics, consider the following excerpt from a recent review of Taguchi's books on experimental design by the eminent statistician Soren Bisgaard:[26] " . . . if Volume 1 (of Taguchi's book on experimental design) was to become a standard course in design of experiments we would be regressing to a standard that even books from the early 1940s would easily exceed . . . Much of the literature that has appeared over the past 40 years for dealing with a wide variety of engineering problems seems to have been ignored (by Taguchi). The median publishing date of all of the 41 references in Taguchi's book is 1955, and, stratifying into Japanese and non-Japanese references, the latter category includes 14 references with a median date of 1950 and with no references after 1957 . . . The (recent) excitement about the use of statistics in manufacturing and engineering design has shown a definite need for textbooks that are more easily accessible with more industrial and manufacturing examples, more use of graphics and exploratory data analysis, more adaptation to the computer revolution, less emphasis on hypothesis testing, no coin flipping, and above all, more emphasis on design of experiments, in particular two-level fractional factorial and response surface methods."

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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 1994 Roon Awards Committee, N. Bradford Brakke, Lilly Industries, Inc., 521 W. McCarthy St., Indianapolis, IN 46225. (For complete details, see "Roon Awards" section of the JOURNAL in the January 1994 issue.)

MANUSCRIPT PREPARATION

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 repititious 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 solicted. 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.

Abstracts

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.

Text

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.

Metric System

Metric system units should be used wherever applicable with the equivalent English units shown afterwords 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.

Tables, Graphs, and Drawings

Tables, rather than descriptive text, should be used only when they are genuinely helpful. They should be proportioned in accordance with the height and width limitations of the JOURNAL's pages. Each table should be typed on a separate sheet, rather than included in the text, and appended to the manuscript. Each table should be numbered and have a descriptive caption. Tables should be referenced in the text (e.g., "See *Table* 1").

In numerical data in tables, numbers less than one should have a zero before the decimal point.

Graphs should be on good quality white or nonphotographic blue-lined 8$^1/_2$ x 11 inch paper. Each graph should be drawn on a separate sheet, numbered, and the captions listed on a *copy* of the original graph. Graph captions and legends should also be typed on a separate sheet from original for typesetting.

Drawings should conform to the guidelines given for Graphs and should be proportioned to fit the height-to-width ratio of the JOURNAL's pages and columns.

Photographs

All photographs should be sharp, clear, black-and-white prints no larger than 8 x 10 inches in size. Photos should be clearly labeled on the reverse side, taking care not to mar the image.

Color prints and slides are unacceptable.

When illustrations are secured from an outside source, the source must be identified and the Editor assured that permission to reprint has been granted.

Nomenclature

Whenever possible, generic names should be used in preference to trade names. When trade names must be used to avoid ambiguity, and the name is a registered trademark, the symbol R, in a circle or parentheses, should be given immediately following, and the manufacturer listed as a footnote. In general, trade names should be used only in footnotes or in an appendix, rather than in the text.

If special nomenclature is used, include a nomenclature table giving definitions and dimensions for all terms.

Nomenclature of chemical compounds should conform to the style of *Chemical Abstracts* and the IUPAC rules. For oligomeric or polymeric materials, characteristics such as molecular weight, polydispersity, functional group content, etc. should be provided.

Equations

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.

Acknowledgment

If used, it should follow the summary.

References

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).

OTHER INFORMATION

Galley proofs will be sent to the author for checking about six weeks prior to publication.

Offprints may be purchased in quantities of 100 or more. Authors will receive price quotations. Each author will receive a complimentary copy of the JOURNAL issue in which his or her paper was published.

* * * *

Committee Activities

Federation Technical Advisory Committee and Society Technical Committee Chairmen Met Aug. 19-20, 1993, in San Diego, CA

Fourteen Society Technical Committee representatives met with members of the Federation's Technical Advisory Committee (TAC) on August 19-20, 1993, at the Sheraton Harbor Island Hotel, in San Diego, CA.

The meeting was called to order by TAC Chairman Gail Pollano (New England) with the following in attendance: Roland Staples (Birmingham), Kenneth Pendleton (CDIC), Phil Smith (Chicago), Ben J. Carlozzo (Cleveland), David Siller (Houston), Steve Bussjaeger (Kansas City), V.C. "Bud" Jenkins (Los Angeles), Rene Decary (Montreal), Frank Nejezchleba (New England), John W. Du (New York), William S. Hahn (Pacific Northwest), Neil R. Shearer (Philadelphia), Nellie Morentz (Piedmont), Walter R. Naughton, Jr. (Southern).

Technical Advisory Committee Members in attendance were: Robert Athey (Golden Gate), Edward Ferlauto (Northwestern), John Flack (Toronto), Richard Max (Chicago), and Rose Ryntz (Detroit).

John Lanning, FSCT President-Elect (Louisville), attended the meeting as a guest.

Also present was Michael G. Bell, FSCT Director of Educational Services.

Motivational Presentation

FSCT President-Elect John Lanning addressed the attendees on the status of activities of FSCT and his views on the Federation. He expressed how important the work of the Technical Committees is to both the Federation and the Societies and felt this was evident by the work of both the New York Society with its new video and the Chicago Society on the CD-ROM project. He said the goal is to have the Societies that stand out be used as an example for others.

Mr. Lanning added that meetings such as this help members improve their worth to the Societies and FSCT. He said the coatings industry is facing challenges and that only the strong will survive. Mr. Lanning pointed out that he strongly supports the work of the Committee and the Society Technical Committees and will work closely with them during his Presidency.

He discussed the activities between FSCT and NPCA and said the two would not be merging. Because of the many regulatory battles the Association has, FSCT has been willing to assist with a grant for the State Paint Councils. Mr. Lanning amplified the work that has been going in a cooperative fashion to allow both organizations to better serve the industry and cited the fact that NPCA has dropped its Technology Committee and is looking to combine several other committees. He stated that the two organizations will be meeting again soon to discuss the cooperative efforts of the two groups. (The New York Society added that the NYPCA representative comes to its Board Meeting every month.)

Mr. Lanning urged attendees to report the their individual Societies on their participation at this meeting and the benefits of attending.

Society Reports

Birmingham

The Birmingham Club was unable to start any new projects due to the fact that delays have prevented the completion of the existing projects. The projects underway include: solids density, VOC emissions, the Museum, and club records. Also, the Club is concerned with the dwindling number of paint companies in the United Kingdom. The total has been cut in half over the last 20 years.

CDIC

The CDIC Society's most recent project was the development of a list of extender pigments, their suppliers, and the characteristics of each pigment. The Society is looking for input from the members and outside sources regarding the value of such a listing. Another plan is to have a meeting of the Technical Directors of the various companies with members in CDIC. This meeting is tentatively schedule for October, perhaps preceding the regular monthly meeting.

Chicago

The Society's main project for the past few years, the *Panorama Coatings MSDS* on CD-ROM Retrieval System, was highlighted. Phil Smith was appointed Chairman, succeeding Darlene Brezinski, who was nominated for the position of FSCT Secretary-Treasurer.

Cleveland

The Cleveland Society will be presenting two papers at the 1993 Annual Meeting. The papers are entitled, "Clear Liquid Separation in Latex Paints Containing Cellulosic/Associative Thickener Systems, Part II" and "Accelerated Weathering/Exterior Exposure: A Study to Correlate Exterior Exposure Sites and Several Old and New Accelerated Test Methods." The Technical Committee also presented a program in conjunction with the Society's Educational Committee, "Advances in Coatings Technology." The committee will continue to work on the corrosion study in 1994 and will do an additional study on "Clear Liquid Separation."

Detroit

The Society will be presenting two papers at the 1993 Annual Meeting in Atlanta. The titles are: "The Effect of Siloxane Modification on the Physical Attributes of an Automotive Coating II: Studies on Interpenetrating Polymer Networks (IPNs) Based on Silicone Epoxy Resins and Urethane Acrylates" and "The Role of 'Odor Quantified' Solvents on the Viscosity of High-Solids Resins and the Physical Behavior of Formulated Paints." The Technical Committee is also planning future work on UV-curable coatings.

Golden Gate

The Golden Gate Society delivered a paper at the 1992 Annual Meeting on pencil hardness testing and will be delivering a paper at the 1993 event entitled "Coefficient of Friction Determination." The committee hopes to have additional information for the 1994 Annual Meeting on the same topic.

Houston

The Houston Society will be resubmitting its 1991 Annual Meeting paper, "Variable Characteristics of Titanium Dioxide Pigments Using SEM and Particle Size

Analysis—Part I," to the *Journal of Coatings Technology* with significant revisions. The committee is also working on Parts II and III of the study. These will cover long-term tests of all submitted hiding pigments in a vinyl acrylic water-based system and the exterior pigments in a high-solids urethane formulation. The fourth phase, evaluation of gloss pigments, will follow.

Kansas City

The Society is currently involved with four projects. These are: "Performance of Exterior Finishes on Medium Density Hardboard"; "Compliant Coatings: Artificial vs Natural"; "Performance of Extender Pigments in Exterior Latex Finishes"; and "Extractive Staining on Wood Substrates Induced by Finishes Containing Calcium Compound Extenders." The Society is also working on a major recruitment drive to increase the membership and is considering adding individuals from the ink industry.

Los Angeles

The Los Angeles Society presented a paper at the 1992 Annual Meeting entitled, "Color Standards—Wet, Dry or Spectrophotometric?" The Society is currently on the third printing of the "Graffiti Abatement and Prevention Handbook" and plans to distribute 1,000 copies of the book to mayors' offices throughout the country to help fight graffiti. The Society is also investigating the possibility of presenting another paper at a future Annual Meeting. The tentative title of the paper is "The Limit of Coatings Performance as VOC Approaches Zero."

Montreal

The Montreal Society has been involved in three projects in the last 12 months. These are: "New Method of Determining the Vehicle Demand of Organic Pigments" (with the Toronto Society), "Acid Rain Study" (with the Northwestern Society), and "Ultra Fine TiO_2 Study." The first project resulted in a paper presented at the 1992 Annual Meeting and the other two are currently underway with results expected shortly.

New England

A six-member Technical Committee has been formed by the Society and met on August 11. The committee began working on a project dealing with reproducibility of artificial weathering, with the goal being to check the reproducibility of weathering equipment at different sites. The New York Society has offered to help with this project.

New York

The New York Society will be delivering a technical paper at the 1993 Annual Meeting in Atlanta entitled, "Silicone Additives for High-Solids Coatings." The committee also prepared a 20-minute video entitled, "VOC Determination Errors—How to Avoid Them." The Society held a two-day symposium, "Recent Advances in Additives and Modifiers for Defoamers in Waterborne Systems, Color Computer Usage Survey, and Rheological Modifiers for High-Solids Coatings." The committee will be investigating more areas for work in 1994 and beyond.

Northwestern

The Northwestern Society Technical Committee will be presenting a paper a the 1993 Annual Meeting entitled, "Review of the Lead Abatement Issue in the United States." The committee has also been working on a project with the Montreal Society to measure the effect of acid rain on selected clear and pigmented coatings. A project to measure free formaldehyde and formaldehyde released on cure form coatings formulated with formaldehyde crosslinking agents is also being developed. This information will be available in the future for review and eventually for delivery at an Annual Meeting.

Pacific Northwest

The Pacific Northwest Society completed a booklet entitled, "Exterior Finishing of Wood Houses in the Pacific Northwest." The Society is giving one copy free to each company with members in the Society. Copies were distributed to all meeting attendees and they were encouraged to contact the Pacific Northwest Society if additional copies are needed. The books are available for a nominal fee.

Philadelphia

The Society has been working on two major projects for the last few years: defining the influence of the variables in determination of VOC in high-solids coatings using ASTM Test Method D 2369 and the Formulators Data Disc. The Committee is currently undertaking the task of correcting an error that was found in determining VOC in multi-component coatings with ASTM D 2369. The Formulators Data Disc reached critical mass in March and the Society has been investigating ways to distribute the information. The Society will survey the industry and determine its interest in this program at the FSCT 1993 Annual Meeting in Atlanta. Also, announcements have been made in *JCT*. The Technical Committee also holds a monthly meeting, in addition to the Society's regular meeting. The 1992-93 schedule included both speakers and trips to offsite locations for tours.

Piedmont

The main activity of the Society last year was a mini-technical symposium and exhibit trade fair in March. There were four technical presentations and the sessions were attended by 70 people. The exhibition had 33 exhibitors and over 200 attendees. The highlight of the event was the luncheon, sponsored by the Piedmont Paint and Coatings Association, which featured a talk on, "The Status and Future of the Coatings Industry."

Southern

The Southern Society is working on a project dealing with the yellowing of drywall coatings. The Society found a couple members willing to work on the projects but both have since left the paint industry. The Society will contact Rose Ryntz, of the Detroit Society, and The University of Southern Mississippi for information which might assist in the project.

Overview of TAC Activities

Reference Testing Update

Richard Max reported on the status of the Reference Testing program. He provided the participants with the history of the project and said the Technical Advisory Committee was considering a proposal to reinstitute the program. He encouraged the attendees to notify Ed Ferlauto, John Flack, or himself with any suggestions for the program. He said the subcommittee welcomed any information which will help make the program become a reality.

Lead Abatement Update

Ed Ferlauto reported on the activities related to lead abatement with which the TAC is currently involved. He said the work with ASTM is going well but he has not heard much from NIBS regarding its project. He will continue to provide information as it becomes available.

Developing Quality Slides for Technical Presentations

John Flack and Bob Athey reviewed a collection of slides to demonstrate the proper way for developing a quality slide presentation. Some of the suggestions for better slides were:

—Be certain as to the clarity of the slide and avoid distractions on the slide.

—Color determines how an audience reacts and certain colors perform better than others.

—Too much data is not good for a slide.

—How the data is presented makes a difference (graphs, type face, etc.).

—It is more valuable to the audience if you take the extra time to develop quality slides.

Society Meetings

BIRMINGHAM .... JAN.

"Epoxy Resins"

M.L. Robins, of CIBA Polymers, was the evening's guest speaker. His presentation was entitled, "EPOXY RESINS: PAST, PRESENT, AND FUTURE."

The speaker outlined the early discovery of epoxydation of olefins with peroxy acid by a Russian scientist in 1909. Through research in the 1930s and 1940s, solid epoxy resins became available; during the 1960s, liquid epoxy resins were obtainable.

Dr. Robins mentioned a survey conducted in 1991 showed that the world market for epoxy resins was 600,000 tons. Of this, 400,000 tons was involved in surface coatings and civil engineering applications. Approximately 12.5% of the market was used in powder coatings, 12% in can coatings, and 13% in maintenance and marine coatings.

Dr. Robins continued with an explanation of the basic chemistry of epoxy resin production and cure. In recent years, he said, improvements in the quality of bisphenol A and epichlorohydrin, together with continuous removal of sodium chloride during dehydrohalogenation and the use of more selective advancement catalysts, had produced better quality resins with better color, more consistent epoxy value, lower chloride and EHC contents, etc.

The speaker reviewed the advantages and disadvantages that epoxy resins provide in coatings systems. The advantages include: (1) addition reaction is involved in cure, hence no volatile released; (2) excellent adhesion; (3) low shrinkage on cure; and (4) good chemical and solvent resistance as well as good mechanical properties. The disadvantages are: (1) poor wettability (for bisphenol A aromatic backbone types); and (2) no elastomeric properties.

Dr. Robins stated that the epoxy/surface coatings market can be split in terms of hot cure (can, drum, coil, and automotive primer); cold/warm cure (structural, marine, and floor binders); and powder coatings (appliance, pipe, rebare, and automotive). He then detailed the future developments for these markets.

DAVID C. MORRIS, *Secretary*

BIRMINGHAM .... FEB.

"British Steel "

During the 497th meeting of the Club, the Federation awarded Merit Certificates to all members of the Club who helped produce the "Solids/Density Project."

Terry Goodwin, of British Steel, presented a talk on "BRITISH STEEL—MANAGING THE SUPPLIER INTERFACE, OR WHAT BRITISH STEEL EXPECTS OF ITS SUPPLIERS."

Dr. Goodwin began his talk by stating that his company purchases approximately 10 million liters of paint products per year. Since they are facing competition from Europe and the Far East, it is imperative for them to have a quality product. He stated that many paint suppliers are sometimes ignorant of the market forces on British Steel. Dr. Goodwin concluded by saying that there is a need for paint suppliers to have a better understanding of the quality and technical issue which the steel manufacturers face. He urged paint suppliers to collaborate long-term in producing new and improved coatings.

A heated question and answer session followed.

DAVID C. MORRIS, *Secretary*

CDIC .... FEB.

"Ethylene Vinyl Acetate Terpolymers"

Society President, Paul R. Guevin, Jr., of P.R. Guevin Associates, presented the results of a ballot on three proposed Society By-Laws amendments:

Proposal 1—"Establishing a delegate to the Ohio Paint Council"—Approved 58:1;

Proposal 2—"Establishing a Manufacturing Committee"—Approved 56:3; and

Proposal 3—"Limiting Officer-Terms of Associate Members"—Approved 44:15.

President Guevin announced that the Society's 75th Anniversary celebration will be held April 10, 1995, in Cincinnati, OH.

The evening's technical speaker was Bill Currie, of Nacan Products Ltd. His presentation was entitled, "ETHYLENE VINYL ACETATE TERPOLYMERS AND THEIR APPLICATIONS IN SOLVENT-FREE COATINGS."

Mr. Currie briefly reviewed the impetus and logic behind the drive for "solvent-free" latex coatings. He pointed out that, using current consumption figures and (arbitrarily) selecting a typical four percent cosolvent level, 125 million pounds of unnecessary VOC could be eliminated by solvent-free coatings.

The speaker presented the chemical composition of EVA terpolymers. They consist of (1) vinyl acetate—that contributes hydroplasticization; (2) ethylene—that causes softness without tackiness, and (3) acrylic—for added toughness.

Mr. Currie illustrated and discussed three formulations—a semi-gloss, eggshell, and flat of relatively increasing PVC.

He then went on to present a number of performance comparison results of the three illustrative formulas versus conventionally coalesced vinyl acrylic coatings, lab formulas using solvent-free acrylic and vinyl acrylic resins, and a commercially available solvent-free paint. Scrub resistance of the EVA terpolymers, stated Mr. Currie, was found at least equal to, or better, and was also shown to improve drastically with age—beyond seven days. The EVAs appear to be equal for dry adhesion and slightly better for wet adhesion; again, showing the tendency to improve on aging up to six weeks. The speaker acknowledged that block resistance is about equal to the vinyl acrylic; but less than the acrylic paints. The semi-gloss formula was also shown to have better gloss retention, after aging for three months, than its acrylic counterpart.

BIRMINGHAM CLUB OFFICERS (standing, from left): Martin Hailey, G. Bill Jenkins, J. Terry Baker, and Gerry J. Gough. Seated: David C. Morris, Garret C. Simmons, and D.A.A. Wallington

CDIC SOCIETY OFFICERS (from left): Alan L. Machek, William Jelf, III, Paul R. Guevin, Jr., John C. Avery, and Bill M. Hollifield

Mr. Currie concluded by stating that there is "much work left to do" in order to attain satisfactory zero-VOC paints. He said that solvent-free tinting systems need to be perfected and that rheology modifiers need to have cosolvents and residual monomers removed.

Q. Is this technology currently restricted to architectural vehicles?

A. Yes, strictly.

Q. Has work been restricted to interior applications?

A. For the most part, yes. Some work is now being directed toward exterior. QUV results indicate that exterior exposure results will approximate vinyl acrylics. Actual exposures have not been run as yet.

The evening's second speaker was David Weinschott, of the Hudson Institute, and he spoke on "HEALTH CARE REFORM IN AMERICA."

During his presentation, Dr. Weinschott addressed the following issues: (1) what is wrong with the current system; (2) what are the long-term questions and considerations; (3) the Clinton agenda; and (4) aternate agendas.

JOHN AVERY, *Secretary*

CDIC .... MAR.

"Ultrafine Titanium Dioxide"

The meeting began with a presentation by John Clayton, of Tioxide, on "ULTRAFINE TITANIUM DIOXIDE—ITS PROPERTIES AND APPLICATIONS IN COATINGS."

Mr. Clayton opened by defining ultrafine titanium dioxide (TiO_2) as either rutile and anatase with a crystal structure approximately 1/10th common pigment grades of TiO_2. By greatly reducing crystal structure, he stated, a product results with much different optical properties and UV absorption characteristics than is normally associated with TiO_2. Mr. Clayton added that it is these characteristics that suggest the application of the pigment in coatings.

Following a brief discussion of the preparation of the pigment and the resultant physical properties, Mr. Clayton then proceeded to detail applications of the pigment, namely in obtaining novel optical effects and its use as a UV absorber in clear and pigmented paints. The novel optical effects, obtained in conjunction with aluminum pigments in metallic coatings, were illustrated using slides. The speaker pointed out that most automotive manufacturers feature metallics based on these combinations. According to the speaker, the use of ultrafine TiO_2 as a UV absorber is suggested by the pigment's transparency, non-migratory nature, and that it is stable and chemically inert. Mr. Clayton mentioned that work is in process on a number of accelerated comparisons with other UV absorbers, with and without hindered amine lights stabilizers.

According to the speaker, there are limitations to the pigment. In particular, in clear varnishes, a slight haze can be determined at levels greater than 2% (on resin solids), and as with any pigment, dispersion is necessary. Mr. Clayton also noted that, originally, media mills were found necessary. However, full clarity has been achieved, using specific grades, with high-speed dispersion.

During the business portion of the meeting, Society Technical Committee Chairman Kenneth Pendleton, of K.A. Pendleton Co., Inc., reported on a meeting of Technical Directors to discuss ideas for future projects. He also discussed the Philadelphia Society's Formulator's Data Disk, and mentioned that Philadelphia might be interested in adding data on pigments collected from an earlier CDIC project.

Mr. Pendleton, also Environmental Committee Chairman, reported on a regulation that will no longer permit landfilling of picture tubes, computer monitors, etc., after May 8, 1994.

Scholarship Committee Chairman Andy Nogueira, of Hunting Industrial Coatings, announced that Jill Swint, of Akzo, is the recipient of the 1994 CDIC Society educational grant.

JOHN AVERY, *Secretary*

CHICAGO .... MAR.

"Hydrophobic Fumed Silica"

The meeting's technical presentation was given by Maria Nargiello, of Degussa Corp. She spoke on "IMPROVED RHEOLOGICAL AND SUSPENSION CHARACTERISTICS OF WATER-REDUCIBLE AND TWO-COMPONENT EPOXY-AMINE COATINGS WITH HYDROPHOBIC FUMED SILICAS."

Ms. Nargiello mentioned that this presentation is a combination of two studies on hydrophobic fumed silicas. The first study was an evaluation on the performances of different types of hydrophobic fumed silicas with different surface treatments, levels of hydrophobicity, surface areas, and pH against standard 200 M^c/g hydrophilic fumed silica in several water-reducible coatings. The speaker provided information on how to optimally use hydrophobic fumed silica, and practical suggestions for incorporation into water-based systems.

The second part of the study evaluated the performance of hydrophobic fumed silicas in filled and unfilled two-component epoxy amine systems. Ms. Nargiello compared pot life stability, suspension, and rheology behavior to standard hydrophilic fumed silica. Dispersion and incorporation procedures were also discussed by the speaker.

VICTOR M. WILLIS, *Publicity*

GOLDEN GATE .... MAR.

"Aqueous Polyurethane Dispersions"

Past-President and long-time member of the Golden Gate Society, Louie Sanguinetti, was unanimously elected to Society Honorary Membership. Society President Dennis Owen, of Technical Coatings Co. presented him with a commemorative plaque.

Educational Committee Chairman Jack Duis, of Pacific Coast Chemicals, reported on the Basic Polymers and Coatings Course scheduled for June 21, at Cal Poly.

Tim Simpson, Second Vice President of the Golden Gate Paint and Coatings Association, announced that the joint meeting between the Golden Gate Society and GGPCA will be held July 27, during a San Francisco Giants-Los Angeles Dodgers baseball game.

"AQUEOUS POLYURETHANE DISPERSIONS FOR COATINGS AND INKS," was the technical presentation by Charles Shearer, of ZENECA Resins.

Mr. Shearer began his talk by stating that polyurethane dispersions are becoming an increasingly important class of materials in the surface coating industry. Because of the synthetic procedure employed in the preparation of aqueous polyurethanes, he added, they differ significantly from typical emulsion polymers in terms of colloid stability characteristics and particle morphology. Mr. Shearer noted that spectroscopy techniques have demonstrated that the particles in a polyurethane dispersion are swollen with water. The consequences of the morphology, he said, lead to interesting application properties. Mr. Shearer concluded by emphasizing that the particle size distribution of aqueous polyurethanes was found to be broader than that of typical emulsion polymers.

Eve Stromquist, *Secretary*

NEW YORK .... JAN.

"High Performance Thickener"

Technical Committee Chairman Shiela Westerveld, of Standard Coating Corp., reported to the membership that the Society's defoamer project is being restructured and redirected. Those wishing to join the committee were invited to contact the chairman.

Ms. Westerveld presented Certificates of Merit to the following members of the Technical Committee for their outstanding contributions: Larry Waelde, of Troy Chemical Co.; John Du, of Hüls America; Jerry Willner, of D/L Laboratories; and Emil Vyskocil, of Eastech Chemical Inc.

It was announced that the "Rheological Modifier Study," chaired by Rudy Berndlmaier, of King Industries, is still in progress.

The meeting's technical speaker was David Bryant, of RHEOX Inc. His presentation was entitled, "Novel High Performance Thickener."

Through the use of slides and graphics, Mr. Bryant explained that in a typical profile of a coating, viscosity is usually measured against some other force. The particular example used in this study, he said, was the viscosity of a coating measured against shear rate. As the shear rate was increased, certain effects on the viscosity were noticed. The coatings evaluated were pseudoplastic coatings, and they did not change much when the shear rate was increased. Mr. Bryant said the shear rates were usually due to either mixing or application; high shear rates are usually due to higher applications, and low shear rates were due to the force of gravity, e.g., as the coating sits in a can. The speaker stated that the application properties of the two coatings should be very different. It is important to know how a coating thins out as shear is applied.

Mr. Bryant described the various types of instruments used to check viscosity.

In conclusion, the speaker discussed the makeup of associative thickeners. The low polymer products have the carboxyl-silica groups attached and are in a coiled situation. Mr. Bryant emphasized that once they are incorporated, they need to be neutralized to a pH of about 9. At this point, the long polymer straightens out and chain entanglements develop. The speaker pointed

Constituent Society Meetings and Secretaries

BALTIMORE (Third Thursday—Martin's West, Baltimore, MD). Albert Holder, U.S. Navy, David Taylor Research Ctr., Code 2841, Annapolis, MD 21402-5067.

BIRMINGHAM (First Thursday—Strathallan Hotel, Birmingham, England). P. Hassall, Newtown Industrial Paints Ltd., Silica Rd., Amington Ind. Est., Tamworth, Staffs. B77 4DT, England.

CDIC (Second Monday—Location alternates between Columbus, Cincinnati, Dayton, and Indianapolis). John C. Avery, Cintech Industrial Coatings, Inc., 2217 Langdon Farm Rd., Cincinnati, OH 45237-4792 .

CHICAGO (First Monday—Sharko's Restaurant, Villa Park, IL). C. David Stromberg, Standard T Chemical, 290 E. Joe Orr Rd., Chicago, IL 60633.

CLEVELAND (Third Tuesday—Brown Derby, Independence, OH). Michael A. Wolfe, Seegott Inc., 5400 Naiman Pkwy., Solon, OH 44139.

DALLAS (Second Thursday following first Wednesday—Radisson Hotel, Dallas, TX). Paul Kaplan, Cookson Pigments, Inc., 2001 San Miguel Dr., Plano, TX 75704.

DETROIT (Second Tuesday—meeting sites vary). Tedd L. Strobehn, Boehle Chemical Inc., 19306 W. 10 Mile Rd., Southfield, MI 48037.

GOLDEN GATE (Monday before third Wednesday—alternates between Francesco's in Oakland, CA, and Holiday Inn in S. San Franscisco). Eve Stromquist, Flecto Corp., 100 45th St., Oakland, CA 94608.

HOUSTON (Second Wednesday—Houston Medallion Hotel, Houston, TX). Edward E. Boss, Bossco Industries, Inc., P.O. Box 680023, Houston, TX 77268-0023.

KANSAS CITY (Second Thursday—Cascone's Restaurant, Kansas City, MO). William T. Porter, Hillyard Industries, Inc., P.O. Box 909, St. Joseph, MO 64502.

LOS ANGELES (Second Wednesday—Steven's Steakhouse, City of Commerce, CA). Robert J. Skarvan, McWhorter Inc., 5501 E. Slauson Ave., Los Angeles, CA 90040.

LOUISVILLE (Third Wednesday—Executive West Motor Hotel, Louisville, KY). Andrew Traister, Courtaulds Coatings, Inc., 400 S. 13th St., Louisville, KY 40201.

MEXICO (Every fifteen days—Gabriel Mancera, Mexico City, Mexico). Sergio Rojas, Pinturas International, S.A. De C.V., Ganaderos 234, Col. Granjas Esmeralda, 09810 Mexico, D.F., Mexico.

MONTREAL (First Wednesday—Le Bifthèque Steakhouse, Ville St. Laurent, Quebec). Esther Rouleau McCarthy, Stochem Inc., 1455 32nd Ave., Lachine, Que. H8T 3J1, Canada.

NEW ENGLAND (Third Thursday—Sheraton Lexington Hotel, Lexington, MA, and other locations in Massachusetts and Rhode Island). Charles Shearer, ZENECA Resins, 730 Main St., Wilmington, MA 01887.

NEW YORK (Second Tuesday—Landmark II, East Rutherford, NJ). Cary Grobstein, Cardinal Color & Chemical, Inc., 50-56 First Ave., Paterson, NJ 07524.

NORTHWESTERN (Tuesday following frist Monday—Jax Cafe, Minneapolis, MN). Harold H. Christhilf, The Valspar Corp., P.O. Box 1461, Minneapolis, MN 55440.

PACIFIC NORTHWEST (Portland Section—Tuesday before third Wednesday—Rose's, Portland, OR; Puget Sound Section—Third Wednesday—Barnaby's, Tukwila, WA; Vancouver Section—Thursday after third Wednesday—Delphi Steak & Pizza, Vancouver). Richard C. Tomczak, Specialty Polymers, Inc., 17316 E. Riverside Pl., Bothell, WA 98011.

PHILADELPHIA (Second Thursday—Williamson's Restaurant, GSB Bldg., Bala Cynwyd, PA). Howard Salmon, Akzo Coatings, Inc. 100 Belmont Dr., Somerset, NJ 08873.

PIEDMONT (Third Wednesday—Ramada Inn Airport, Greensboro, NC). Bob Bishop, Ashland Chemical Co., P.O. Box 19959, Greensboro, NC 27419.

PITTSBURGH (Second Monday—Montemurro's Restaurant, Sharpsburg, PA). W. Ray Lyman, Jr, Ray Lyman & Co. 3462 Hills Church Rd., Export, PA 15632.

ROCKY MOUNTAIN (Monday following first Wednesday—Zangs Brewery, Denver, CO). Paul Delmonico, Old Western Paint Co., Inc., 2001 W. Barberry Pl., Denver, CO 80204.

ST. LOUIS (Third Tuesday—Salad Bowl Cafeteria, St. Louis, MO). James Lindsley, Akzo Resins, 2904 Missouri Ave., E. St. Louis, IL 62205.

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). Robert Wayne West, Thompson & Formby, Inc., 10136 Magnolia Dr., P.O. Box 667, Olive Branch, MS 38117.

TORONTO (Second Monday—Cambridge Motor Hotel, Toronto). Kevin Pelling, Inortech Chimie Inc., 4135 LaStrada Hts., Mississauga, Ontario L5C 3V1, Canada.

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

out that a hydrophobic head and a hydrophilic tail will yield various properties depending on the length of each. Mr. Bryant showed a schematic of some of the thickening mechanisms.

Q. The viscosity study shows a one-month stability study, what would the viscosity be after three months?

A. The viscosity would hold basically the same with no measurable difference, but would be very system-dependent.

CARY GROBSTEIN, *Secretary*

PACIFIC NORTHWEST PORTLAND SECTION ....OCT.

HM 181

Environmental Committee Chairman Roald Berg, of Associated Chemists, updated members on the changes to HM 181.

It was announced that the Educational Committee is fine-tuning its February seminar. The committee is also searching for ideas for carrier day at local colleges.

By-Laws Committee Chairman Steve Rearden, of Imperial Paint Co., recommended changing the Section's By-laws regarding membership classes. He proposed changing the membership to only one class. The action, which was voted on and approved, will now go to a second vote.

KEN WENZEL, *Section Secretary*

PACIFIC NORTHWEST PORTLAND SECTION ....NOV.

Paint Class at Cal Poly

Scholarship Committee Chairman John Daller, of Miller Paint Co., reported that the Committee has decided to open the paint class at Cal Poly to members or offspring of members working in the field of paint. It was also mentioned that the Portland Section will send two people to a four-day class and the Society will cover tuition and lodging. Mr. Daller noted that the recipients will supply their own travel expenses.

By-Laws Committee Chairman Steve Rearden, of Imperial Paint Co., announced the second reading of the proposed change to the By-laws regarding membership classes. The By-laws change to have only one class of membership was voted on and passed unanimously.

KEN WENZEL, *Section Secretary*

PHILADELPHIA ....NOV.

"Organic Pigments"

Technical Committee Chairman Neil Shearer, of the 3E Group, reminded the members that the Technical Committee meets the first Thursday of the month and encouraged everyone to attend. Mr. Shearer solicited suggestions for a topic for the Society's annual technical seminar to be held this spring. He also mentioned that the VOC Committee is working on an experimental design for variables in the test method for VOC.

Subcommittee Chairman, Thomas Brown, of Consultants Consortium, reported on the introduction of the Formulators Data Disk (FDD) at the Federation's 1994 Paint Industries' Show. He said that the Society received over 200 inquiries and a survey was conducted that showed most respondents were in favor of the FDD and that this product will aid the coatings industry.

Ted Vernardakis, of Sun Chemical Corp., gave the evening's technical presentation entitled, "DISPERSION OF ORGANIC PIGMENTS."

Dr. Vernardakis began his presentation with a general discussion of how dispersion of pigments, both organic and inorganic, can be achieved. He described how pigment agglomerates and aggregates are broken down to the correct particle size to achieve the desired properties. Mr. Vernardakis emphasized that dispersion, as well as stabilization of the dispersed pigment particles, is very important. Without stabilizing the pigment, there is no dispersion. As the particle size decreases, said the speaker, the color strength and the gloss increase, but unfortunately the rheology increases.

Examples of how pigments are surface treated to improve their dispersibility were presented by Dr. Vernardakis. The surface characteristics of the pigment particles are changed by using surfactants, amines, acidic compounds, and polymeric species. According to the speaker, the wetting properties of the pigment surface are changed to ease dispersion and prevent reagglomeration.

In conclusion, Dr. Vernardakis covered various general classes of pigments by showing micrographs and schematic representations of surface treatments to illustrate his points.

HOWARD J. SALMON, *Secretary*

PHILADELPHIA ....DEC.

"Formaldehyde in Coatings"

The meeting's technical speaker was Rudi Moerck, of Troy Chemical, who spoke on "FORMALDEHYDE IN COATINGS."

Dr. Moerck began by stating that new OSHA guidelines for formaldehyde have led to a re-examination of the possible levels of formaldehyde associated with paint and coatings. For the most part, he said, the main source of formaldehyde emissions from paint and coatings comes from resins and crosslinking agents used in the manufacture of coatings. According to Dr. Moerck, the amount of "free" formaldehyde evaporating into the environment from the use of polymers or crosslinking agents is small because of the low vapor pressure of formaldehyde under the alkaline conditions usually associated with coatings products.

The Environmental Science and Technology Laboratory at the Georgia Institute of Technology was commissioned to conduct a series of formaldehyde exposure level tests, said the speaker. The results showed that certain products, when used at the recommended use-levels, gave formaldehyde levels below that which requires OSHA labeling.

Dr. Moerck then discussed various methods for the determination or analysis of formaldehyde, such as "cleavage" techniques, infrared, FTIR, FT-NMR, and FT-C^{13}NMR methods. In addition, the presence of free formaldehyde in air from the use of formaldehyde/amine bactericides in coatings cannot be demonstrated and therefore special labeling to comply with OSHA's formaldehyde exposure rules is not required.

In conclusion, Dr. Moerck said the minimization of formaldehyde release from coatings products can be achieved through careful formulation. Formaldehyde levels below the OSHA labeling requirement threshold can easily be achieved for alkaline paint and coatings. He also stated that the use of formaldehyde/amine building block bactericides for in-can protection of coatings prod-

GOLDEN GATE SOCIETY OFFICERS (from left): Richard Cooper, Dennis R. Owen, Timothy J. Donlin, Donald Nolte, and Eve Stromquist

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007	027	047	067	087	107	127	147	167	187	207	227	247	267	287
008	028	048	068	088	108	128	148	168	188	208	228	248	268	288
009	029	049	069	089	109	129	149	169	189	209	229	249	269	289
010	030	050	070	090	110	130	150	170	190	210	230	250	270	290
011	031	051	071	091	111	131	151	171	191	211	231	251	271	291
012	032	052	072	092	112	132	152	172	192	212	232	252	272	292
013	033	053	073	093	113	133	153	173	193	213	233	253	273	293
014	034	054	074	094	114	134	154	174	194	214	234	254	274	294
015	035	055	075	095	115	135	155	175	195	215	235	255	275	295
016	036	056	076	096	116	136	156	176	196	216	236	256	276	296
017	037	057	077	097	117	137	157	177	197	217	237	257	277	297
018	038	058	078	098	118	138	158	178	198	218	238	258	278	298
019	039	059	079	099	119	139	159	179	199	219	239	259	279	299
020	040	060	080	100	120	140	160	180	200	220	240	260	280	300

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ucts does not contribute to formaldehyde release and does not require any special labeling for these products.

HOWARD J. SALMON, *Secretary*

PHILADELPHIA .... JAN.

"Regional Economy Results"

Technical Committee Chairman Neil Shearer, of the 3E Group, updated the members on the Society's annual spring seminar. This year's event will be held on Monday, May 23, 1994, and the theme is "Filler Pigments." Program speakers will address each major class of filler pigments.

"REGIONAL ECONOMY RESULTS FOR 1993, FORECAST FOR 1994," was the topic of the evening's talk presented by Richard Stein, Regional Economist, of CoreStates Bank.

Mr. Stein explained that the reasoning behind the recent downsizing in business staffing is due to capital being cheaper than labor. Therefore, companies increase production by investing in capital equipment rather than maintaining or increasing the size of the workforce.

The prediction of growth for the coming year is three percent, stated the speaker. Health-care reform is very important to business growth since inflation in the cost of health care is detrimental to business growth as it is a growing share of corporate overhead, he stated.

Mr. Stein concluded by comparing our economy to the economies of our trading partners. Their economies, he said, are currently weaker than ours. As such, we cannot look forward to growth through expanded trade with them.

HOWARD J. SALMON, *Secretary*

ROCKY MOUNTAIN .... FEB.

Arizona Chapter

It was reported that the Federation made a contribution of $400 to the Society's scholarship fund.

The Society's directory should be printed and ready to mail in April.

The Society is interested in adding an Arizona Chapter and needs about 10 members to accomplish this.

PAUL DELMONICO, *Secretary*

TORONTO .... SEPT.

"Titanium Dioxide"

Juergen H. Braun, of DuPont Chemicals, was the meeting's technical presenter and spoke on "TITANIUM DIOXIDE AND THE DURABILITY OF PAINT FILMS."

Dr. Braun pointed out that while titanium dioxide (TiO_2) may be one of the best white pigments available for coatings formulations, it does pose a dilemma for the formulator: how to maximize utilization of this pigment while paying attention to its catalytic effect in destroying the environment in which it is used (i.e., a paint film).

The destruction which Dr. Braun alluded to was, in effect, the chalking mechanism noticed in many exposed coating films due to UV exposure. To emphasize this, the speaker delved into the mechanism by which UV photons break the chemical bonds, irreversibly in organic polymers and organic pigments, and reversibly in TiO_2.

Dr. Braun discussed testing he has conducted using stabilized "rutile" TiO_2 versus unstabilized "anatase" TiO_2. Comparisons were noted between film degradation in a binder of low light stability versus a binder of high light stability.

The speaker continued by outlining the chemical reaction(s) involved in the chalking process by highlighting "the cycle of TiO_2 oxidation catalysis." In essence, this catalytic reaction consumes a photon, oxygen, and water while generating two free radicals, which then assist in the repetition of the cycle. Dr. Braun said that the practice of "electron spin resonance" is used to track the various stages of polymer and/or pigment consumption in the film.

The final segment of the presentation dealt with the issue of "testing relevance" and the methods by which chalking and film degradation may be tested. Dr. Braun noted two methods: Method A—by simulation—otherwise known as exposure testing through the use of exterior test fences, etc., and Method B—by measurement of scientifically relevant characteristics. The second method offers the benefits of being quantitative, quick, and reproducible, he commented.

In conclusion, Dr. Braun noted that the process of chalking can be controlled through adjustments made to the production of TiO_2 during the crystal phase: encapsulation of the pigment itself (i.e., rutile pigment in SiO_2 glass), and deactivation through the chemical processes of hydroxylation and recombination.

KEVIN PELLING, *Secretary*

TORONTO .... JAN.

"Stabilization of Coatings"

Society Representative Art Hagopian, of ICI Paints (Canada) Inc., reported on the Federation's 1993 Annual Meeting and Paint Industries' Show, in Atlanta, GA. He stated that it was the Federation's second largest in terms of attendance, with a registration figure of 8,576, and, for the first time, over 300 (301) exhibitors. Mr. Hagopian also pointed out that a delegation from Russia was in attendance in Atlanta.

"LIGHT AND HEAT STABILIZATION OF COATINGS," was the evening's technical paper and it was presented by Mark Holt, of Ciba Additives.

Dr. Holt's presentation highlights the ways in which both hindered amine light stabilizers (HALS) and ultra violet light absorbers (UVA) serve to protect and stabilize coating systems.

The speaker stated that in order to substantiate the need for stabilization of coating systems, the following trends affect the coating's durability: (1) Clean Air Act (lower solvent emissions and lower molecular weight); (2) styling trends (move to basecoat/clearcoat, pearlescent, and transparent); and (3) consumer expectations (acid etch resistance, long-term durability, and consumer awareness of the effect of UV light).

Dr. Holt then discussed three ways in which weatherability of coatings can be improved: (1) polymer composition (monomers, functionality, and molecular weight); (2) basic formulation (pigment type, crosslinker used, and types of additives in formulas); and (3) light stabilizing additives (UV absorbers and free radical terminators.)

The speaker showed, with diagrammatic illustrations, the various photochemical pathways involved in the exposure of a paint film to UV light. Dr. Holt explained these pathways and the role played by both UVAs and the pigment contained within any given film. According to the speaker, although certain metal complexes will sometimes serve to "quench" the effect of UV light on the paint film, they are generally restricted in their suitability because of their toxicity and color bodies (lend unwanted color to the film).

There is increasing use of weathering devices (i.e., QUV cabinets, etc.) by research and development chemists, and Dr. Holt described the spectral energy distribution of these units. The speaker then illustrated the plot of wavelength (X-axis) versus watts/square meter (Y-axis) for units employing the following wavelengths: 313, 340, 351 (which mimic sunlight in automotive interiors), and Xenon arc lamp.

Dr. Holt continued by saying that there are two types of coating polymers: UV absorbing and UV transparent. The UV absorbing type undergo photooxidation by means of a three-step process: (1) initiation, (2) propagation, and (3) termination. The speaker emphasized that when discussing UVAs, to keep in mind that more than one type (benzophenones, benzotriazoles, and triazines) exists.

For determining and analyzing the migration of UVAs into basecoat/clearcoat automotive systems, Dr. Holt briefly reviewed the microtome technique. This technique, said the speaker, permits a person to cut a 2 μm thick shaving from a film of lacquer for microscopic examination. However, it is possible to obtain slice thicknesses varying between 1 and 100 μm using this process.

In conclusion, Dr. Holt presented similar information on HALS products along with a review of the properties and mechanisms of each.

KEVIN PELLING, *Secretary*

Elections

CDIC

Active

Walter, Ronald K.—Senco Products, Inc., Cincinnati, OH.

Associate

Corrigan, Brian P.—Nacan Products Ltd., Hudson, OH.
Peyton, Charles E.—William B. Tabler Co., Louisville, KY.
Sewell, Richard W.—William B. Tabler Co., Louisville.
Sharrock, Robert F.—Daicolor-Pope, Inc., Cincinnati, OH.

CHICAGO

Active

Chess, Joseph A.—Akzo Coatings, Inc., Zion, IL.
Danapilis, Vince—Pearl Paints NA, Inc., Chicago, IL.
Mancini, Joseph A.—Mid-America Protective Coatings, Elk Grove, IL.
Reza, Naser—Domino Amjet Inc., Gurnee, IL.
Salvador, Lo—W.C. Richards Co., Blue Island, IL.
Shearer, Jackie A.—Syn-Tech Ltd., Addison, IL.
Smith, Jerry L.—Rheox Inc., Channahon, IL.

Associate

Kobat, Randall B.—The CP Hall Co., Chicago, IL.
McCoy, John C.—Monsanto Co., Itasca, IL.
Pannell, Regina L.—Chicago.
Pomykala, Richard L.—Conap, Schaumburg, IL.
Srabian, Garo—Pearl Paints NA Inc., Chicago.
Srabian, Greg—Pearl Paints NA Inc., Chicago.
Vanderberg, Paul J.—U.S. Gypsum Co., Chicago.
Wasko, Joseph T.—Union Carbide Corp., Alsip, IL.

CLEVELAND

Active

Berzinskas, Dianne M.—The Sherwin-Williams Co., Cleveland, OH.
Boone, David B.—The Sherwin-Williams Co., Cleveland.
Bosway, Michael W.—Man-Gill Chemical, Bedford, OH.
Byrne, Christine J.—Ferro Corp., Olmstead Township, OH.
Cohen, Martin A.—BFGoodrich Co., Brecksville, OH.
Faulkner, Roger W.—Sealmaster, Inc., Sandusky, OH.
Hendring, Wayne T.—The Sherwin-Williams Co., Cleveland.
Olchovy, Ronald J.—Sheffield Bronze, Cleveland.
Reno, Kurtis P.—Universal Poly-Roof, Wadsworth, OH.
Wolens, Denise J.—The Sherwin-Williams Co., Cleveland.

Associate

McKenna, Michael F.—Cleveland Pigment and Color Co., Akron, OH.

Educator/Student

Hoskins, Maria S.—Cleveland State University, Lakewood, OH.
Micco, Michael J.—Westminster College, New Castle, PA.
Yarabenetz, Eric M.—Kent State University, Kent, OH.

LOUISVILLE

Active

Glancy, Charles W.—United Catalysts Inc., Louisville, KY.

Associate

Amback, Gerald B.—Sepr, Louisville, KY.
Galitzine, Peter N.—The Argus Co., Louisville.
Houts, Jennifer—McWhorter Technologies, Elgin, IL.
Wehrenberg, Thomas A.—Law Environmental, Lousiville.

MONTREAL

Associate

Langlois, Simon—DuPont Canada Inc., Montreal, Que.

NORTHWESTERN

Active

Killilea, Howard—The Valspar Corp., Minneapolis, MN.
Prenosil, Michael—Hoffers', Schofield, WI.

ROCKY MOUNTAIN

Active

Davis, Robin—Colorado Paint Co., Denver, CO.
Gauntt, Jerry E.—Luzenac America, Englewood, CO.
Padden, Roger M.—F.I.M. Mica Div., Littleton, CO.
Trousil, Mark T.—R.E. Trousil Co., Inc., Boulder, CO.

ST. LOUIS

Active

Wolfe, Michael J.—Masterchem Industries, Barnhart, MO.
Zweifel, Kenneth—Carboline Co., St. Louis, MO.

Associate

Wakso, Joseph T.—Union Carbide Corp., Highland, IN.
Zilz, Fredrick A.—Lucas Meyer Inc., Decatur, IL.

SOUTHERN

Active

McCormick, James A.—Enhansco, Ponte Vedra Beach, FL.

Associate

Clucas, Richard A.—Sogem, Charleston, SC.
Cottrell, Ernest J.—Union Carbide Corp., Tucker, GA.
Emmott, Bryan H.—Eagle Bridges, Byron, GA.
Strohauer, Mark W.—Applied Technical Services, Marietta, GA.
Unger, James G.—Aqualon Co., Buckhead, GA.

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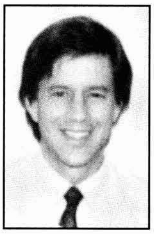
"Adhesion in Coatings: Technology and Characterization"

Spring Week Schedule

May 12-13—FSCT Spring Seminar
May 14—FSCT Incoming Society Officers Meeting
May 15—FSCT Board of Directors Meeting

People



C. Reitter

Chuck Reitter, President of American Paint Journal Co., St. Louis, MO, has announced his resignation, effective January 31, 1994, to pursue other opportunities. Mr. Reitter is joining a major financial-services company with offices in the St. Louis area. He will continue to assist APJ Co. on an as-needed basis during a management-transition period.

Mr. Reitter was named President of the 86-year-old publishing company in February 1991 after serving as Editor/Vice President for three years. He joined the company in 1981 as Associate Editor, was named Editor a year later, and was promoted to Editor/Vice President in 1988.

Currently Vice President of the St. Louis Society for Coatings Technology, Mr. Reitter also served the Society as Assistant Treasurer, Treasurer, and Secretary, and on several Society committees. He also was active with the Management Information Committee of the National Paint and Coatings Association.

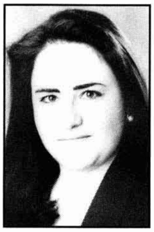
Lothar S. Sander of Princeton, NJ, has returned from Brazil where he served as a volunteer with the International Executive Service Corps (IESC). Mr. Sander, Consulting Research Scientist, was recruited by IESC to assist Unimuau Industrias Quimicas. He evaluated their line of products and marketing tools. Mr. Sander is a member of the Philadelphia Society.

Thomas L. Johnson has been promoted to the position of Commercial Development Manager at ANGUS Chemical Co., Buffalo Grove, IL. In this role, Mr. Johnson will coordinate product development programs from conception to commercialization. In his previous position as Market Development Manager, he commercialized Zoldine® MS-Plus, the additive. Mr. Johnson is a member of the Chicago Society.

In addition, **Kenneth J. Littel** has been appointed Market Development Manager. In this capacity, Mr. Littel will focus on the growth of the company's existing biocide products in new and developing areas. Previously, he was responsible for marketing ANGUS's biocides for such applications as coatings, adhesives, cosmetics, metalworking fluids, oil and gas, paper and pulp, and cooling water treatment. Mr. Littel is a member of the Chicago Society.

Jamestown Paint Co., Jamestown, PA, has named **Richard M. Shannon** Laboratory Manager. Mr. Shannon will direct all research and laboratory activities in this position. He started his career at Jamestown in 1974 and has worked for the company as Technical Service Representative and Assistant Superintendent for Production. Before joining Jamestown, Mr. Shannon spent six years as General Manager for Beaver Paint Co. He is a member of the Cleveland Society.

Richard Barry and **LeRoy Frank** have joined the staff of the Global Sales and Marketing Department of The Mearl Corp., New York, NY, as Regional Coordinators. Both men will function in technical sales/service capacities, assisting customers and Mearl's North American Representatives in the application of the company's pigments as they relate to plastics, surface coatings, and printing inks.



M. Viglielmo

Witco Corp., New York, NY, has named **Melissa Viglielmo** Director of Strategic Planning. Ms. Viglielmo will be responsible for ongoing analysis of the company's business portfolio and will formulate recommendations for Witco's senior management. She brings to this position experience in corporate strategic planning, business development, financial and operations management, and marketing.

The Commercial Development Association, Washington, D.C., presented its 1994 Honor Award to **Richard White**, Executive Vice President of Miles, Inc. The award honors outstanding achievement in building technology-driven businesses. Dr. White began his 27-year career at Miles in 1967 as a Research Chemist for Mobay Corp. He now heads three Miles businesses—the Organic Products Division, the Polysar Rubber Division, and the Polysar Rubber Corp.

RHEOX Inc., Hightstown, NJ, has appointed **Wilbur S. Mardis** to Vice President, Technology. Dr. Mardis will be responsible for all research and analytical activities including new product development and new technology analysis. He recently served as Director of Research for Pierce and Stevens Co., Buffalo, NY.

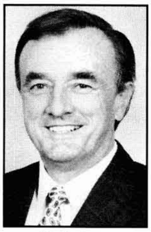
David Strong has been appointed General Manager of Beaver Paint Co., Girard, PA. Mr. Strong will direct all laboratory and manufacturing operations for the company. He was previously Purchasing Manager and Production Control Manager at Ridg-U-Rak, Inc.

International Specialty Products Inc., Wayne, NJ, appointed **Carl J. Eckardt** President and Chief Operating Officer. Mr. Eckardt succeeds **Thomas Bohrer**, who is leaving the company to pursue other interests. Mr. Eckardt, a member of the company's Board of Directors, has been with the firm for 20 years and was President and Chief Operating Officer from 1982-87.

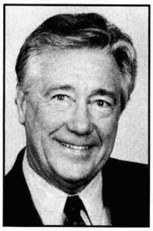
Robert V. Dietz has accepted the position of Chief Financial Officer and Vice President of Finance of Duron Paints and Wallcoverings, Beltsville, MD. In this capacity, he will manage the accounting, credit, finance, and information services departments.

Benjamin F. Tiley has assumed the title and responsibilities of Sales Engineer for the Environmental Products Group of Johnson Matthey, Wayne, PA. Mr. Tiley will be responsible for the sales of pollution control catalysts to the chemical process industry (CPI); in particular, he will help CPI companies meet their VOC, NOx, and hazardous air pollutant emission requirements through the use of oxidation catalysts to reduce hydrocarbons and NOx abatement catalysts for NOx reduction.

The recent acquisition of all the capital stock of Industrial Chemical Products (ICP) West, City of Industry, CA, by Ardrox Inc., La Mirada, CA, has resulted in new personnel appointments at Ardrox. **Donald O. Law**, President of ICP West and **Charles W. Graham**, Executive Vice President of ICP West, will assume leading sales and technical roles at the La Mirada facility.



D.O. Law



C.W. Graham

Dyno-Cytec (formerly Dyno Cyanamid), Rotterdam, The Netherlands, has announced new staff appointments. **Erling Sendstad** was named Managing Director, replacing **Jørn Lunde** who has been elected President, Specialty Chemicals Division, Chemical Plastic Group Dyno. Mr. Sendstad previously held the position of Vice President Business Developments, Chemicals Dyno.

In addition, **Jan Heezen** has been appointed Deputy Managing Director for Dyno-Cytec. He will also continue as Marketing Director for the company.

The Mautz Paint Co., Madison, WI, has appointed **Robert J. Gurske** to President. Mr. Gurske, who most recently served as Vice President of Finance, joined the company in 1971 as Controller. He was named Vice President of Finance in 1976, and to the Board in 1983. Mr. Gurske succeeds **Bernhard F. Mautz** who will become the President of the Coatings Research Group, Inc. Mr. Mautz will continue to be actively involved in the business as owner and Chairman of the Board. He had been directing operations at Mautz for 20 years. Mr. Mautz just completed a term as President of the National Paint and Coatings Association.

Obituary

A.F. Voss Jr.

A.F. "Gus" Voss Jr., President of American Paint and Coatings Journal Co. (APJ Co.), died on March 2, 1994 in St. Louis, MO. He was 71 years old.

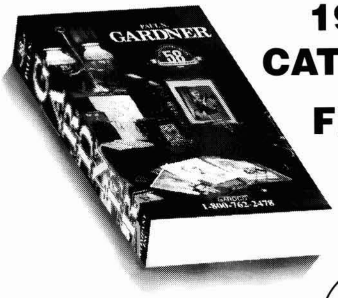
A World War II Army Air Corps veteran, Mr. Voss served as a sergeant in his fighter squadron's meteorology section during his tour of duty in Europe. Following the war, he attended the University of Missouri School of Journalism and then joined APJ Co. in 1947. In the early 1950s, Mr. Voss was assigned to the company's eastern sales office in New York for three years. While there, he sold advertising in the company's magazines. About the same time, Mr. Voss took on the role of convention photographer at all annual meetings of the Federation of Societies for Coatings Technology (FSCT) and the National Paint and Coatings Association (NPCA).

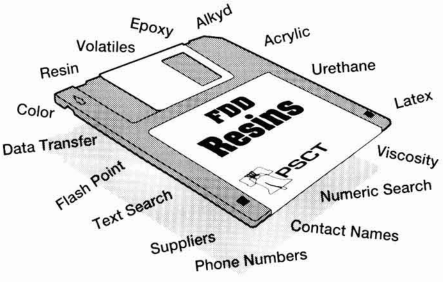
From 1969-91, Mr. Voss served as President of American Paint Journal Co. He also was active in several NPCA committees, including the Management Information, Architectural Coatings, and Chemical Coatings committees. In addition, Mr. Voss participated in the conventions of decorating-product dealers and painting contractors.

Mr. Voss is survived by his wife Virginia; a brother, Clark; a daughter, Mary Elizabeth; a son, A.F. Voss III; and two grandchildren.

Louis E. Ludwig, Past-President of the Chicago Society, died on November 19, 1992. Mr. Ludwig was a 50-year member of the Federation of Societies for Coatings Technology, as well as a Society and Federation Honorary Member.

John Kemper, a long-time member of the St. Louis, MO, paint industry, died recently. A member of the St. Louis Society, Mr. Kemper was employed by Sinnett-Elpaco Coatings Corp. in St. Louis.





"Sharing Knowledge" is the Theme for Southern Society Annual Meeting Scheduled for April 20-22 in Norcross, GA

The Southern Society for Coatings Technology's (SSCT) Annual Meeting will be held at the Northeast Atlanta Hilton, Norcross, GA, on April 20-22, 1994. This year's theme is "Sharing Knowledge."

The technical program is scheduled to include the following presentations:

"New Age Resins as a Tool in Helping the Coatings Industry Comply with Upcoming Regulations"—Bill Buttrick, of Union Carbide;

"New Developments in Waterborne Technology"—Rich Johnson, of Cargill;

"Rheological Modifiers for Aqueous Systems"—Harold F. Haag, of Aqualon Co.;

"Filler Pigments that Can Be Used in Industrial and Trade Sale Products"—Thad T. Broome, of J.M. Huber, Clay Division;

"Factors Influencing Defoamer Selection in the Coating, Ink, and Adhesive Industry"—Alfred A. Lamy, Ultra Additives, Inc.;

"Opaque Polymer: The All-Purpose Pigment"—Steve Cooper, Rohm and Haas/Unocal.

In addition to the technical program, a buying and selling seminar will take place on Thursday afternoon. This seminar will examine the interaction of people from six different jobs. Each person will describe his/her job and how it fits into the process. This seminar should interest Purchasing Agents, R&D Chemists, Company Owners, and General Managers. From the seller's viewpoint, Salespersons, Sales Managers, Customer Service, and Technical Service Personnel should benefit. The panel will be made up of the following: chemist, purchasing agent, retired sales manager, telephone salesperson, salesman, and technical service salesperson.

A day of golf and tennis will precede the Annual Meeting on Wednesday, and a spouses' tour is planned for Thursday. A coat and tie dinner with a live band is scheduled for Thursday evening. A mystery magician will perform at the break.

Registration for meeting after March 25, is $110 for SSCT members; non-member registration is $135 and includes the technical program and the Thursday evening dinner party. There is a separate charge for golf, tennis, and the spouses' tour.

For more information on attending the SSCT Annual Meeting, contact Jeff Shubert, Shubert Paints, 2157 Mountain Industrial Blvd., Tucker, GA 30084, (404) 938-3600.

41st Annual Joint Meeting
Kansas City and St. Louis
Societies for Coatings Technology

"PROGRESS THROUGH INNOVATION"

June 10-11, 1994
Holiday Inn
Lake of the Ozarks, MO

The 41st Annual Joint Meeting of the Kansas City and St. Louis Societies for Coatings Technology is scheduled for June 10-11, 1994 at the Holiday Inn, Lake of the Ozarks, MO.

The theme of this event is "Progress Through Innovation." The technical program will focus on a wide variety of subjects on formulation, regulatory issues, quality programs, and manufacturing concepts for the coatings and ink industry. The technical sessions will be on Friday afternoon and continue on Saturday morning. These sessions should be of interest to laboratory, production, purchasing, and administrative personnel.

In addition, a reception is slated for Friday evening and there will be a catered luncheon on Saturday afternoon.

The registration fee for this event is $110 and there is no additional fee for a registrant's spouse.

For further information, contact either Tom Hilton, Program Chairman, Weskem-Hall, Inc., 310 Armour Rd., Ste. 211, N. Kansas City, MO 64116, (816) 221-6713 or Steve Bussjaeger, Program Coordinator, Davis Paint Co., P.O. Box 7589, N. Kansas City, MO 64116, (816) 471-4447.

CALL FOR PAPERS

Western Coatings Societies' 22nd Symposium and Show

"NEW OPPORTUNITIES—CHALLENGES AND SOLUTIONS"

February 20-22, 1995
San Francisco, CA

All prospective authors are invited to submit papers for presentation at the 22nd Western Coatings Societies Symposium and Show on February 20-22, 1995, in San Francisco, CA. The Golden Gate Society for Coatings Technology is hosting this biennial event.

If you are interested in presenting a paper during the technical sessions, please submit a 200-300 word abstract of your proposed presentation. The abstract should detail the main theme and principal points and should be comprehensive enough to allow assessment of the scope and content of the paper. A brief biography and photograph of the author(s) with speaker's name underlined should accompany the abstract.

Abstracts are due by August 12, 1994, and should be sent to either Adrian S. Adkins, Schoofs, Inc., P.O. Box 67, Moraga, CA 94556; (510) 376-7311 or Ronald Hughes, Ashland Chemical, Inc., 8600 Enterprise Dr., Newark, CA 94560; (510) 796-9333.

SSPC To Host Conference on Evaluating Coatings for Environmental Compliance

The Steel Structures Painting Council (SSPC), Pittsburgh, PA, is sponsoring a conference on "Evaluating Coatings for Environmental Compliance: VOC and Lead Abatement" to be held on June 13-15, 1994 at the Buena Vista Palace at Walt Disney World Village in Lake Buena Vista, FL.

The conference will examine both the regulations driving the protective coatings industry and the responses to those regulations. These include new materials, new accelerated and fundamental evaluation methods, and new corporate and public compliance and management strategies. Major themes include:

- Explanation of imminent regulations restricting VOC of industrial maintenance and marine coatings and their impact on owners, applicators, specifiers, and manufacturers.
- Latest technology and experience for painting over existing lead-coated structures along with a review of basic principles.
- Special problems with waterborne inorganic zinc-rich coatings and advances in their resolution.
- Field experiences and new technology for low VOC protective coatings.
- New technology for evaluating and predicting coating performance by cyclic accelerated testing, imaging of defects, and other nondestructive methods.

The conference is designed for coating specifiers; testing and research laboratories; coating, resin, and pigment manufacturers; maintenance, material, and corrosion engineers; and procurement personnel from public and private facility owners.

In addition, three open forum committee meetings and five educational training sessions will be held prior to and during the conference. The first event, "OSHA Lead Instructor Training for Supervisors and Foremen of Industrial Lead Paint Abatement Projects," will be held June 10. This course provides a review of OSHA lead in construction standard and informs supervisors and foremen of the hazards of lead exposure and the means to protect themselves and their families.

The newly revised "Industrial Lead Paint Removal and Abatement Tutorial" is scheduled for June 11-12. This tutorial, which focuses on industrial lead paint abatement issues, provides the information on complying with environmental and health regulations; techniques for containing, removing, and disposing of debris; strategies, costs, specifications; legal and health consequences and training requirements.

A special course entitled "Specifying and Managing Protective Coatings Projects," will be held June 13-17. The curriculum for the five-day event includes the economics of coatings selection, standards and specifications, shop and field painting operations, maintenance programs, contractor qualification, coating failure analysis, and environmental and safety regulations.

"Failure Analysis and Resolution" and "Developing a Performance Evaluation Testing Program" will be offered on June 16. The first course is a one-day training session that discusses the consequences and types of coating systems failure including: deficiencies in design, surface preparation, materials, and application. The second course teaches attendees how to compare application, physical, and durability properties of new and conventional corrosion protective coatings.

For additional information on "Evaluating Coatings for Environmental Compliance: VOC and Lead Abatement," contact SSPC, 4516 Henry St., Ste. 301, Pittsburgh, PA 15213-3728.

International Union of Pure and Applied Chemistry Sponsors Polymer Conference July 11-15 in Akron

The University of Akron, Akron, OH, will be the site for the 35th International Symposium on Macromolecules, scheduled for July 11-15, 1994. This event is sponsored by the International Union of Pure and Applied Chemistry.

The symposium will feature four plenary speakers: Andrew Keller, University of Bristol, England; Toyoki Kunitake, Kyushu University, Japan; Helmut Ringsdorf, University of Mainz, Germany; and Walter Stockmayer, Dartmouth College.

In addition to the plenary speakers, more than 100 lecturers have been invited to present papers at the technical sessions. Major topics for discussion will include new polymerization reactions and reaction mechanisms; complex macromolecular architectures and supramolecular polymers; polymers and biology; frontier polymeric materials; field responsive polymers; and polymers at interfaces.

A presentation on "Industrial Views on Polymers in the 21st Century" is also scheduled.

Contact Cathy Manus-Gray, Symposium Coordinator, Institute of Polymer Science, The University of Akron, Akron, OH 44325-3309, to obtain additional information on the "International Polymer Conference."

ISCC/DCC Annual Meeting and Symposium Slated for April

The Detroit Color Council (DCC) will host the 1994 Annual Meeting of the Inter-Society Color Council (ISCC), on April 24-26, 1994 at the Troy Marriott Hotel, Troy, MI. Following the ISCC meeting on April 24-25, an automotive color symposium "Auto Design Tech," will take place on April 26.

The tentative program for the "Auto Design Tech" symposium includes:

—S. Reznikoff, of Arizona State University, discussing the impact of social and economic patterns and special events on popular color usage in the automotive, clothing and interiors industries;

—Robert Daily, of DuPont Automotive Products, describing the coordination of customer needs and wants with color feasibility realties;

—Trevor Creed, of Chrysler Design, providing an in-depth look at the future direction of color, trim, and mastering;

—Tom Matano, of Mazda Design, dealing with bi-cultural issues in color design;

—Harold Fitzpatrick, of Fitzpatrick and Israels, updating heavy metal pigment developments since the 1993 Newport ISCC meeting;

—Allan Rodrigues, of DuPont Automotive, measuring the three-angle color of automotive metallic colors; and

—Roy Burns, of Rochester Institute of Technology, discussing possible revision of the recommended CIE color difference equation.

Additional information on the ISCC Annual Meeting and Auto Design Tech Symposium may be obtained from James R. Keiser, ISCC Annual Meeting Chairperson, 945 Stephenson Highway, Troy, MI 48007.

BGSU and DeVilbiss Cosponsor Spray Finishing Workshop

A "Spray Finishing Technology Workshop" will be conducted May 11-13, 1994, by Bowling Green State University (BGSU), Bowling Green, OH, and DeVilbiss Industrial Coating Equipment Co., Toledo, OH.

The emphasis of the workshop will be on spray finishing associated with industrial, contractor, and maintenance applications, as well as automotive refinishing. Spray system and equipment selection, operation, maintenance, surface and material preparation, and other topics will be included. In addition, topics relating to the latest technologies—e.g., high volume low pressure—and environmental and regulatory concerns will be addressed.

For additional information or a brochure, contact Richard A. Kruppa, Professor of Manufacturing Technology, College of Technology, BGSU, Bowling Green, OH 43403.

Member of

Federation of Societies for Coatings Technology

YE OLDE PAINT STONE 1737

Since 1922

37th Annual Cleveland Society Conference

on

"Advances in: 1) Film Characterization and Properties; 2) Chemistry and Physics of Film Formation"

Tuesday, May 17, 1994

BFGoodrich Research & Development Center
Brecksville, Ohio

Breaks, lunch, tour of BFGoodrich Research Facility, and cheese and beverage party will be provided.
The conference dress code is casual. A BBQ picnic dinner will follow the conference.
An evening speaker and CSCT monthly meeting will follow the picnic dinner.

Conference Registration:

Name: ______________________________

Company Name: ______________________________

Mailing Address: ______________________________

City/State/Zip: ______________________________

Telephone Number: ______________________________

If FSCT Member: ________________ Society

FSCT Member Conference Registration	( )	$110.00
Member Registration with Dinner	( )	135.00
Retired Member—Conference Only	( )	45.00
Full-Time Student—Conference Only	( )	45.00
Retired/Student—Conference & Dinner	( )	70.00
Non-FSCT Members, Add	( )	10.00
Registration after May 1, Add	( )	10.00
Tour and/or Cheese & Fruit Social	( )	30.00

Total Amount Enclosed: .... $________

Picnic Dinner Choice:

Strip Steak _____ BBQ Chicken _____ Vegetarian _____

Send registration to:

Mr. Jim Miller
3057 Kent Rd.
Cuyahoga Falls, OH 44224

Accommodations:

Holiday Inn
Cleveland/Richfield (Coliseum)
42 Brecksville Rd.
Richfield, OH 44286
Phone: (216) 659-6151

For more information, call:

Ms. Sharie Moskaluk, The Sherwin-Williams Co., (216) 566-3661.

Please make your reservation directly with the Holiday Inn. Use CSCT Conference Rate of $51.00 (without tax) for single room (king-size bed).

Book Review

BIODEGRADABLE POLYMERS AND PACKAGING

Edited by
Chauncey Ching, David L. Kaplan,
and Edwin L. Thomas

Published by
Technomic Publishing Co., Inc.
851 New Holland Ave.
P.O. Box 3535
Lancaster, PA 17604 (1993)
411 pages, $145

Reviewed by
Rose A. Ryntz
Ford Motor Co.
Detroit, MI

Biodegradable Polymers and Packaging provides a thorough review of the biodegradability of polymers and environmental test methods for determining biodegradability. The 411-page book is divided into 28 chapters that in their own right could stand alone as excellent reference works in the area of biodegradable polymers.

Biodegradable polymers such as starch, protein, starch-mineral complexes, cellulose acetates, bacterial polyesters, carbohydrates, and liquid crystalline polymers such as silk, Levan (a homopolysaccharide), and Mucin (a macromolecular matrix of mucus, a polymer hydrogel) are discussed. Preparation of the materials are examined in context to the biodegradability, with subsequent discussions on their characterization, properties, and biodegradation mechanisms. Additional chapters discuss the effects of processing conditions on properties of the plastics, effects of crosslinking agents, processing aides, and processing environment on overall biodegradability.

The effects of the marine environment on the biodegradability of starch and related materials are presented. Biodegradable kinetics, laser and infrared analysis, the undersea fluorescence confocal microscope probe, and bioluminescence are but a few of the topics described in depth.

Subsequent chapters discuss military applications for biodegradable polymers. An excellent presentation is also given on the Navy consumers' attitudes toward marine environmental problems and biodegradable polymers. The book concludes with a discussion of responsible disposal.

Overall, *Biodegradable Polymers and Packaging* provides a well-rounded view of the biodegradable polymers market, including scientific as well as environmental stewardship discussions. This book will make an excellent addition to one's reference library acting as an up-to-date source for information on a most intriguing and complicated scientific problem.

HANDBOOK OF INDUSTRIAL SURFACTANTS

Compiled By
Michael and Irene Ash

Published by
Gower Publishing Co.
Gower House, Croft Road
Aldershot, Hampshire,
England (1993)
905 pages

Reviewed by
Hugh Lowrey
Perry & Derrick Co., Inc.
Cincinnati, OH

This book describes and crossindexes over 16,000 commercially available industrial surface active agents, raw materials from which surfactants are manufactured, and defoamers and antifoaming agents. Its scope is worldwide.

All surfactants are listed alphabetically by tradename. Descriptions, chemical compositions, physical and performance data, application information, and CAS numbers are included to the extent that these various items have been supplied by the surfactant manufacturers. In a second list, subdivided into 17 areas of industrial application, each tradename is listed according to its major usage. One such area of application is paints, coatings, lacquers, inks, and adhesives. A third listing is by principal chemical component. A manufacturers directory completes the volume.

Among several useful tables which are supplied as appendices are cross-references from CAS number to tradename and to chemical composition. Also, classification by ionic type is provided, as is an HLB listing of about 4,600 of the products. Additional listings and cross-references provide historical tracing of discontinued or altered tradenames and of successor manufacturers.

The listings of products and manufacturers are not comprehensive, and data are only as complete as the information supplied to the compilers would permit; nevertheless, it is difficult to imagine the publication of a more complete coverage of the subject matter. Anyone, including paint formulators, who needs to locate or select surfactants or to quickly characterize specific commercial surface active agents, will find this book valuable.

Literature

Capillary Process Viscometer

A process viscometer designed to continuously measure the dynamic viscosity of Newtonian fluids and the apparent viscosity of non-Newtonian substances or multi-component systems is introduced through literature. This product is reportedly suited for control of reaction processes, optimization of coating processes, control of addition or subtraction criteria in the processes, and control of combustion (optional and low-pollution) processes. To obtain more information on the Physica Viscoflow KV 100, contact Paar Physica USA, 1090 King Georges Post Rd., Ste. 607, Edison, NJ 08837.

Circle No. 200 on Reader Service Card

Monitoring Equipment

A product release highlights a company's new equipment line. This equipment includes systems for monitoring containment effectiveness during removal of lead paint; for monitoring air flow in containment during lead paint removal operations; for monitoring worker protection during removal of hazardous paint materials; and gas monitoring equipment and lifeline air filtering systems. For more information on any of these devices, write KTA-Tator, Inc., 115 Technology Dr., Pittsburgh, PA 15275.

Circle No. 201 on Reader Service Card

Industrial Painting

A company presents a new approach to industrial metal painting. The combination of Aquaclean surface preparations with Aqualite waterborne paints has resulted in a patent application for a system that tailors one part of the finishing process to the other. To obtain additional information on System 21®, write Finishes Unlimited, Inc., Wheeler Rd., P.O. Box 69, Sugar Grove, IL 60554.

Circle No. 202 on Reader Service Card

Benchtop Spectrophotometer

A multipurpose portable and benchtop spectrophotometer that measures color, gloss, and density is described in a brochure. The four-page publication reviews the benefits and applications of this spectrophotometer; charts provide specifications, colorimetric functions, illuminants/observers; and indices offer at-a-glance information. For more details on the Spectro/plus® spectrophotometer, contact Color and Appearance Technology, Inc., Princeton Commerce Center, 29 Emmons Dr., Bldg. G-2, Princeton, NJ 08543-3709.

Circle No. 203 on Reader Service Card

Management Software

Literature describes software designed to solve new measuring applications, store, retrieve, and export data. This window-structured, PC-driven program reportedly employs mathematical solutions for applications such as triple coatings, Cr/Ni/Cu/Fe, thickness and alloy determination of ternary coatings, AuAgCu, and phosphorus determination for electroless nickel deposits. For additional information on FTM software, write Fischer Technology, Inc., 750 Marshall Phelps Rd., Windsor, CT 06095.

Circle No. 204 on Reader Service Card

Epoxy Acrylates

A new 25-page product bulletin describes the properties of a company's epoxy acrylate oligomers. This publication summarizes in chart format the performance properties of these oligomers. Tables and charts detailing the physical and chemical properties are included. In addition, the bulletin gives application suggestions for each epoxy acrylate. Contact Sartomer Co., 468 Thomas Jones Way, Exton, PA 19341 for more information on their line of epoxy acrylate oligomers.

Circle No. 205 on Reader Service Card

Weathering Services

A 40-page weathering services and equipment catalog is now available. The four-color publication contains information on a company's range of services including conventional and accelerated weathering; automotive products testing; color, gloss, and visual assessment; optical and mechanical properties; window energy analysis; environmental testing; and special projects. For additional information on DSET's weathering services and equipment, contact the Customer Service Dept., Heraeus DSET Laboratories, Inc., 45601 N. 47th Ave., Phoenix, AZ 85027-7042.

Circle No. 206 on Reader Service Card

GC Regulators

A line of stainless steel and brass regulators for the laboratory and gas chromatographic marketplace is introduced in a product release. This product reportedly has only one nonmetallic seal, Kel-F, in each stage to minimize sources of gas stream contaminants. For more information on the Model 6S Series, write Applied Technology Equipment Corp., 1968 Bishopwood Blvd., Harleysville, PA 19438.

Circle No. 207 on Reader Service Card

Waterjet Cleaning

A lightweight, hand-held waterjet cleaning tool is the subject of a data sheet. This device, which reportedly uses water pressurized at 40,000 psi, is designed for applications including: cleaning car carriers in the automotive industry; removing paint, rust, and corrosion from offshore oil platforms; stripping materials from the insides of storage tanks; and removing paint from bridges and other structures. Contact Flow International, 23500 64th Ave., S., Kent, WA 98032, to obtain information on the A-3000 Ultralight.

Circle No. 208 on Reader Service Card

Two-Gun Line Striper

Literature focuses on a two-gun line striper designed for striping applications and general painting. This product is reportedly capable of spraying dual line patterns from 2 to 24 in., and both guns can be triggered together or separately, enabling the painter to use one gun to spray a solid line while using the other to spray a perforated line. For more information on the Promark 5500, contact Titan, 556 Commerce St., Franklin Lakes, NJ 07417.

Circle No. 209 on Reader Service Card

Product Catalog

A 1200-page catalog with new product descriptions, instructions, specification references, and prices of paint testing instruments, corrosion control gages, coating inspection gages, friction and wear testers, and laboratory instruments and equipment is available. This publication includes a section on viscosity with 35 documented calibrated viscosity cups. To receive a complimentary copy of the "1994 Gardco Catalog of Laboratory Instruments and Equipment," contact the Paul N. Gardner Co., Inc., The Gardner Bldg., 316 NE First St., Pompano Beach, FL 33060.

Circle No. 210 on Reader Service Card

Steel Drum Insert

A product release introduces a smooth-sided, plastic insert for 16 gallon steel drums. This insert, designed for use with greases, adhesives, paints, inks, urethanes, dyes, and various applications where a smooth wall insert is preferred, is made from low density polyethylene with an average wall thickness of 15 mil. For specifications and a free sample of the 16SS, write CDF Corp., 100 Enterprise Dr., Marshfield, MA 02050.

Circle No. 211 on Reader Service Card

Polyaspartic Esters

Polyurea coatings based on polyaspartic esters for maintenance and architectural applications, as well as automotive and product finishing markets, are the topic of literature. Reported benefits provided by these coatings include high-build characteristics, rapid and low temperature curability, improved adhesion and corrosion resistance, and ultraviolet weathering and yellowing resistance. To learn more about polyaspartic esters for use in polyurea coatings, contact Miles Inc., Mobay Rd., Pittsburgh, PA 15205-9741.

Circle No. 212 on Reader Service Card

Anti-Graffiti Polyurethane

A company presents a new, two-component polyurethane that resists adhesion of graffiti. This product is available in high gloss custom matched colors or a clear gloss topcoat which can be used to overcoat powder coatings or other paint systems and is suitable for news racks, exterior electronic enclosures, and to clear coat roadway signs. For more information on the anti-graffiti polyurethane, contact Cardinal Industrial Finishes, 1329 Potrero Ave., So. El Monte, CA 91733-3088.

Circle No. 213 on Reader Service Card

Marine Coatings

A product release introduces a vinylester resin system that reportedly provides a legal in-water-cleanable surface. This coating, available for in-mold application during manufacturing, can be applied to boats, planes, walls, ships, offshore rigs, bridges, rooms, pipelines, homes, cars, and swimming pools. To obtain more information on Max Pro-Coat™, contact Pier Pressure Marine Systems, Inc., 800 Fifth Ave., Ste. 198, Seattle, WA 98104.

Circle No. 214 on Reader Service Card

Circulation Attritor

A brochure illustrates and describes how a circulation attritor grinding mill works. The design of this product combines an attritor with a large holding tank. Using a high circulating pumping rate, the entire contents of the holding tank are passed through the attritor at least eight times per hour. Options for the machines include tank linings, arm sleeves, covers, and torque meters, which are also discussed in the brochure. To receive a copy of the brochure on "Q" Series Circulation Attritor Grinding Mills, contact Union Process, 1925 Akron-Peninsula Rd., Akron, OH 44313.

Circle No. 215 on Reader Service Card

Yellow Pigments

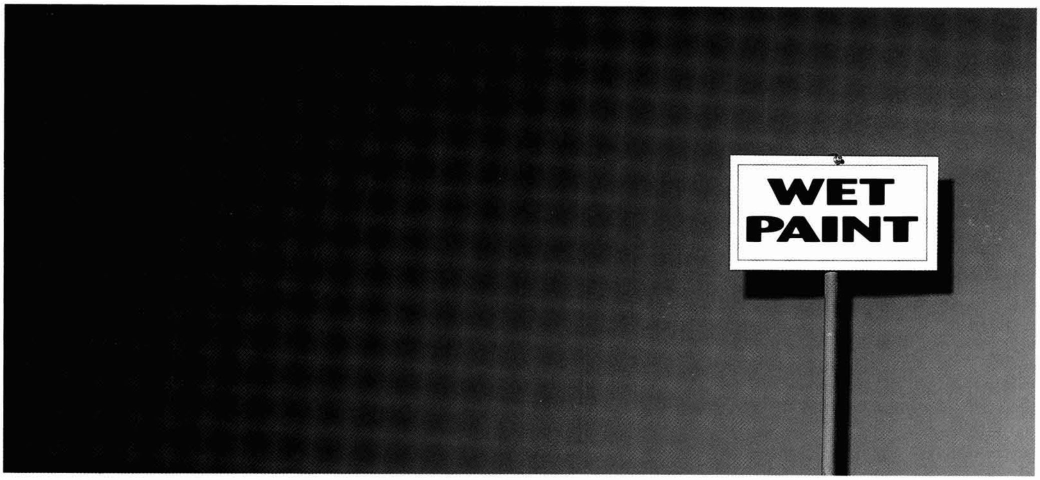
A line of Hansa yellow pigments for water- and solvent-based traffic grade paints is introduced through literature. These non-heavy-metal-containing organic pigments are designed as substitutes for a range of lead-containing shades from primrose chrome yellow through medium chrome yellow. For additional information on the Harshaw® Hansa yellow pigments, write Engelhard Corp., Specialty Minerals and Colors Group, 101 Wood Ave., Iselin, NJ 08830-0770.

Circle No. 216 on Reader Service Card

Antifoam/Defoamer

An antifoam/defoamer concentrate for use in water-based coatings and similar emulsion-based systems is the topic of a product release. Designed for use with acrylics, vinyl acrylics, polyvinyl acetates, and water-reducible alkyds, this product reportedly performs as an antifoam agent by breaking foam formation and as a defoamer by breaking down existing foam. Additional information on Bubreak 4419 may be obtained from Buckman Laboratories, 1256 North McLean Blvd., P.O. Box 80305, Memphis, TN 38108-0305.

Circle No. 217 on Reader Service Card



Surface Area Analyzers

A full-color brochure describes a company's surface area analyzers that are reportedly capable of providing automated B.E.T. surface area measurements in less than five minutes. This series of analyzers includes single, double, and triple station models as well as a sample preparation facility for high volume applications. To receive a complimentary copy of brochure 93-S, contact Horiba Instruments Inc., 17671 Armstrong Ave., Irvine, CA 92714.

Circle No. 218 on Reader Service Card

Decorating Guides

Three guides designed to help specifiers, interior designers, and builders integrate wall and ceiling colors into overall interior decor have been printed. These publications contain swatches of fabric and vinyl coverings available in a company's wall and ceiling systems. To receive a copy of any of the three "Color Solutions" guides, write USG Interiors, P.O. Box 4470, Chicago, IL 60680-4470.

Circle No. 219 on Reader Service Card

Seal-Less Mixer

Literature has been released on a sealless mixer. This product reportedly employs rare-earth magnets and advanced ceramic bearings to provide high torque without need for any type of seal and offers a choice of power ranges up to 30 hp and impeller shaft diameters from 1.5 to 3.5 in. Additional information on the MagMixer™ may be obtained from Lightnin, 135 Mt. Read Blvd., P.O. Box 1370, Rochester, NY 14603-1370.

Circle No. 220 on Reader Service Card

Slurry Grades

A family of TiO_2 pigment slurry grades are highlighted in a data sheet. The new slurry grades reportedly contain no amines, mercury, formaldehyde donor compounds. For more information on KRONOS® 4310—a high durability, high-gloss grade; KRONOS 4102—a universal grade; KRONOS 4020—an interior/exterior enamel grade; and KRONOS 4132—an interior/exterior flat grade, contact KRONOS, Inc., Wyckoff Mills Rd., Hightstown, NJ 08520.

Circle No. 221 on Reader Service Card

Lab Directory

An international directory of testing laboratories has been printed. This publication includes indexes listing laboratories by location, name, fields of testing, materials, and products. Contact ASTM, 1916 Race St., Philadelphia, PA 19103-1187, for information on how to obtain a copy of "International Directory of Testing Laboratories."

Circle No. 222 on Reader Service Card

Light Booths

Two new light booths for color matching are the subject of a data sheet. These instruments reportedly allow the users to calibrate the color temperature of their daylight to an NIST-traceable standard. To obtain additional information on the ColorView® LightBooth and the ColorView® MiniBooth, contact Tailored Lighting Inc., 9 Tobey Village Office Park, Pittsford, NY 14534.

Circle No. 223 on Reader Service Card

Environmental Chambers

A company presents an intermediate size chamber that allows external visual observation of a product during testing to its family of environmental chambers. The intermediate chamber is six cubic meters and reportedly provides a realistic test environment for computers, printers, seating, and wall panels. For more information on the intermediate size chamber, write Air Quality Sciences, Inc., 1331 Capital Circle, Atlanta, GA 30067.

Circle No. 224 on Reader Service Card

Pigment Dispersion

An application bulletin introduces a dispersant series for use with organic pigments in nonaqueous coatings. These A-B type dispersants reportedly offer lower viscosity pigment grinds as well as flocculation resistance. This publication also describes a three-step approach to measuring dispersant performance. For additional information on the Drewsperse® 300 Dispersant Series, contact Drew Industrial Div., One Drew Plaza, Boonton, NJ 07005.

Circle No. 225 on Reader Service Card

Data Collection Software

A brochure details full-function SPC software for plant floor data collection, charting, and analysis. This publication describes the software's ability to integrate data collection and user-customized operator interface. For a complimentary copy of this brochure, write Northwest Analytical, Inc., 519 SW Park Ave., 6th Floor, Portland, OR 97205-3207.

Circle No. 226 on Reader Service Card

Dew Point Transmitter

A dew point and temperature transmitter that monitors moisture on-line in a gas stream is highlighted in a product release. In operation, this device reportedly measures condensation temperature (direct moisture content) plus temperature in air or in other gases. For more details on the 4112 dew point and temperature transmitter, write Leeds and Northrup, 351 Sumneytown Pike, P.O. Box 2000, North Wales, PA 19454.

Circle No. 227 on Reader Service Card

UV/VIS Spectrometer

A 12-page, four-color brochure describes a new UV/VIS spectrometer designed for a variety of applications, including: water analysis, autosampling, and remote sampling with fiber optics. Some of the reported features of this product are double-beam optics, wavelength range of 190 to 1100 nm, and scan speed from 7.5 to 2880 nm/min. For a complimentary copy of the Lambda 2S UV/VIS Spectrometer brochure, contact The Perkin-Elmer Corp., 761 Main Ave., Norwalk, CT 06859-0012.

Circle No. 228 on Reader Service Card

Epoxy Curing Agent

The benefits of a company's epoxy curing agent for use in industrial flooring, high-solids coatings, secondary containment, and chemically resistant tank linings and mortars are discussed in a data sheet. This curing agent is a modified cycloaliphatic amine designed for use at ambient temperatures with liquid epoxy resins in two-package formulations. For a copy of "Ancamine® 2280 Curing Agent," contact Air Products and Chemicals, Inc., Pacific Anchor Chemical, 7201 Hamilton Blvd., Allentown, PA 18195-1501.

Circle No. 229 on Reader Service Card

Order Entry System

A four-page brochure introduces a PC-based software system for process manufacturers. The module includes features such as multiple units of measure for both item price and quantity, unlimited sales pricing options, automatic commission calculation (including split commissions), and bill of lading. Additional modules for inventory, production, laboratory, and labeling are also available. For a free demonstration diskette of BatchMaster 3, please write Pacific Micro, 1500 Pacific Coast Hwy., Ste. E, Seal Beach, CA 90740.

Circle No. 230 on Reader Service Card

CLASSIFIED ADVERTISING

EXECUTIVE DIRECTOR

COATINGS RESEARCH GROUP, INC., the premier international coatings technical organization since 1956, needs an Executive Director to help lead it into the future.

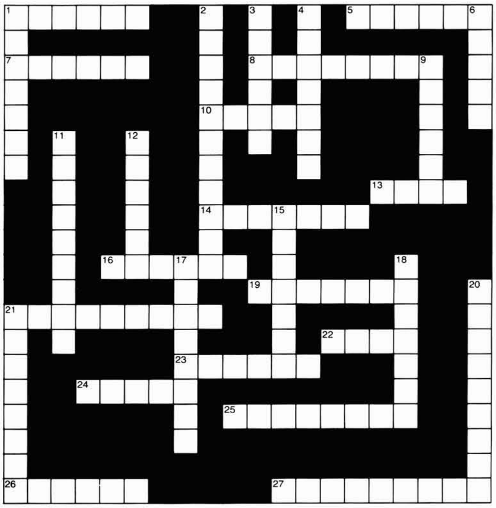
Established technical excellence and people skills required for a challenging leadership position in a financially strong organization.

Send resume and expression of interest to President, CRGI, P.O. Box 2371, Birmingham, AL 35201.

CrossLinks

Natural Products II

by Earl Hill



Solution
to be
Published in
May Issue

No. 59

ACROSS

1. Pigment used in wood stains
5. Type of bitumen, A_____
7. Salts with 21 Down have anticorrosive properties
8. What fatty acid is found in linseed oil?
10. Material from pine tar
13. Kind of natural oil, T_____
14. Word with moss
16. Metal used in compounds to kill 27 Across
19. Painting method using pigments in gum
21. Naturally occurring cinnabar, C_____
22. Chaser of terra
23. Amyl acetate (Syn.); an oil
24. Goes with 22 Across
25. The glyceride of 8 Across
26. A natural root used to make a red pigment, M_____
27. Grows on marine vessels (Pl.)

DOWN

1. What is a protein derived from egg whites called?
2. A clay mineral used as a viscosity modifier, A_____
3. A tree excretion used as a substitute for gutta-percha
4. An alcohol found in terpene solvents
6. Natural iron oxide pigment
9. A phenolic compound found in cashew nuts
11. What is an old name for rosin?
12. Notable dark blue transparent dye, I_____
15. Grease from wool
17. Graphite (Syn.), P_____
18. Yet another protein, used in emulsions
20. Botanical class of trees which is a source of tung oil, A_____
21. Which metal salts are now frowned upon for ecological reasons?

Coming Events

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.

1994

(May 12-15)—Federation "Spring Week." Spring Seminar on the 12th and 13th; Incoming Society Officers Meeting on the 14th; Board of Directors Meeting on the 15th. Marriott City Center Hotel, Minneapolis, MN.

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

1995

(Oct. 9-11)—73rd Annual Meeting and 60th Paint Industries' Show. Cervantes Convention Center, St. Louis, MO.

1996

(Oct. 23-25)—74th Annual Meeting and 61st Paint Industries' Show. McCormick Place North, Chicago, IL.

SPECIAL SOCIETY MEETINGS

1994

(Apr. 20)—"Coatings A-Z." Sponsored by the Louisville Society. Executive West Motor Hotel, Louisville, KY. (Mike Moilanen, United Catalysts, Inc., 1230 S.12th St., P.O. Box 32370, Louisville, KY 40232).

(Apr. 20-22)—"Sharing Knowledge." Southern Society Annual Meeting. Northeast Atlanta Hilton Hotel at Peachtree Corners, Norcross, GA. (Jeff Shubert, 2157 Mountain Industrial Blvd., Tucker, GA 30084; (404) 938-3600).

(Apr. 28-May 1)—47th Annual Spring Symposium. Sponsored by the Pacific Northwest Society. The Empress Hotel, Victoria, B.C., Canada. (Ed Linton, Cloverdale Paint Inc., 6950 King George Hwy., Surrey, B.C. V3W 4Z1, Canada; (604) 596-6261).

(May 17)—"Advances in Coatings Technology." 37th Annual Educational Symposium. Sponsored by the Cleveland Society. BFGoodrich Research Center, Brecksville, OH. (Sharie Moskaluk (216) 566-3661).

(May 23)—"Filler Pigments—More Than Dead Space." Sponsored by the Philadelphia Society. Holiday Inn—Philadelphia Stadium, Philadelphia, PA. (Neil R. Shearer, The 3E Group, 850 Glen Ave., Moorestown, NJ 08057; (609) 866-7600).

(June 10-11)—"Progress Through Innovation." Joint Meeting of the St. Louis and Kansas City Societies. Holiday Inn, Lake of the Ozarks, MO. (Tom Hilton, Program Chairman, Weskem-Hall, Inc., 310 Armour Rd., Ste. 211, N. Kansas City, MO 64116; (816) 221-6713, or Steve Bussjaeger, Program Coordinator, Davis Paint Co., P.O. Box 7589, N. Kansas City, MO 64116; (816) 471-4447).

1995

(Feb. 20-22)—Western Coatings Societies' 22nd Biennial Symposium and Show. Sponsored by the Golden Gate, Los Angeles, Pacific Northwest, and Rocky Mountain Societies. Hilton Hotel and Towers, San Francisco, CA. (Gordon Pioch, WCS Chairman, Eureka Chemical Co., P.O. Box 2205, S. San Francisco, CA 94083; (415) 761-3536).

OTHER ORGANIZATIONS

1994

North America

(Apr. 20-22)—9th Annual Conference. Sponsored by the Architectural Spray Coaters Association (ASCA). Westin Mission Hills Resort, Rancho Mirage, CA. (ASCA, 230 West Wells St., Ste. 311, Milwaukee, WI 53203).

(Apr. 20-27)—Surface Treatment '94. Hannover Fairgrounds, Hannover, Germany. (Hannover Fairs USA Inc., 103 Carnegie Center, Princeton, NJ 08540).

(Apr. 21)—"Viscoelastic Properties of Polymers." Short course sponsored by Polytechnic University, Brooklyn, NY. (Eli M. Pearce, Polymer Research Institute, Polytechnic University, Six Metrotech Center, Brooklyn, NY 11201).

(Apr. 23-24)—Eastern Decorating Products Show. Sponsored by National Decorating Products Association (NDPA). Garden State Convention & Exhibit Center, Somerset, NJ. (Ruth Wilms, NDPA, 1050 N. Lindbergh Blvd., St. Louis, MO 63132).

(Apr. 24-26)—ISCC Annual Meeting. Sponsored by the Inter-Society Color Council. Troy, MI. (James R. Keiser, ISCC Annual Meeting Chairperson, 945 Stephenson Highway, Troy, MI 48007).

(Apr. 25-29)—"Applied Rheology for Industrial Chemists." Short course sponsored by Kent State University, Kent, OH. (Carl J. Knauss, Director, Cooperative & Continuing Education—Chemistry, Kent State University, P.O. Box 5190, Kent, OH 44242-0001).

(May 1-5)—RadTech '94 North America. Conference sponsored by RadTech International North America. Walt Disney World Dolphin Hotel, Orlando, FL. (Chris Dionne, RadTech International North America, 60 Revere Dr., Suite 500, Northbrook, IL 60062).

(May 2-4)—"Fundamentals of Adhesion: Theory, Practice, and Applications." Lake Mohonk, New Paltz, NY. (A.V. Patsis, State University of New York, New Paltz, NY 12561).

(May 2-4)—"Polymer Blends & Alloys: Phase Behavior, Characterization, Morphology, Alloying Technology." Lake Mohonk, New Paltz, NY. (A.V. Patsis, State University of New York, New Paltz, NY 12561).

(May 2-4)—"Basic Coatings for Sales and Marketing Personnel." Short course sponsored by University of Missouri-Rolla (UMR), Rolla, MO. (Cynthia N. Campbell, UMR Coatings Institute, Dept. of Chemistry, 142 Schrenk Hall, Rolla, MO 65401-0249).

(May 2-4)—"Advances in Membrane Technology." Lake Mohonk, NY. (A.V. Patsis, State University of New York, New Paltz, NY 12561).

(May 2-5)—"Pigment Dispersions: Science and Technology." Short course sponsored by State University of New York. Lake Mohonk, New Paltz, NY. (A.V. Patsis, State University of New York, New Paltz, NY 12561).

(May 4-5)—"Paint Volatile Organic Compounds (VOC)." Course sponsored by American Society for Testing and Materials (ASTM). Chicago, IL. (Tina Falkenstein, ASTM, 1916 Race St., Philadelphia, PA 19103).

(May 8-12)—85th AOCS Annual Meeting and Expo. Sponsored by the American Oil Chemists' Society (AOCS). Atlanta Marriott Marquis, Atlanta, GA. (AOCS, P.O. Box 3489, 1608 Broadmoor Dr., Champaign, IL 61826-3489).

(May 8-13)—37th Annual Technical Conference of the Society of Vacuum Coaters (SVC). Westin Hotel/Copley Place, Boston, MA. (SVC, 440 Live Oak Loop, Albuquerque, NM 87122-1407).

(May 9-11)—"Polymer Degradation and Stabilization." Short course sponsored by State University of New York. Lake Mohonk. (A.V. Patsis, State University of New York, New Paltz, NY 12561).

(May 9-13)—"Dispersion of Pigments and Resins in Fluid Media." Short course sponsored by Kent State University, Kent, OH. (Carl J.

Knauss, Director, Cooperative & Continuing Education—Chemistry, Kent State University, P.O. Box 5190, Kent, OH 44242-0001).

(May 11-13)— 11th Annual Atlas School of Natural and Accelerated Weathering. Miami, FL. (Margaret MacBeth, Atlas Electric Devices Co., 4114 N. Ravenswood Ave., Chicago, IL 60614).

(May 11-13)—"Spray Finishing Technology Workshop." Sponsored by Bowling Green State University (BGSU), Bowling Green, OH and DeVilbiss Industrial Coating Equipment Co., Toledo, OH. (Richard A. Kruppa, Dept. of Technology Systems, College of Technology, Bowling Green, OH 43403-0301).

(May 16-19)—"Coatings Science for Powder Coatings." Short course sponsored by University of Southern Mississippi (USM). Hattiesburg, MS. (Shelby F. Thames or Debbie Ballard, USM, Dept. of Polymer Science, Box 10076, Hattiesburg, MS 39406-0076).

(May 16-20)—"Introduction to Paint Formulation." Short course sponsored by University of Missouri-Rolla (UMR), Rolla, MO. (Cynthia N. Campbell, UMR Coatings Institute, Dept. of Chemistry, 142 Schrenk Hall, Rolla, MO 65401-0249).

(May 16-21)—"Interpretations of IR and Raman Spectroscopy." Course and workshops sponsored by Vanderbilt University, Nashville, TN. (Clara Craver, Director, Fisk Infrared Institute, P.O. Box 265, French Village, MO 63036).

(May 18-20)—1994 Weather-Ometer® Workshop. Sponsored by Atlas Electric Devices Co. Holiday Inn O'Hare, Chicago, IL. (Margaret MacBeth, Atlas Electric Devices Co., 4114 N. Ravenswood Ave., Chicago, IL 60613).

(May 23-27)—"Adhesion Principles and Practice for Coatings and Polymer Scientists." Short course sponsored by Kent State University, Kent, OH. (Carl J. Knauss, Director, Cooperative & Continuing Education—Chemistry, Kent State University, P.O. Box 5190, Kent, OH 44242-0001).

(June 5-17)—Intensive Coatings Science Course. Sponsored by North Dakota State University (NDSU). Fargo, ND. (Marek W. Urban, NDSU, Dept. of Polymers and Coatings, 54 Dunbar Hall, Fargo, ND 58105).

(June 6-9)—"Coatings Science for Coatings Chemists." Short course sponsored by University of Southern Mississippi (USM). Hattiesburg, MS. (Shelby F. Thames or Debbie Ballard, USM, Dept. of Polymer Science, Box 10076, Hattiesburg, MS 39406-0076).

(June 6-10)—"Advances in Emulsion Polymerization and Latex Technology." Short course sponsored by Lehigh University, Bethlehem, PA. (Mohamed S. El-Aasser, Emulsion Polymers Institute, Lehigh University, 111 Research Dr., Bethlehem, PA 18015).

(June 13-15)—"Evaluating Coatings for Environmental Compliance: VOC & Lead Abatement." Conference sponsored by Steel Structures Painting Council (SSPC). Buena Vista Palace, Walt Disney World Village, Lake Buena Vista, FL. (Dee Boyle or Krista Hughes, SSPC, 4516 Henry St., Ste. 301, Pittsburgh, PA 15213-3728).

(June 13-16)—"Coatings Science for Coatings Formulators." Short course sponsored by University of Southern Mississippi (USM). Hattiesburg, MS. (Shelby F. Thames or Debbie Ballard, USM, Dept. of Polymer Science, Box 10076, Hattiesburg, MS 39406-0076).

(June 21-25)—"Basic Polymer and Coatings Chemistry." Short course sponsored by California Polytechnic State University, San Luis Obispo, CA. (James Westover, Chemisty Dept., California Polytechnic State University, San Luis Obispo, CA 93407).

(June 27-29)—"Coating Process Fundamentals." Short course sponsored by the University of Minnesota. Minneapolis, MN. (Jackie O'Brien, Dept. of Chemical Engineering and Materials Science, University of Minnesota, 421 Washington Ave., S.E., Minneapolis, MN 55455).

(July 11-15)—MACROAKRON '94 International Symposium. Sponsored by the International Union of Pure and Applied Chemistry. University of Akron, Akron, OH. (Dr. Joseph P. Kennedy, Organizing Chairman for the Symposium, or Cathy Manus-Gray, Symposium Coordinator, Institute of Polymer Science, The University of Akron, Akron, OH 44325-0604).

(July 18-20)—"Basic Coatings for Sales and Marketing Personnel." Short course sponsored by University of Missouri-Rolla (UMR), Rolla, MO. (Cynthia N. Campbell, UMR Coatings Institute, Dept. of Chemistry, 142 Schrenk Hall, Rolla, MO 65401-0249).

(Aug. 17-19)—1994 Weather-Ometer® Workshop. Sponsored by Atlas Electric Devices Co. Holiday Inn O'Hare, Chicago, IL. (Margaret MacBeth, Atlas Electric Devices Co., 4114 N. Ravenswood Ave., Chicago, IL 60613).

(Sept. 26-30)—"Introduction to Paint Formulation." Short course sponsored by University of Missouri-Rolla (UMR), Rolla, MO. (Cynthia

N. Campbell, UMR Coatings Institute, Dept. of Chemistry, 142 Schrenk Hall, Rolla, MO 65401-0249).

(Sept. 28-30)—"Accelerated and Natural Weathering Techniques." Short course sponsored by Kent State University, Kent, OH. (Carl J. Knauss, Director, Cooperative & Continuing Education—Chemistry, Kent State University, P.O. Box 5190, Kent, OH 44242-0001).

(Oct. 4-5)—"Advanced Radiation (UV/EB) Curing Marketing/Technology." Seminar sponsored by Armbruster Associates Inc. Marriott Hotel, Newark Airport, Newark, NJ. (David Armbruster, Armbruster Associates Inc., 43 Stockton Rd., Summit, NJ 07901).

(Oct. 4-7)—"Introduction to Coatings Technology." Short course sponsored by Kent State University, Kent, OH. (Carl J. Knauss, Director, Cooperative & Continuing Education—Chemistry, Kent State University, P.O. Box 5190, Kent, OH 44242-0001).

(Nov. 13-17)—Third North American Research Conference on Organic Coatings Science and Technology. Sponsored by the American Chemical Society, PMSE Division. Hilton Head, SC. (A.V. Patsis, Institute of Materials Science, State University of New York, New Paltz, NY 12561).

(Nov. 15-18)—"Second Color Imaging Conference: Color Science Systems and Applications." Sponsored by the Society for Imaging Science and Technology (IS&T), Springfield, VA, and the Society for Information Display (SID), Playa del Rey, CA. (Pam Forness, IS&T, 7003 Kilworth Ln., Springfield, VA 22151).

(Nov. 16-18)—1994 Weather-Ometer® Workshop. Sponsored by Atlas Electric Devices Co. Holiday Inn O'Hare, Chicago, IL. (Margaret MacBeth, Atlas Electric Devices Co., 4114 N. Ravenswood Ave., Chicago, IL 60613).

Asia

(May 18-19)—Fourth Asia/Pacific Coatings Show. Organized by the Paint Research Association. Hong Kong Convention and Exhibition Center, Hong Kong, China. (Jane Malcolm-Coe, FMJ International Publications Ltd., Queensway House, 2 Queensway, Redhill, Surrey, RH1 1QS, England).

Europe

(May 4-6)—"Coating Process Fundamentals." Short course sponsored by the University of Minnesota. Antwerp, Belgium. (Jackie O'Brien, Dept. of Chemical Engineering and Materials Science, University of Minnesota, 421 Washington Ave., S.E., Minneapolis, MN 55455).

(May 16-18)—"Waterborne Coatings—Stability and Rheology." Course sponsored by Institute for Surface Chemistry. Stockholm, Sweden. (K. Arvidsson, Institute for Surface Chemistry—YKI, P.O. Box 5607, S-114 86, Stockholm, Sweden).

(May 23-25)—International Symposium on Polymer Analysis and Characterization. Les Diablerets, Switzerland. (ISPAC Registration, 815 Don Gaspar, Sante Fe, NM 87501).

(June 5-9)—XXIInd FATIPEC Congress and Exhibition. Budapest Convention Centre, Budapest, Hungary.

(June 13-16)—"Science and Technology of Pigment Dispersion." Luzern, Switzerland. (A.V. Patsis, State University of New York, New Paltz, NY 12561).

(June 14-17)—Workshop on "Polymer Blends and Alloys." Luzern, Switzerland. (A.V. Patsis, State University of New York, New Paltz, NY 12561).

(June 20-22)—16th International Conference on Advances in the Stabilization and Controlled Degradation of Polymers. Luzern, Switzerland. (A.V. Patsis, State University of New York, New Paltz, NY 12561).

(June 21-22)—Surfex '94. Exhibition organized by Surfex Ltd., a wholly owned subsidiary of the Oil & Colour Chemists' Association. Harrogate, North Yorkshire. (H. Pooley, Surfex Ltd., Priory House, 967 Harrow Rd., Wembley HAO 2SF, England).

(July 4-8)—20th International Conference on Organic Coatings Science & Technology. Athens, Greece. (A.V. Patsis, State University of New York, New Paltz, NY 12561).

(Aug. 22-26)—"Advances in Emulsion Polymerization and Latex Technology." Davos, Switzerland. (G.W. Poehlein, OIP/CRB, Georgia Institute of Technology, Atlanta, GA 30332-0370).

(Sept. 14-15)—"Waterborne Coatings and Additives." Symposium sponsored by the Royal Society of Chemistry and the Society of Chemical Industry. Manchester Conference Centre, UMIST, UK. (Carol L. Sharp, Conference Secretary,The Royal Society of Chemistry, 41 Exeter Rd., Davyhulme, Manchester, UK, M41 ORF).

(Sept. 28-30)—"Fluorine in Coatings." Conference organized by the Paint Research Association in conjunction with Chemical-Polymer and Chemserve (UMIST). Salford, England. (Conference Secretary, Paint Research Association, 8 Waldegrave Rd., Teddington, Middlesex TW11 8LD, UK).

(Oct. 4-5)—"Polypropylene '94." Conference sponsored by Maack Business Services. Swissôtel, Zürich, Switzerland. (Maack Business Services, Moosacherstrasse 14, CH-8804 AU/Zürich, Switzerland).

(Oct. 24-28)—"Surfactants and Polymers in Aqueous Solution." Course sponsored by the Institute for Surface Chemistry. Athens, Greece. (K. Möller, Institute for Surface Chemistry—YKI, P.O. Box 5607, S-114 86, Stockholm, Sweden).

(Oct. 24-26)—"Speciality Plastics '94." Conference sponsored by Maack Business Services. Swissôtel, Zürich, Switzerland. (Maack Business Services, Moosacherstrasse 14, CH-8804 AU/Zürich, Switzerland).

(Dec. 6-7)—"Styrenics '94." Conference sponsored by Maack Business Services. Swissôtel, Zürich, Switzerland. (Maack Business Services, Moosacherstrasse 14, CH-8804 AU/Zürich, Switzerland).

Pacific Rim

(Nov. 6-10)—International Adhesion Symposium. Sponsored by The Adhesion Society of Japan. Tokyo, Japan. (Hiroshi Mizumachi, Professor, Chemistry of Polymeric Materials, The University of Tokyo, Yayoi 1-1-1, Bunkyo-ko, Tokyo 113, Japan).

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1995

North America

(Jan. 14-18)—RCMA 1995 Annual Conference & EXPO. Sponsored by the Roof Coatings Manufacturers Association (RCMA). The Ritz-Carlton Laguna Niguel, Dana Point, CA. (Sally Choquette, RCMA Meetings Coordinator, RCMA, 6000 Executive Blvd., Ste. 201, Rockville, MD 20852-3803).

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NOTE: The Advertisers' index is published for the convenience of our readers and as an additional service to our advertisers. The publisher assumes no liability for errors or omissions.

'Humbug' from Hillman

Sad to note that it appears that Sam Firestone has caught the Pundit Disease. Readers and associates are cautioned that the symptoms may be catching and might be fatal due to excessive guffawing. The first signs of Sam's affliction showed up when he became entranced by an article written by James Lipton in the *New York Times* entitled, "What Do You Call a Group of Dentists?" I quote, in part:

"Alone among the planet's babble of tongues, English often assigns to groups of things a sometimes humorous, sometimes poetic, and always revealing collective term. This linguistic pastime began in the 14th century with "terms of venery"—hunting phrases like a gaggle of geese, a pride of lions, a skulk of foxes, and a charm of finches.

. . . So, in the spirit of the 14th century, I have coined some collective terms designed to illuminate, glorify or skewer the professions and occupations of the modern world.

A perseverence of secretaries
An omnipotence of administrative assistants
A column of accountants
A riddle of economists
A clutch of corporate raiders
A lot of realtors
A pinch of producers
A slouch of models
A pound of pianists
A brow of scholars
A drove of cabbies
A horde of misers
A chisel of repairmen
A ring of jewelers
A wince of dentists
A rash of dermatologists
A nucleus of physicists
A qwerty of typists"

Apparently, his condition has worsened for Sam followed that with a letter to the editor authored by a John Terris, who responded to a letter that suggested that "Punning Pedants" should not go unPUNished with:

Ploughmen zigzagging will be farmed out.

Street sweepers found littering will be brushed aside.

Firemen failing to respond to the alarm will be extinguished.

Cocktail waiters mixing the wrong drink will be disbarred.

Accountants found transposing numbers will be discounted.

Pig farmers producing substandard stock will be disgruntled.

As if things were not bad enough, Barbara Lauren innocently sent me a copy of the following from the *Washington Post*, which resulted from a contest in the paper asking readers to "come up with headlines representing the next step in political correctness mania":

And the winner was:

- Congress Approves Five Day Waiting Period for Men Wanting Sex

Some of the runners up:

- Candidates to Seek Consent before Kissing Babies
- Congress Outlaws Death—It is "Ageist" Lawmakers Conclude
- Manic-Depressives Protest Term "Gay"—Demeans Those Who Choose to Stay in Bed and Brood
- Nobel Prize Discontinued—Found to Discriminate Against Mediocre Persons
- Native Americans Protest Use of "Geronimo" by Paratroopers, Suggest Substitution of "Gesundheit"
- Santa to Get Extra Reindeer—Ahmed, Jorge, and Motohiro to Join Sleigh
- Caucasian Group Protest Mimes' Use of Whiteface
- And last: Expression "Politically Correct Deemed Offensive—Use is Banned Under New Speech Code"

Let's return to what amounts to erudition and to our esteemed Technical Editor, Dr. Bob Brady, who thinks that he found the following from a book review in the *Economist*:

Frank Lloyd Wright, by Meryl Secrest, Chatto & Windus; 634 ($20 & $35)

Some time in 1935, Herbert Johnson—heir to the Johnson's Wax empire—saw the plans for Fallingwater, Frank Lloyd Wright's "organic" house in Bear Run, PA. Impressed, Johnson immediately commissioned Wright to design a corporate headquarters for his Wisconsin-based firm and another house, Wingspan, for his family.

As things turned out, the three buildings were to be alike in a way that Johnson may not have expected. Where a stream meandered romantically through the foundations at Fallingwater, rain poured through the ceilings of Wingspan and the Johnson office building with every passing storm. When this fault was pointed out to the architect, his apocryphal response was less than helpful. "Three hundred leaks?" sniffed Wright, "then buy 300 buckets."

Apropos to the above story, Humbug found an article by the same author, Meryle Secrest, in the February *Smithsonian* in which Secrest revealed the punch line in the Fallingwater problem. His cousin, for whom the Wright house was built, irately called complaining that the leaking roof was pouring water on his desk. Wright calmly replied, "Richard, why don't you move your desk?"

The trouble with being a leader today is that you can't tell if the people are following you or chasing you.

If at first you don't succeed, try looking in the wastebasket for directions.

—The Lion

—Herb Hillman
Humbug's Nest
P.O. Box 135
Whitingham, VT 05361

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