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MAY 1982



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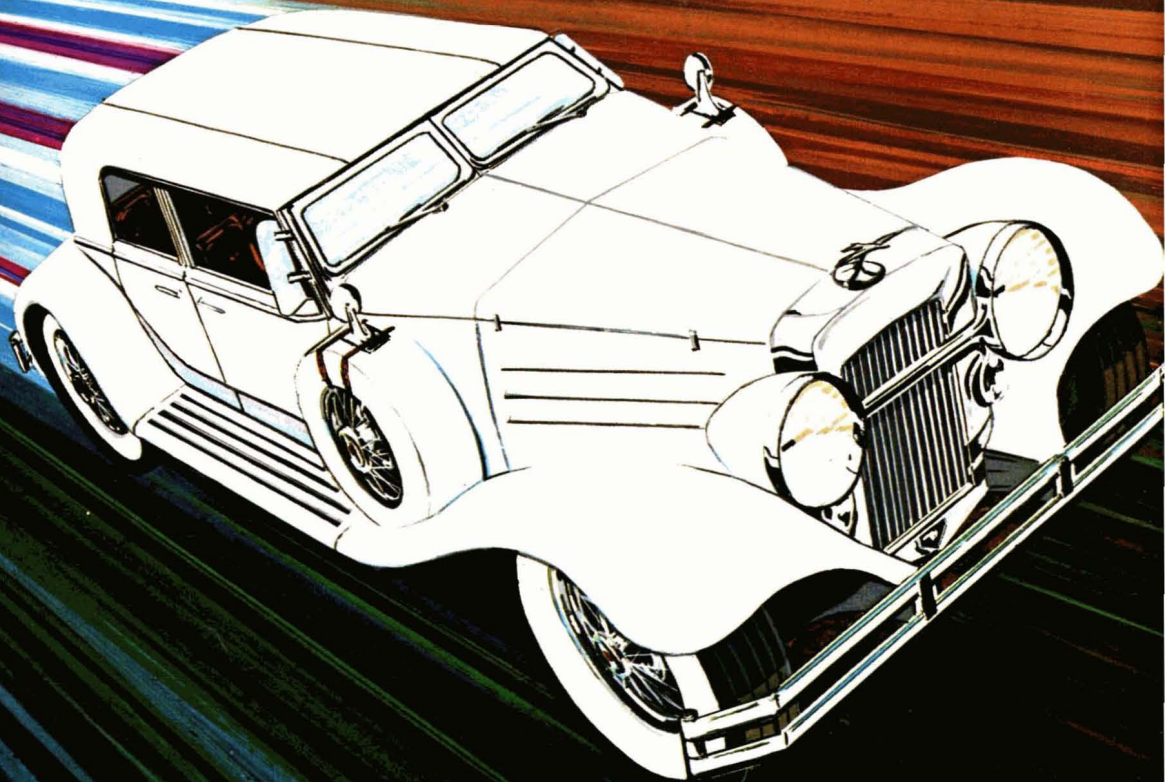
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JOURNAL OF COATINGS TECHNOLOGY

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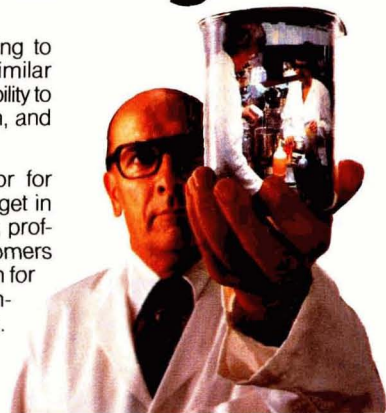
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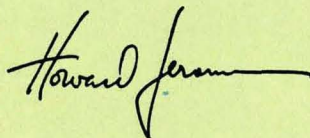
The Federation Executive Committee has instructed your President to appoint an Ad Hoc committee to "study and suggest ways and means for the Federation to promote and publicize career opportunities in the coatings industry." The prime reason for this action is that we, as an industry, are not achieving the degree of success we should have in attracting students to coatings-related programs at universities.

The St. Louis Society has, for some years, maintained close liaison with local high school science teachers. In all those years, very few students from Missouri have enrolled in the coatings-related courses at the University of Missouri at Rolla.

Recently, the St. Louis Paint and Coatings Association offered a scholarship of \$1,080 for a student to attend Rolla. This information was publicized in all area high schools. Not one student applied for this grant, even though it covered two full year's tuition, including books. I have been told that similar situations exist with other Society grants.

In the January 1982 issue of *CHEMTECH*, the Editor noted that Peter Yankowich, V.P. for Academic Affairs at the University of Illinois, characterized the industry/academic interface as a "hammer/anvil relationship." How appropriate. Lots of noise, lots of sparks. But if there is nothing between the hammer and the anvil, not much else is produced.

The new Ad Hoc Committee is chaired by Dr. Herman J. Lanson, who has been requested to have a report for the 1982 Annual Meeting. If any member can be of some assistance to this committee, please communicate directly with Dr. Lanson at LanChem Resin Corp., 2904 Missouri Ave., E. St. Louis, IL 62205.



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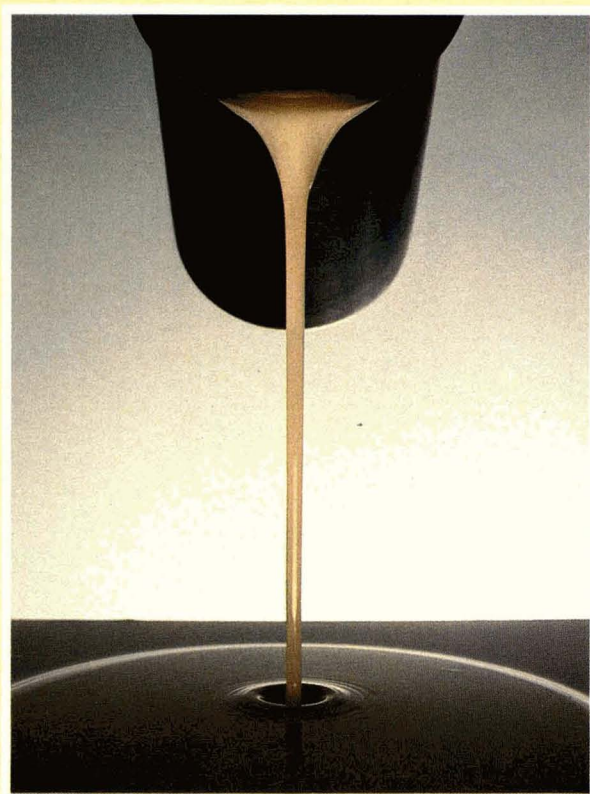
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Abstracts of Papers in This Issue

RECLAIMING THE ENERGY VALUE OF COATINGS WASTES THROUGH PYROLYSIS—Louisville Society for Coatings Technology

Journal of Coatings Technology, 54, No. 688, 23 (May 1982)

Ten of the twenty paint manufacturers in the Louisville, Kentucky area were sent questionnaires to survey production rates and waste generation rates. Data from the seven respondents show approximate values of waste generation as follows: 10,000 gal/mo cleaning solvent, 12,000 gal/mo process water, 3800 gal/mo paint sludge, 26,300 gal/mo off-specification batches, and 30,000 pigment bags/mo.

A waste treatment process consisting primarily of solvent recovery distillation under vacuum and heat followed by pyrolysis of the remaining solution of resin has been investigated. An actual industrial sales sample was subjected to solvent recovery at 61 kPa absolute for one hour and pyrolysis at each condition in a $2 \times 3 \times 3$ factorially designed experiment. Two levels of pressure (3000 kPa and 4000 kPa), three levels of temperature (600 K, 650 K, and 700 K), and three levels of pyrolysis duration (1.0 hr, 1.5 hr, and 2.0 hr) were used. The weight fractions of the resultant products showed that the quantity of pyrolytic liquid produced was favored by high temperatures and long times.

Solvent recovery returns the most valuable component for reuse as a material resource. Pyrolysis converts a resin solution into a fuel-like liquid which has value as an energy resource. The solid residue, which is of little value, appears to be a candidate for landfill disposal or use as an inert filler.

CATHODIC ELECTRODEPOSITION—M. Wismer, et al.

Journal of Coatings Technology, 54, No. 688, 35 (May 1982)

Cathodic electrodeposition coating technology has progressed to the point of significant worldwide penetration of automotive, industrial, and appliance markets. The development of this technology is discussed, and its merits with respect to alternate coating processes are described.

The process, its resin chemistry, and its total system composition and performance are reviewed. Selected physical and electrochemical concepts relating to performance are discussed.

EVALUATION OF LININGS FOR SO₂ SCRUBBER SERVICE—D.M. Berger, R.J. Trewella, and C.J. Wummer

Journal of Coatings Technology, 54, No. 688, 47 (May 1982)

Lining materials to protect steel surfaces from corrosion were evaluated utilizing the Atlas Test Cell. Collected gas condensate from within an operating flue following a SO₂ Scrubber Unit was analyzed and used as the media within the cell. This synergistic test correlated closely with field experience and appears to be a very effective method to evaluate coating materials. Microscopic observations of both coating and steel were made after completion of the test.

MORPHOLOGY OF 'WATER-SOLUBLE' ACRYLIC COPOLYMER SOLUTIONS—Z.W. Wicks, Jr., E.A. Anderson, and W.J. Culhane.

Journal of Coatings Technology, 54, No. 688, 57 (May 1982)

It has been previously proposed that "water-soluble" acrylic copolymers dissolved in cosolvent aggregate on dilution with water. The presence of aggregates has now been confirmed by microscopy and ultrafiltration. It has also been demonstrated that the aggregates are highly swollen with water and cosolvent. Viscosity is independent of molecular weight in relatively dilute, low cosolvent ratio systems. However, viscosity is very dependent on molecular weight at intermediate concentrations or cosolvent ratios even though the copolymer is completely aggregated. It is proposed that viscosity of such systems is dependent on aggregate phase viscosity.

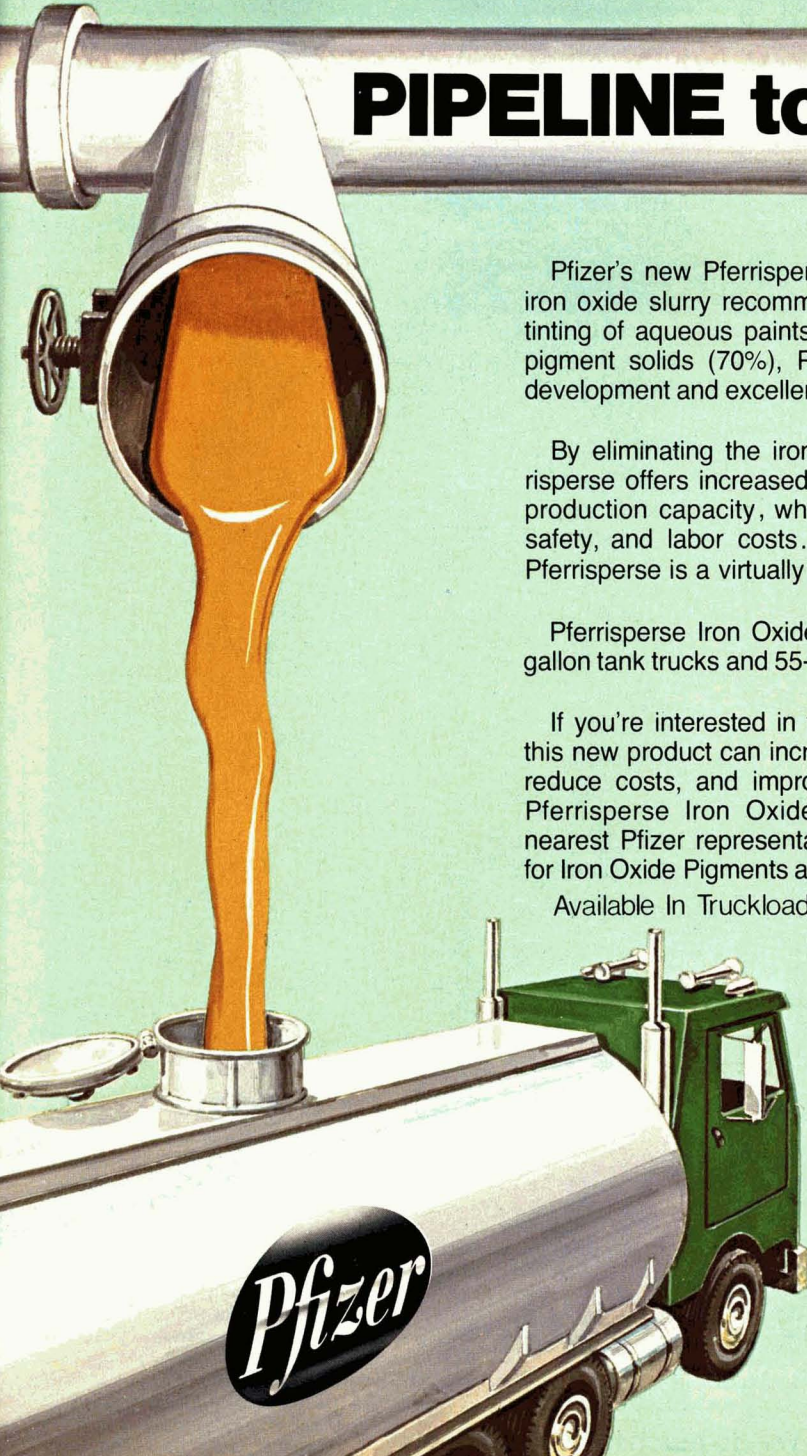
EQUATIONS FOR CALCULATING HOMOLOG SOLUBILITY PARAMETERS. THE LIMITING SOLUBILITY PARAMETER—C.H. Fisher

Journal of Coatings Technology, 54, No. 688, 67 (May 1982)

Simple logarithmic equations ($\sigma = b + m \log(x + k)$) were developed for relating homolog solubility parameters (σ) to number of carbons (x). These equations (k , adjustable parameter), which confirm Seymour's observation that σ is linear with $\log x$, can be used to evaluate published solubility parameters and to calculate new ones. The solubility parameters of some moderately polar homologs may be represented by simple linear equations ($\sigma = b + mx$). Equations are provided for relating homolog solubility parameters to several other properties. Some of the equations suggest the limiting solubility parameters (σ_{∞} for an n -alkane of infinite length) is approximately 8.8.

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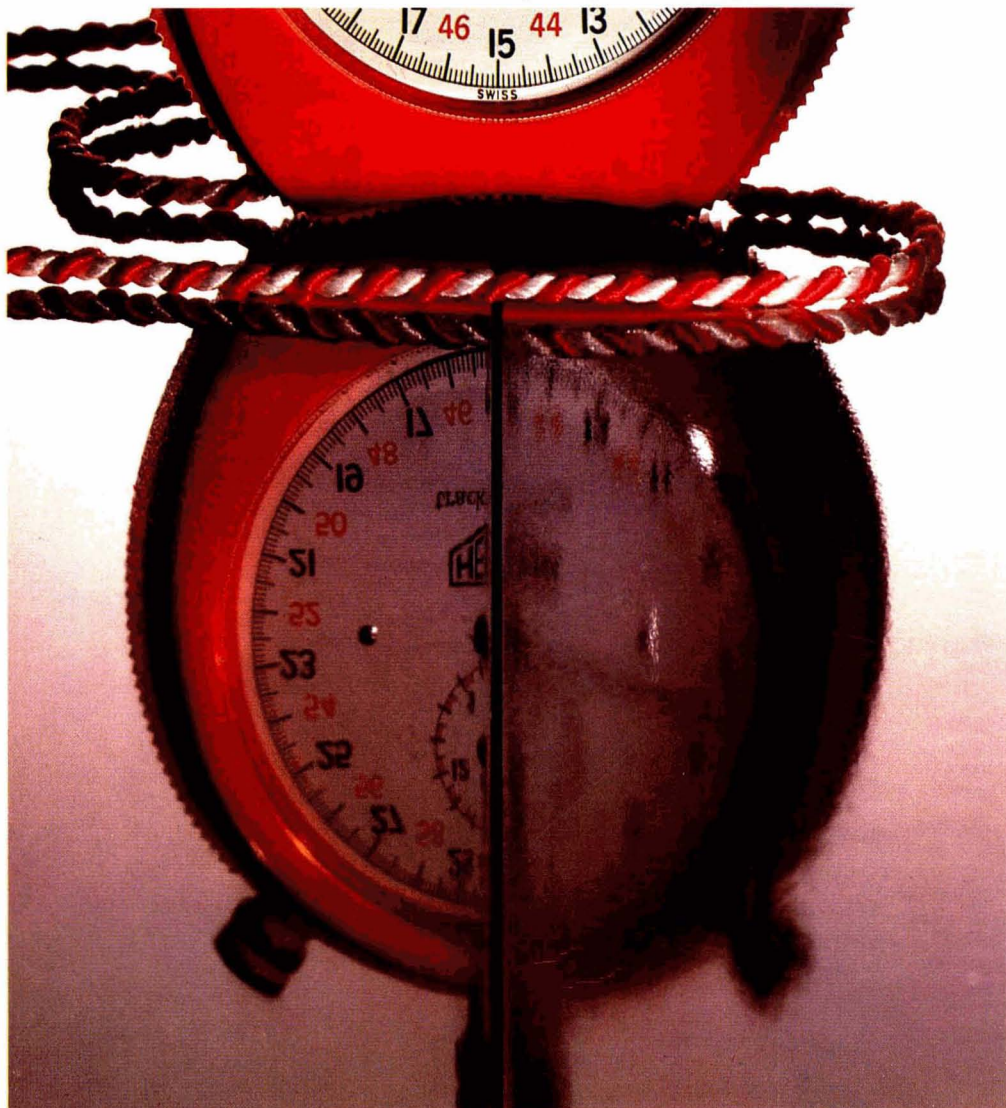


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Journal of Coatings Technology

1982 Annual Meeting Highlights

Washington, D.C. • Nov. 3-5

Program

The 60th Annual Meeting program will open Wednesday, November 3, at the Sheraton Washington Hotel in Washington, D.C.

Program Chairman John C. Ballard, of Kurfees Coatings, Inc., Louisville, has announced the theme, "Quality Designed/Confidence Renewed," and he and his Program Steering Committee are developing a schedule of presentations around this topic.

Featured presentations tentatively scheduled include:

- Keynote Address
- Mattiello Lecture by Dr. Shelby F. Thames (see accompanying story on page 16)
- Paint Research Institute Session honoring Research Director Dr. Raymond R. Myers
- Symposium on Ensuring Quality Management and Technology Through Computer Utilization
- Manufacturing Committee Seminar on computer applications in the coatings industry, focusing on various areas of production
- Symposium on Designing Quality Through Use of Scientific Instrumentation
- Education Seminars

Concurrent sessions will be held throughout the three-day meeting, but papers will be scheduled so as to avoid conflicting presentations.

Paint Industries' Show

To be held concurrently with the Annual Meeting, the 1982 Paint Show will offer attendees the exhibits of over 155 supplier firms.

The Paint Show is the only national exhibit of raw materials and equipment used in the manufacture of paints and related coatings, and participating firms will have their top technical personnel on hand to discuss the latest developments in coatings manufacturing technology.

Show hours will be noon to 5:30 p.m. on Wednesday, November 3; 9:30 a.m. to 5:00 p.m. on Thursday, November 4; and 9:30 a.m. to 4:00 p.m. on Friday, November 5.

Headquarters Hotel

The Sheraton Washington will serve as headquarters hotel. Other hotels with blocks of rooms set aside for the Annual Meeting are the Shoreham, Washington Hilton, and the DuPont Plaza.

Room Reservations

All requests for rooms and suites must be sent to the Federation office on the official housing form which has been mailed to all members and is included in this issue (see pages from 17-19). Additional housing forms are available from the Federation headquarters office.

NPCA Meets Same Week

The National Paint & Coatings Association will hold its annual meeting on November 1-3 at the Washington Hilton.

The back-to-back scheduling of Association and Federation events provides coatings industry personnel with a full week of programming.

Registration Fees

Regular "on-site" registration fees will be \$50 for Federation members and \$65 for non-members. Advance registration will be available for \$40 for members and \$55 for non-members. Fee for spouses' activities will be \$35 on-site and \$25 in advance.

Once again there will be a special registration fee of \$20 each for retired members and their spouses. This applies to advance registration only.

In Washington, the registration hours will be: Tuesday, 1:00 p.m. to 5:00 p.m.;

Wednesday, 8:00 a.m. to 5:30 p.m.; Thursday, 8:00 a.m. to 5:00 p.m.; and Friday, 8:00 a.m. to 4:00 p.m.

Registration forms will be included in future issues of the *JOURNAL OF COATINGS TECHNOLOGY*, and were mailed to all members in April.

Spouses' Activities

Included in the spouses' registration fee will be a get acquainted wine and cheese social on Wednesday afternoon; continental breakfast on Thursday and Friday at the Sheraton Washington; and a guided tour of Annapolis (with lunch) on Thursday.

Federation Luncheon

The Annual Federation Luncheon will be held on Friday at the Sheraton Washington.

Presentations will be made to the recipients of the George Baugh Heckel Award (outstanding individual who has contributed to the advancement of the Federation) and the Flynn Awards (firms judged to have the best exhibit booths in the 1982 Paint Industries' Show).

The featured speaker will be Mark Russell, well-known political satirist, who stars in his own show on the PBS network and is regularly featured on NBC's "Real People."

(Continued on page 16)



The U.S. Capitol, perhaps the most famous building in the United States, will be visited by many members of the paint industry this November

Dr. Shelby F. Thames, of USM, To Present 1982 Mattiello Lecture At Federation Annual Meeting in D.C.

The Federation of Societies for Coatings Technology is pleased to announce that Dr. Shelby F. Thames, Vice-President for Administration and Regional Campuses at the University of Southern Mississippi, will present the 1982 Joseph J. Mattiello Memorial Lecture at the 60th Annual Meeting of the Federation, to be held November 3-5 at the Sheraton Washington Hotel, in Washington, D.C.

Dr. Thames will speak on, "Bunte Salts as Crosslinking Agents in Thermosetting Water-Borne Polymers," at the morning session on Friday, November 5.

Joined USM in 1964

Dr. Thames, a native of Hattiesburg, Miss., the site of USM, received his B.S. Degree at the University in 1959, and his Master's Degree in 1961. He received the Ph.D. Degree from the University of Tennessee in 1964 and began his professional association with USM as Assistant Professor of Chemistry that year, teaching courses in general and organic chemistry, polymer science, and surface coatings.

Dr. Thames is probably best known for his direct involvement in the establishment of USM's Department of Polymer Science, the first autonomous academic department in the U.S. for training B.S. Degree graduates in polymers and coatings. The department is now known nationwide and boasts of seven full-time faculty, and a total of 75 majors at the B.S., M.S., and Ph.D. levels. It presently has the highest per capita research funding level of any department in the university.

Dr. Thames was made Chairman of the department in 1970 and in 1971 became Dean of the University's College of Science and Technology, where he developed nine new degree programs bringing the total degree offering to 20 with an annual class enrollment of over 20,000 students.

Research

Dr. Thames' educational philosophy embodies the concept that research is a worthwhile and meaningful activity



which, if administered and conducted in the proper perspective, enhances the instructional function of a university. This philosophy is practiced personally in that he has authored or co-authored 37 scientific publications and presented 50 lectures to scientific organizations and groups. He has competed for and secured research funds in excess of one million dollars during his tenure at the university.

As a result of his scientific activities he has served as a consultant or lecturer to: the National Aeronautics and Space Administration, Paint Research Institute, Standard Paint and Varnish Co., Union Carbide Corp., Hercules Incorporated, Diamond Shamrock Corp., Wilmington Enameling Co., the DeVilbiss Co., Dow Corning Corp., U.S. Steel Corp., and Sears, Inc.

He presented the Keynote Address at the 1974 Annual Meeting of the Federation.

Vice-President—Administration

As Vice-President for Administration, Dr. Thames has the responsibility of overseeing the regional Gulf Coast and

Natchez campuses, USM's Division of Extension and Public Service, the Alumni Association, the University's Computer Center, Office of Public Relations, and the Office of Research and Sponsored Programs.

In addition, Dr. Thames is the University's official liaison with the Mississippi state legislature, where he is active in lobbying for the needs of the University and higher education in general.

Dr. Thames is a member of the Southern Society for Coatings Technology, the American Chemical Society (in which he is a Past-Chairman of the Mississippi Section), American Association for the Advancement of Science, and the American Institute of Chemists.

Annual Meeting Highlights

(Continued from page 15)

Program Committee

Assisting Chairman Ballard on the Program Steering Committee are: Peter Hiscocks (Vice-Chairman), of CIL Paints, Inc., Toronto; Steven Crouse, of Kwal Paints, Denver; Loren W. Hill, of Monsanto Co., Indian Orchard, MA; Gus W. Leep, of Seymour of Sycamore, Sycamore, IL; Robert G. Modrak, of Benjamin Moore & Co., Milford, MA; Tom Ruland, of Cook Paint & Varnish Co., Houston; and Gary Van de Streek, of Wyandotte Paint Products Co., Troy, MI.

Mr. Hiscocks will be Chairman of the Program Committee for the October 12-14, 1983 Annual Meeting and Paint Show in Montreal, Que., Canada.

Host Committee

Members of the Baltimore Society are serving on the Host Committee under General Chairman Gordon Allison, of McCormick Paint Works. Assisting him are: Mitchell Dudnikov, of Genstar Stone Products; James A. McCormick, of Inland Leidy; and Thomas Mitchell, of Tenneco Chemicals, Inc.

Mrs. Gordon (Margaret) Allison is serving as Spouses' Program Chairman.

Federation of Societies for Coatings Technology

HOUSING FORM

1982

60th ANNUAL MEETING
47th PAINT INDUSTRIES' SHOW

WASHINGTON DC

SHERATON
WASHINGTON
HOTEL

NOVEMBER 3, 4, 5, 1982



**FEDERATION OF SOCIETIES FOR COATINGS TECHNOLOGY
 1982 ANNUAL MEETING AND PAINT INDUSTRIES' SHOW
 SHERATON-WASHINGTON HOTEL, WASHINGTON, DC
 NOVEMBER 3, 4, 5
 (Wednesday, Thursday, Friday)**

APPLICATION FOR HOTEL ACCOMMODATIONS

MAIL TO:	Fed. Socs. Coatings Tech. 1315 Walnut St.—Dept. H Philadelphia, PA 19107
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Please indicate below the type of accommodations requested and choice of hotels. All reservations will be processed by the Housing Bureau of the Washington Convention & Visitors Assn. Hotel assignments will be made in accordance with prevailing availability. The Housing Bureau will send you an acknowledgment, noting the hotel to which you have been assigned. The confirmation of your reservation will come to you directly from the hotel, to whom you must direct all inquiries. No reservations at cooperating hotels can be guaranteed after October 4.

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

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

NAMES AND ADDRESSES OF ROOM OCCUPANTS AND DATES OF ARRIVAL/DEPARTURE

Type of Room	Name	Address	Dates	
			Arrive	Depart

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

SEND CONFIRMATION FOR ALL RESERVATIONS TO:

NAME _____

COMPANY _____

ADDRESS _____

CITY _____ STATE _____ ZIP _____

TELEPHONE _____

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

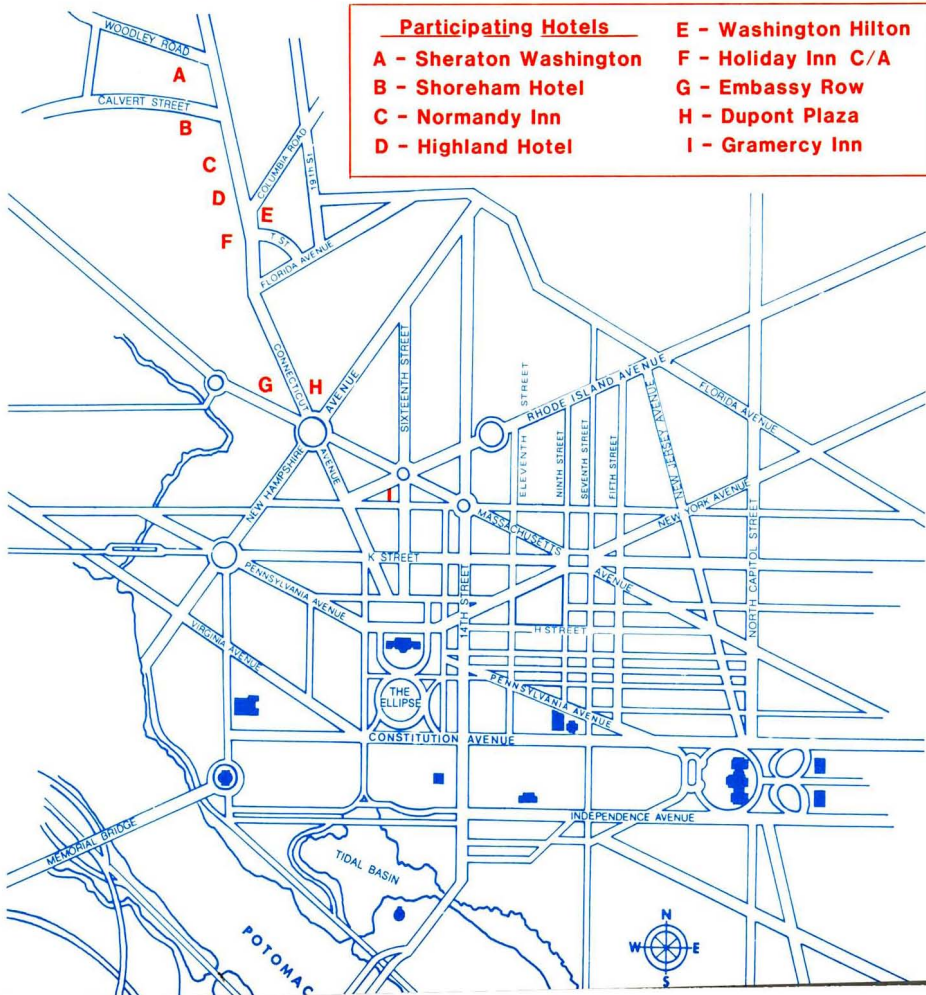
HOTEL INFORMATION AND RATES

All room rates in Washington, DC are subject to an additional Sales Tax of 10%, and .80¢ per night, per room occupancy tax.

Hotel	Singles	Doubles Twin	Parlor & 1 Bedroom	Parlor & 2 Bedrooms
SHERATON WASHINGTON* (see below)	\$81/90/95	\$95/105/109	\$180/240 260/275	\$265/325 345/360
SHOREHAM	\$75/80	\$87/92	\$125/200	\$225/400
WASHINGTON HILTON† (see below)	\$60/80/90 100/110	\$78/98/108 \$118/128	\$198/378 478	\$326/506 606
DU PONT PLAZA	\$65/76	\$85/95	\$170/200	\$240/270
GRAMERCY INN	\$64	\$74	\$130	—
EMBASSY ROW	\$95	\$115	\$175	\$250
HIGHLAND	\$60/70	\$80	\$100	—
HOLIDAY INN	\$57	\$65	—	—
NORMANDY INN	\$56	\$66	\$120	—

*Requests for accommodations at the Sheraton Washington will be limited to seven rooms per company. A parlor counts as one room. Additional reservations will be assigned to other cooperating hotels.

†Reservations for the Washington Hilton will be accepted for arrival beginning Wednesday, November 3, only.



LIAISON

Progress Report on IUPAC's Supported Polymer Films Group

The International Union of Pure and Applied Chemistry (IUPAC) is the only international organization that is involved with *all* branches of chemistry. Its purpose is the advancement of chemistry and the world-wide dissemination of such knowledge. Created after World War I, the IUPAC, in the United States, is an arm of the National Academy of Sciences—National Research Council. A total of about fifty national organizations are represented in IUPAC.

We in the organic coatings industry are fortunate to be represented by a Supported Polymer Films Group (SPF) which is part of the large Macromolecular Division of IUPAC. The official representatives to this group are Percy Pierce, of the Pittsburgh Society; Milton A. Glaser, of the Chicago Society; and Raymond R. Myers (for the American Chemical Society), of the Cleveland Society.

The Macromolecular Division will meet at its Symposium at the University of Massachusetts, in Amherst on July 12–16.

The following is a progress report of the Group by its Secretary, Dr. J. Sickfeld, of Germany. Included are the minutes of the Group's meeting in Sassenheim, The Netherlands, held on October 1–2, 1981. It is felt that information on these activities will be of interest to all JCT readers.

MILTON A. GLASER,
Federation Liaison Committee

CHAIRMAN'S REPORT AND MEMBERSHIP

Chairman Dulog addressed the participants of the last meeting of IUPAC's Supported Polymer Films Group at Sassenheim, the Netherlands, and gave a report on the results of a meeting of Commission 4 of IUPAC-Macromolecular Division (MMD) held from August 26 to 28, 1981, at Leuven, Belgium.

In this meeting the IUPAC-working principles were once more stressed as already cited in the last report (JCT, March 1981, p. 20) with the addition that the projects should be finished within a definite time of not more than one year and a half, and that all members of a working party should actively contribute to the projects, meaning that the participants to the projects should themselves be the members of the working parties.

Three new participants were welcomed to the group: Mr. David Lovegrove, of Carrs Paints Ltd., Birmingham, UK as a representative for the Federation of Societies for Coatings Technology; Mr. Erich V. Schmid as a representative of the Schweizerische Vereinigung der Lack- und Farbenchemiker (SVLFC); and Mr. Olof Vorster, of the Technikon Pretoria, South Africa. Dr. Søren Hvilsted was substituting for Dr. Hansen, of the Scandinavian Paint and Printing Ink Research Institute, and Dr. Vollmer

had expressed his wish to resign from membership.

PROGRESS REPORT

Analytical Group—With the current project on the "Stability of Amino Resin Containing Systems" headed by Luthardt, difficulties were encountered with the application of ^{13}C -NMR in connection with a new model polyester. This compound, synthesized by Biethan, fulfilled one requirement of ^{13}C -NMR that the absorption bands of the polyester did not interfere with those of the functional groups; however, problems with solubility have developed, and so another model polyester must be prepared.

The project on the "Analysis of Emulsion Paints" headed by Hansen has been started, and Hvilsted gave a first report on the results of the analysis of three emulsion paints by three participating laboratories, namely those of Christensen (Sadolin & Holmblad), of Scandinavian Paint and Printing Ink Research Institute itself, and of Mr. Swafford, of Glidden Coatings & Resins, Strongsville, Ohio. All participating laboratories were to apply their own analytical facilities. No problems arose with the determination of the nonvolatile content, the total pigmentation, and the content of organic nonvolatiles. Fairly good agreement was reached with the identifi-

cation of the organic binders and that of the volatiles. But there were greater problems with the analysis of the additives, as could be expected. Additional results are expected from three laboratories (from England, India, and South Africa). Sickfeld reported on the application of Thermogravimetry (TG), the results being in good agreement with the respective results reported by Hvilsted. The evaluation of the TG-curves have also resulted in the speculation of the presence of dolomite in one of the paints, which has been verified according to the theoretical formulation of the paint. The evaluation of the DTG-peaks (DTG = derivative thermogravimetry) was shown to be of some value in comparing the composition of the binders, i.e., especially for control purposes, although at the moment it is not possible to identify the binders by means of DTG.

Adhesion Group—With respect to the adhesion-project, Zorll presented a short retrospective view about past works of different members of the group. In the discussion about the advantages and disadvantages of the different methods of testing, application problems, and limits, Van Laar mentioned his lecture in Athens in July 1977 (Third International Conference in Organic Coatings Science and Technology), "Filiform Corrosion and General Climatic Deterioration of Painted Steel," and to his works concerning the blister method imitating the effects which lead to the detachment of coatings as a consequence of corrosion processes; he was asked to prepare a final draft for publication of his results. Sickfeld mentioned his lecture, "Pull-off Test for Adhesion-Relevance of Test Results" (Symposium on Adhesion Aspects of Polymeric Coatings in Minneapolis, MN, in May 1981), containing a number of practical examples for the application of the pull-off test together with results concerning the influence of a number of different test parameters on test results. Kollek reported on the influence of structures in polymers on adhesion, a subject started in the last year. A zone of lower crosslinking can be found in the neighborhood of the boundary layer, the properties of which are influenced by the surface pretreatment of the metal. Kollek, at the request of Zorll and with the

(Continued on page 30)

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Resins Division

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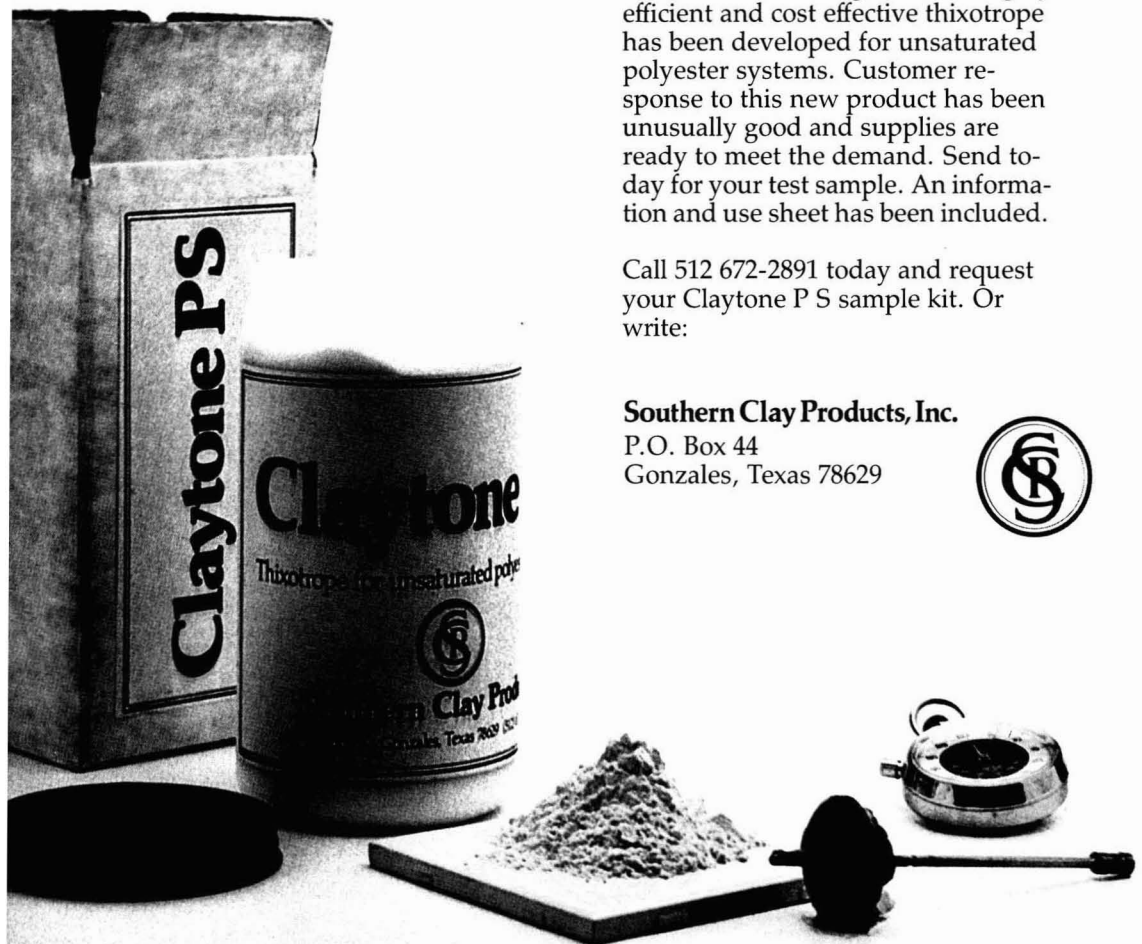
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Reclaiming the Energy Value Of Coatings Wastes Through Pyrolysis

Louisville Society for Coatings Technology
Dean O. Harper,* Joseph R. White,* and Michael A. Brewer*

Ten of the twenty paint manufacturers in the Louisville, Kentucky area were sent questionnaires to survey production rates and waste generation rates. Data from the seven respondents show approximate values of waste generation as follows: 10,000 gal/mo cleaning solvent, 12,000 gal/mo process water, 3800 gal/mo paint sludge, 26,300 gal/mo off-specification batches, and 30,000 pigment bags/mo.

A waste treatment process consisting primarily of solvent recovery distillation under vacuum and heat followed by pyrolysis of the remaining solution of resin has been investigated. An actual industrial sales sample was subjected to solvent recovery at 61 kPa absolute for one hour and pyrolysis at each condition in a $2 \times 3 \times 3$ factorially designed experiment. Two levels of pressure (3000 kPa and 4000 kPa), three levels of temperature (600 K, 650 K, and 700 K), and three levels of pyrolysis duration (1.0 hr, 1.5 hr, and 2.0 hr) were used. The weight fractions of the resultant products showed that the quantity of pyrolytic liquid produced was favored by high temperatures and long times.

Solvent recovery returns the most valuable component for reuse as a material resource. Pyrolysis converts a resin solution into a fuel-like liquid which has value as an energy resource. The solid residue, which is of little value, appears to be a candidate for landfill disposal or use as an inert filler.

INTRODUCTION

Representatives of the Louisville Society for Coatings Technology, the Louisville Paint and Coatings Association, the Economic Development Office of the City of Louisville, and the Department of Chemical and Environmental Engineering of the University of Louisville joined together to seek a long range solution to the problems of waste products disposal from the coatings industry. This tripartite group of industry, government, and academia contributed ideas based on the economically reasonable, the legally permissible, and the scientifically feasible. The sources of the wastes were considered to be (a) wash wastes and (b) off-specification material. Any proposed solution would have to be applicable to both oil-based and water-dispersed systems.

The academic team developed a research proposal which would (a) assess the magnitude of the problem in our area and (b) determine the feasibility of a waste treatment process based on the following criteria.

(1) Recovery of the solvent for reuse as a material resource has the highest priority.

(2) Processing of the resin content of the waste to permit utilization of its energy value as a fuel.

(3) Production of a leach-stable solid waste from the pigment/additive portion.

(4) The off-gases from the process must meet, or be treatable to meet, the legal restrictions on air pollution. Two possibilities were suggested for criterion (item 2)—incineration and pyrolysis. The former is the thermal decomposition of matter in the presence of oxygen (combustion); the latter is the thermal degradation of matter in the absence of oxygen. Pyrolysis has the following advantages over incineration: the pyrolysis products may be stored and shipped, to be used as an

Presented at the 59th Annual Meeting of the Federation of Societies for Coatings Technology, October 29, 1981 in Detroit, MI.

*Mr. Harper is Associate Professor of Chemical Engineering, Dept. of Chemical and Environmental Engineering, University of Louisville, Louisville, KY 40292. Mr. White is with Westvaco, Box 278, Wickliffe, KY 42087. Mr. Brewer is associated with Procter and Gamble, Foods Div., 6071 Center Hill Rd., Cincinnati, OH 45224.

**Table 3—Louisville Area Waste Generation Summary—
Unadjusted Values as Reported**

Cleaning Solvent
10,000 Gal/ Month (100%) ^a
Process Water
1,900 Gal/ Month (16%)
Paint Sludge
2,600 Gal/ Month (69%)
Off-Specification Batches
5,000 Gal/ Month (19%)
Pigment Bags
5,264 Bags/ Month (18%)

(a) Percent production by respondents.

**Table 4—Louisville Area Waste Generation Summary—
Values Adjusted for Percent Production**

Cleaning Solvent
10,000 Gal/ Month (182) ^a
Process Water
12,000 Gal/ Month (218)
Paint Sludge
(3,800 Gal/ Month) ^b (68)
Off-Specification Batches
(26,300 Gal/ Month) (480)
Pigment Bags
30,000 Bags/ Month

(a) Equivalent number of 55 gallon drums.
(b) Adjustment procedure questionable.

batches per month, the volume of waste generated per batch, the solvent type, and the usage of cleaning recycle. Finally, information was sought on waste generated from flushing of milling machines, reclaimed solvent procedures and costs, off-specification batches, and waste disposal facilities.

The summary of the production values as reported by the seven companies which returned the completed forms is presented in *Table 1*. From these data, a rough estimate of the total production for the Louisville area may be made by multiplying these figures by three. A more sophisticated estimate might be made on the assumption that the Louisville production profile follows that of the nation as a whole. National data on the number of plants producing a given volume per month, the distribution of plants engaging in trade sales and/or industrial coatings, the distribution of water-based and/or solvent-based plants, etc., are available.⁷ *Table 2* shows one summary that indicates a predominance of industrial sales.

The waste production data, as reported by the seven participating companies, is summarized in *Table 3*. The corresponding percentages give the portion of the reported Louisville production accounted for by the companies providing the given waste data. Hence, if the reporting company's performance is typical of the others, one may estimate the total Louisville waste generation by dividing the waste amount by the percentage and multiplying by three. White⁸ has written, "The waste types 'off-specification batches' and 'paint sludge' cannot be adjusted in this manner since the amount of reworking of (the former) varies and the waste type 'paint sludge' is not common to all companies." *Table 4* gives values of the waste production of the seven reporting companies, adjusted for their production percentages.

The Kentucky Department of Natural Resources and Environmental Protection requires waste generators to register the amount they generate per year. For 1979, the hazardous waste generators' registration forms were examined, wherein a total of 50,500 gal/mo. had been reported. Of this amount, about 28,000 gal/mo. could be associated with the companies included in the survey. This total compares favorably with the adjusted total as predicted above.

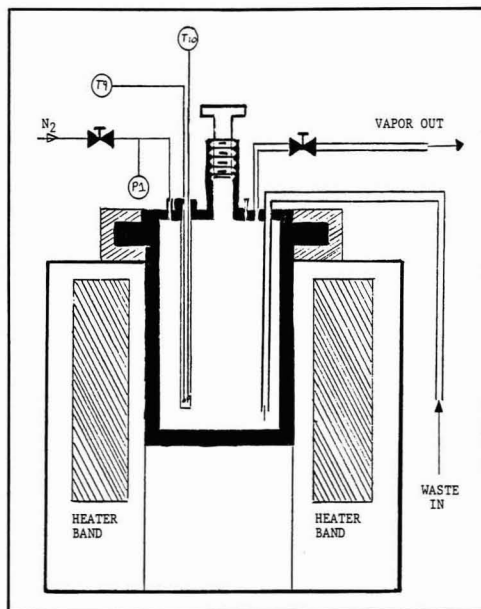
This brief summary of a small portion of the survey results⁴ illustrates the magnitude of the coatings waste problem in the Louisville area. Numerous correlations

are presented in the full report concerning the details of waste generation and waste treatment. Our purpose here is to ascertain (i) the amount of cleaning solvent that should be recovered for reuse as a material resource and (ii) the amount of paint sludge and/or off-specification material that represents a potential energy resource through some process such as incineration or pyrolysis. *Table 4* shows that the latter may range from one-half to four times the volume of the solvent to be recovered.

PROCESS

Introduction

A proposed waste treatment process was suggested by the criteria listed above. Given a "typical" paint waste that contains solvent, dissolved resin, suspended solids, and (perhaps) foreign material,

**Figure 2—Pyrolysis reactor**

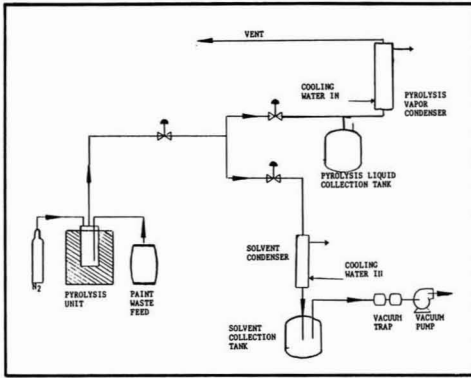


Figure 3—Experimental pyrolysis unit

- (1) remove any macroscopic matter in order to render the sample treatable as a solution or a slurry;
- (2) perform a solvent recovery process through the use of heat and/or vacuum, such as ordinary distillation, steam distillation, thin film evaporation, or the like;
- (3) pyrolyze the remaining resin solution to thermally

Table 5—Experimental Procedure and Design

1. Sample — One liter, 50% solids.
2. Solvent recovery — heated for 1 hr at $P = 61$ kPa.
3. Pyrolysis —
 - a.) $P = 3000$ or 4000 kPa;
 - b.) $T = 600, 650,$ or 700 K;
 - c.) $t = 1.0, 1.5,$ or 2.0 hr.
4. Weigh solvent recovered, pyrolytic liquid, and solid; calculate gas fraction by difference.
5. Factorial design ($2 \times 3 \times 3$) interpreted via ANOVA.

degrade the polymer to smaller molecules which may serve as an energy resource;

(4) separate the remaining solids from the pyrolyzed liquid and dispose or utilize this material;

(5) monitor the off-gases of the entire process to be assured that the procedure is legally permissible.

In order to test such a process, and to use that test to obtain preliminary data on the pyrolysis step, a sample of an actual paint waste was obtained from a local manufacturer of industrial coatings; the sample(s) was provided in three, five-gallon cans, only one of which was used since no uniformity of the waste(s) between these cans could be assumed. The pyrolysis vessel was an

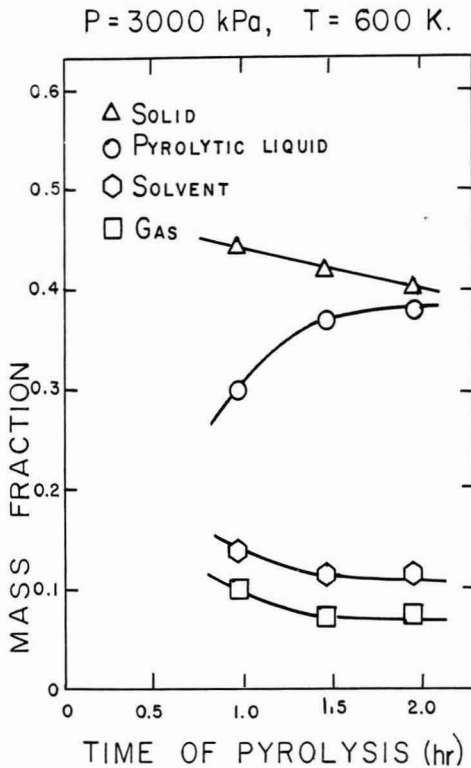


Figure 4—Effect of pyrolysis duration on the mass fractions of solid residue, pyrolytic liquid, solvent recovered, and off-gases, at a pressure of 3000 kPa and a temperature of 600 K

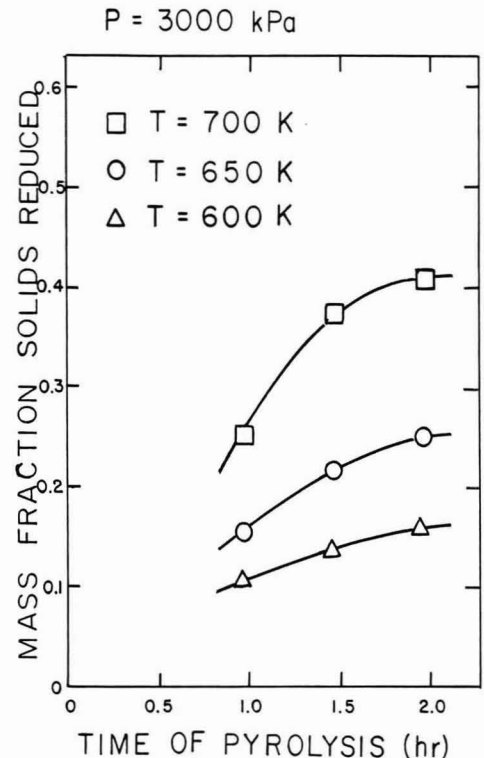


Figure 5—Effect of time and temperature on the mass fraction of solids reduced, at a pressure of 3000 kPa

electrically heated, unagitated, one-liter "combustion bomb" type cylinder, shown in *Figure 2*. This vessel was connected to the other items necessary to carry out the solvent recovery step and the collection of the condensable vapors from the pyrolysis step; the off-gases passed through a wet test meter (not shown in the process schematic) in order to measure their volume (See *Figure 3*).

Thermodynamics of Pyrolysis

Since polymerization reactions are exothermic it was anticipated that the thermal degradation reactions of pyrolysis would be endothermic. Polymerization reactions are thermodynamically feasible since the molecular ordering they bring about is greatly outweighed by the negative enthalpy contribution; that is, for the free energy change to be negative, the heat of reaction must be more negative than the "temperature times entropy-change" is positive. Therefore, for pyrolysis to be thermodynamically feasible, the entropy term must be more negative than the heat of reaction is positive. This accounts for the necessity of high temperatures for pyrolysis.

Experimentally, since the pyrolysis reactions must take place in the absence of oxygen (to prevent combustion), a nitrogen blanket was used. In addition, this nitrogen was

used to provide a high pressure above the degrading resin to raise the boiling points of the newly formed compounds. This permitted the use of a water condenser to recover the pyrolytic products.

Experimental Procedure and Design

The industrial sample, as supplied, measured approximately 50 weight percent solids. Therefore, each one liter sample charged to the unit was adjusted to be about that value (See *Table 5*). The solvent recovery process was carried out under vacuum (61 kPa absolute) and heating as the temperature of the vessel was brought towards the desired temperature of pyrolysis. This step lasted for approximately one hour.

A $2 \times 3 \times 3$ factorial design was planned for the experiments. The design was limited by the fact that each sample had to come from only one, five-gallon can. Guessing that temperature might play a more important role than pressure, only two levels were chosen for the latter. Three levels of temperature were scheduled, as were three "levels" of the duration of pyrolysis. About the latter, it is important to note that the pyrolysis process was halted after 1.0 hr, 1.5 hr, and 2.0 hr; different samples were used for each of these times. The results shown as a function of time are not sequential histories of a single sample.

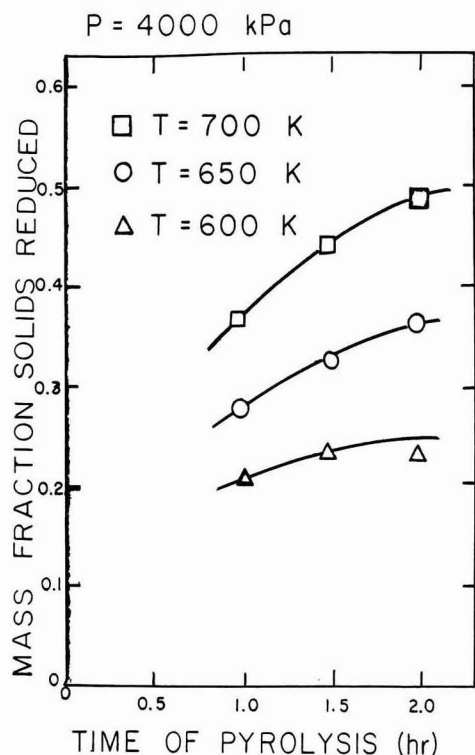


Figure 6—Effect of time and temperature on the mass fraction of solids reduced, at a pressure of 4000 kPa

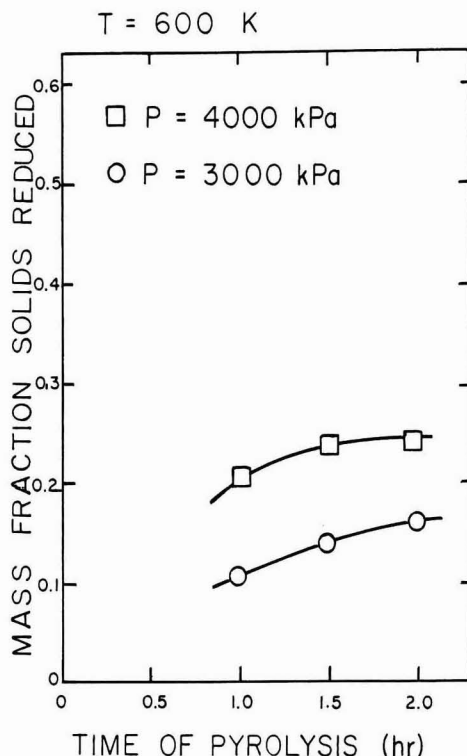


Figure 7—Effect of time and pressure on the mass fraction of solids reduced, at a temperature of 600 K

With pressure, temperature, and time as the independent variables, the primary dependent variable selected was weight fraction of each product phase. The initial weight of the sample was measured; the weight of the solvent recovered was measured; the weight of the pyrolytic liquids was measured; the weight of the resultant char was measured; thus, the weight of the off-gases was determined by difference. From these, data curves of weight fraction of product phase were plotted as functions of pressure, temperature, and time. Figure 4 shows the results for $P = 3000$ kPa and $T = 600$ K after the three preselected times of pyrolysis. These data are typical of those from the six P, T treatment conditions.

Results

As observed in Figure 4 the weight percent solids decreases with the duration of pyrolysis, illustrating that the resin content is diminishing. The weight fraction of the pyrolytic liquid shows a concomitant increase. Although the solvent recovery steps were run in such a manner as to attempt to collect the same amount each time, the data for this particular set of conditions (three runs, one for each time) show a slight variation—a decrease from one run to the other two. The net result of these changes are reflected in a similar slight decrease in the amount of off-gases produced. However, neither of

these last two changes were found to be statistically significant.

Effects of Pressure and Temperature

The effects of pressure and temperature can best be seen on graphs of mass fraction of solids reduced, Figures 5–9. By comparing Figures 5 and 6 one can see that an increase in pressure brings about an increase in the fraction of solids reduced. Likewise, each of these figures shows that an increase in temperature has a similar effect. These graphs also show that the data tend to level off after about two hours. The effect of pressure at each temperature studied may be observed in Figures 7–9.

ANOVA (Analysis of Variance)

An analysis of variance was performed on the collected data, from which the following conclusions may be made.

- (1) Temperature alone was significant at the 99% level as an influence on the yield of pyrolytic liquid.
- (2) Pressure, temperature, and time were each significant at the 99% level as influences on the yield of the solid residue; in addition, the temperature-time interaction term was significant at the 95% level.
- (3) Pressure alone was significant at the 99% level as an influence on the yield of the off-gases; in addition, the

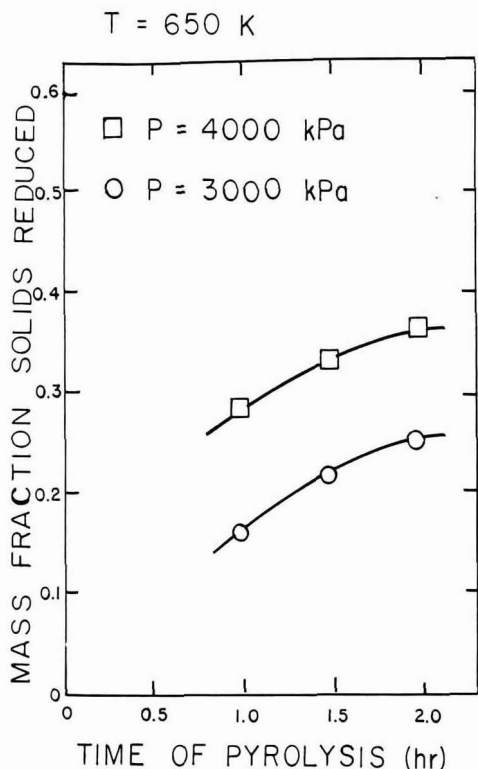


Figure 8—Effect of time and pressure on the mass fraction of solids reduced, at a temperature of 650 K

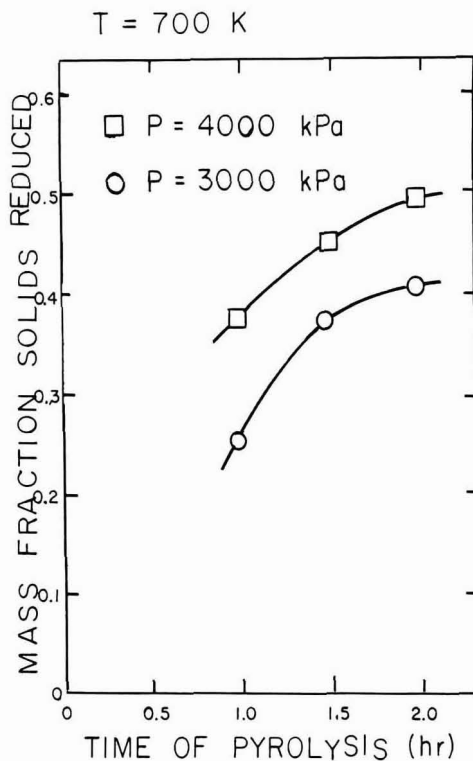


Figure 9—Effect of time and pressure on the mass fraction of solids reduced, at a temperature of 700 K

pressure-time interaction term was significant at the 95% level.

Continuing Analyses

Continuing analyses are being made of the 54 products that remained from the study. For each of the 18 treatment combinations of the independent variables, retained were the (1) solvent recovery fractions, (2) pyrolytic liquid fractions, and (3) solid residues. Characterization of the solvent recovery fractions will determine their suitability for reuse as material resources. Characterization of the pyrolytic liquid fractions will determine those properties important in their use as energy resources, such as density, viscosity, flash point, heat of combustion, etc. The solid residue samples will be subjected to leaching studies to determine their suitability for disposal at a landfill or utilization as inert fillers.

No estimate has as yet been made on the energy balance of the proposed waste treatment process. It consumes energy. After the heating value of the pyrolytic liquid has been determined, one may ascertain if this process is a net-consumer or net-producer of energy.

SUMMARY

The waste products from the coatings industries of the Louisville, Kentucky area are of sufficient magnitude to warrant the development of a treatment process. With increasing costs of solvent for use in the cleaning steps of paint production, primary concern should be given to the recovery of spent solvent for reuse as a material resource. With increasing costs of heating fuels, whether for paint production or the comfort of employees, consideration should be given to utilizing the energy content of those wastes.

Pyrolysis of the resin solutions that remain after solvent recovery produces liquids with physical characteristics like those of the fuels. The thermal degradation pyrolysis reactions (in the absence of oxygen) are a function of the pressure, temperature, and duration of the process. Of these variables temperature was found to be the most important.

At the present time the solvent has the highest dollar value of the products of the waste treatment process; hence, one should maximize the recovery of this valuable material resource. Heating fuels are only slightly less valuable (or costly); hence, the pyrolysis process should be operated in such a way as to maximize the production of the pyrolytic liquids. This means using high tempera-

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tures (700 K) for extended periods of time (1.5–2.0 hr). The resulting solid residue is of very little value; the concern here is for determining a safe and legal method for its disposal.

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- (8) Ref. (4), 45.

Battelle Proposes to Study Emerging Membrane Technology

How companies can benefit from emerging membrane technology will be identified in a research program being proposed by Battelle's Columbus Division.

Membranes, typically made of polymeric materials with a range of strength and permeation properties, are useful in separation processes. They have a number of current or potential applications, including uses in paints, dyes, batteries, chemicals, drugs, electrolysis cells, water treatment, dairy products, and medical equipment.

According to Battelle's Dr. Melville E. D. Hillman, membrane systems have been expanding rapidly in the past few years due to technological innovations, lower costs, and changing sociological conditions. Further expansion is likely to occur in the next 10 years. However,

companies seeking business opportunities in membranes must identify the most appropriate and economical technology if they are to profit from the expansion. These companies also need to identify and project markets and uses for membranes, and consider the availability of materials to produce membranes.

The Battelle study will identify technical performance characteristics, product availability, manufacturing processes and manufacturers, and current uses and markets. In addition, Battelle will forecast future uses and markets through 1992.

To be sponsored on a group basis by a number of companies, the study will be of particular benefit to membrane producers and users and to producers and suppliers of materials used in fabricating membranes.

During the program, researchers will review available data and patents concern-

ing membrane systems. In addition, they will identify and interview leading suppliers of membranes and present and prospective users.

Membrane systems to be analyzed include reverse osmosis, dialysis and electro dialysis, electrolysis, and ultrafiltration. In addition, battery separators and gas and vapor separators will be studied.

Membrane materials to be analyzed include cellulose acetate, polyamides, polysulfone, dimethyl siloxane polymers and copolymers, fluorinated polymers, polypropylene, polycarbonate, poly(vinyl chloride), polystyrene, polyethylene, and impregnated cellulose.

Membership in the 10-month study is available for \$7,500.

Additional information can be obtained from Dr. Melville E.D. Hillman, Battelle's Columbus Div., 505 King Ave., Columbus, OH 43201.

SPF Progress Report

(Continued from page 20)

approval of the group, took over the leadership of the project. Zorll was asked to prepare a publication containing the results of investigations performed within the group during the past years.

New Analytical Projects—Oesterle presented some further remarks concerning his proposed project on the "Properties of Supported Polymer Films and the Related Bulk Polymers." As a means for characterization of such differences he applied a special hardness testing evaluation, IMD, and especially commented on epitactic effects of the substrate influencing the physical properties of the organic coating at the interface to the substrate on account of orientation effects of polarizable groups in the organic binder. This effect was called "Increase of IMD by Transmission of Epitactic Effects" (IITE).

Kooistra presented a proposal for a new project, "Characterization of Cure of Coatings in Relation to Performance Properties." This proposal will be discussed in detail at the next meeting of the SPF-group possibly in connection with the XVth FATIPEC Congress to be held in Liege, Belgium, in May 1982. In case this meeting cannot be realized the next meeting shall take place in Switzerland during October 1982.

J. SICKFELD, *Secretary*

American Chemical Society Division of Organic Coatings and Plastics Chemistry

Membership and Preprint Information

The Division of Organic Coatings and Plastics Chemistry was founded in 1924 as the Paint and Varnish Division. Over the years, the interests of the Division's members have come to include adhesives, biomedical polymers, composites, electronic applications, plastics and other areas of applied polymer science and technology in addition to organic coatings. This diversity of interest is reflected in the symposia sponsored by the Division. Recent titles include Biological Activities of Polymers, Plastics for the 1980s, Non-Polluting Paint Technology, Polymers and Coal, Fast Polymerization Reactions and Reaction Injection Molding, Emulsion Polymerization, and Advances in Coating Metals for Corrosion Protection.

Since its founding, the Division has participated in all but two of the ACS's regular National Meetings. It frequently joins with other ACS Divisions in joint and co-sponsorship of symposia and is an active participant in the Macromolecular Secretariat. Member participation in program planning and in the operation of the Division is actively encouraged.

Proceedings of the Division of Organic Coatings and Plastics Chemistry meetings are published as preprints shortly before the ACS Spring and Fall national meetings. Combined, the two volumes bring about 1500 pages of current technical information to members. The preprints also have long term reference value and library subscriptions are available. Membership of the American Chemical Society is a prerequisite for full membership in the Division. Affiliate membership of the Division is available for nonmembers of the ACS; affiliate members receive the preprints and other benefits of membership, but may not vote or hold office in the Division. Division membership is U.S. \$10.00 annually; affiliate membership is U.S. \$12.00. Contact the Division's membership chairman for details:

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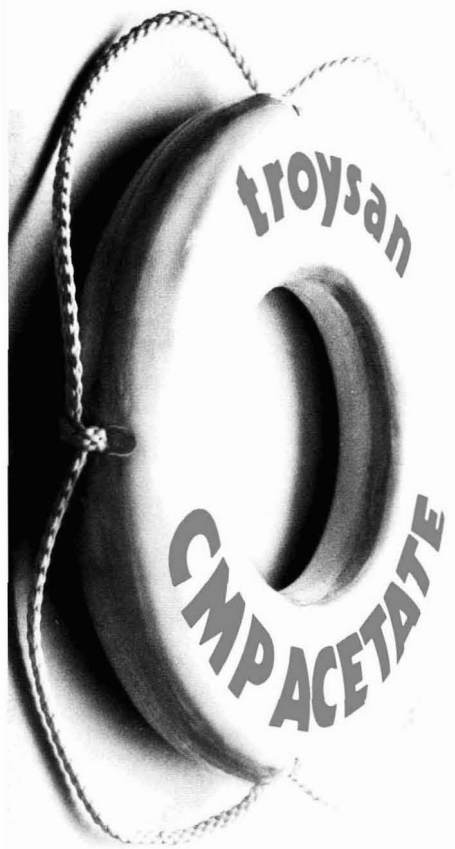
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Cathodic Electrodeposition

M. Wismer, P.E. Pierce, J.F. Bosso,
R.M. Christenson, R.D. Jerabek, and R.R. Zwack
PPG Industries, Incorporated*

Cathodic electrodeposition coating technology has progressed to the point of significant worldwide penetration of automotive, industrial, and appliance markets. The development of this technology is discussed, and its merits with respect to alternate coating processes are described.

The process, its resin chemistry, and its total system composition and performance are reviewed. Selected physical and electrochemical concepts relating to performance are discussed.

INTRODUCTION

Since the introduction of the electrodeposition process for painting metal objects in the early 1960's, this process has been adopted worldwide in the automotive, industrial, and appliance areas to provide the first or prime coat and topcoats to a variety of products.

The first electrodeposition process to attain commercial importance was anodic electrodeposition. In the anodic process the part to be coated is made the anode. The advantages of the electrodeposition process are its automated character, high efficiency of coating utilization, low levels of pollution, and high throwing power, i.e., the ability to coat recessed areas in complex metal shapes such as automotive bodies.

Recently, cathodic electrodeposition has assumed major worldwide commercial significance in the industrial, appliance, and automotive areas. In the cathodic process, the part to be coated is made the cathode. The cathodic process retains the advantages of the anodic process and provides, in addition, higher levels of corrosion protection.

The process, the resin chemistry, and system compositions will be described. Some selected physical and

electrochemical concepts that relate to various performance parameters and variables of the process will also be discussed.

The successful commercialization of the cathodic electrodeposition process required substantial contributions from many people. The references cited in this paper give some indication of the magnitude of these efforts.

ELECTRODEPOSITION AND ITS DEVELOPMENT

Organic coatings can be applied from aqueous media to a conductive substrate by a process known as electrodeposition. Upon application of a direct current, charged polymers will migrate electrophoretically to the electrode of opposite charge, become insoluble, and form an insulating film which limits further deposition. When negatively charged polymers deposit on the anode, the process is termed anionic or anodic electrocoating. When positively charged polymers deposit on the cathode, it is referred to as cationic or cathodic electrocoating.

Electrophoresis and electrodeposition of colloids have proceeded from laboratory experiments in the 19th century to widespread commercial use today.¹ In the 1920's, it was used for deposition of rubber latex. In the 1930's, Crosse and Blackwell electrodeposited lacquer emulsions on the inside of food containers. Modern electrodeposition technology, however, began in 1959 with research by Ford Motor Company on the anodic electrocoating of automobiles,^{2,3} resulting in the first modern electrodeposition plant in 1963. The development of electrocoating technology proceeded very rapidly, and in 1971, cathodic electrodeposition was introduced to the appliance industry. By 1976 high throwpower cathodic automotive systems appeared and were in use by the automotive industry. Cathodic electrodeposition has since become predominant for the coating of automobiles and appliances, while anodic technology remains competitive in many other applications.

*Rosanna Dr., P.O. Box 9, Allison Park, PA 15101.

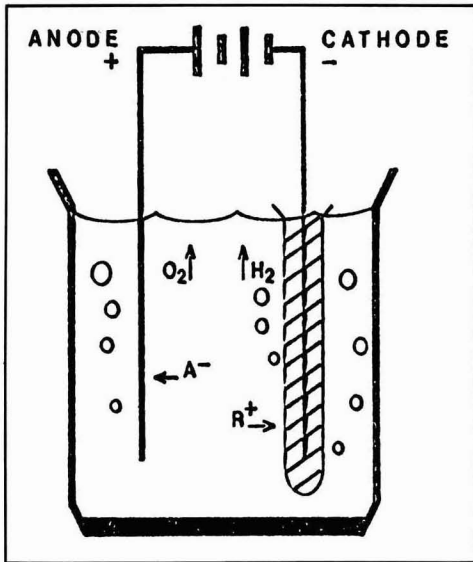


Figure 1—Schematic diagram of the cathodic electrodeposition process

As compared to conventionally applied systems, the advantages of electrocoating are as follows:

- (1) Very uniform coverage is obtainable, including that on edges and corners.
- (2) Access to partially closed areas is good.
- (3) The film deposits at very high solids, eliminating problems of sagging and vapor washing in closed sections.
- (4) Coatings can be formulated with minimal organic solvent content, important for safety and environmental considerations.
- (5) Utilization of paint is high, normally over 90%.
- (6) Complete automation is possible.
- (7) As opposed to conventional water-base systems, the counterion required for dispersion does not usually codeposit with the film and affect film properties.

The disadvantages of electrocoating are as follows:

- (1) Because of required electrochemical considerations, formulation latitude is limited. High pigment levels, soluble or impure anticorrosive pigments, and other highly ionic water soluble species cannot be tolerated.
- (2) Film build is self-limiting, and rarely exceeds 50 microns.
- (3) Only conductive items are coatable.
- (4) It is difficult to coat several colors.
- (5) Initial installation costs are high, and considerable plant space is required.

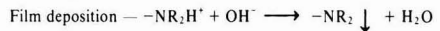
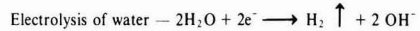
CATHODIC SYSTEMS— REACTIONS AND MECHANISMS

Cathodic electrolytes are polymers with basic moiety in the form of primary, secondary, or tertiary amines, or quaternary ammonium, sulfonium, or phosphonium groups, neutralized with organic or inorganic acids. They form positively charged resin micelles in aqueous media.

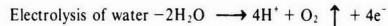
When such a polymer is dispersed in water and supplied with conductive electrodes and direct current, the following physical processes and chemical reactions occur.⁴

ELECTROPHORESIS: The positively charged particles or micelles, under the influence of the electric field, migrate to the cathode.

CATHODIC REACTIONS: (Refer to Figure 1)



ANODE REACTIONS: (Refer to Figure 1) (Assumes inert anode)



ELECTROOSMOSIS: The deposited film is adherent and develops a high resistance. The high voltage gradient across the film produces a phenomenon known as electroosmosis in which water and anions migrate towards the anode and are squeezed out of the film. This results in a very concentrated deposit, normally less than 10% water.

The advantages of cathodic electrodeposition are:

- (1) There is very minimal dissolution of coated part into the film.
- (2) Films are alkaline and readily formulated to be free of saponifiable sites.
- (3) Deposition takes place in a reducing atmosphere, as opposed to an oxidizing atmosphere which can cause chemical complications.
- (4) They can be formulated for excellent color control.

APPLICATIONS

Uses for cationic electrocoating systems are as primers, one-coat systems, and in miscellaneous industrial areas. Automotive applications include primers on automotive bodies and small parts. The driving force for this application is the outstanding corrosion resistance coupled with high throwpower that is attainable in such coatings. Baking temperatures on the order of 360° F are ordinarily used although there are new developments that will cure somewhat lower. The cationic systems are replacing the previous anionic systems at a rapid rate. The anionic systems previously used were based on epoxy esters, allyl alcohol-styrene copolymer esters, and polybutadiene. The conversion of anionic primer tanks to cathodic primer tanks is far advanced in the United States and Japan and is rapidly progressing in western Europe and other automotive manufacturing areas. Quite a high

percentage of the tanks in appliances, approximately 45%, use cationic systems for the significant advantages in detergent and corrosion resistance in such systems.

While the highly corrosion resistant systems can provide good protection as one-coat systems, they are often deficient in retained gloss and color when used in exterior applications. They are principally epoxy resin based materials cured with blocked aromatic isocyanates.¹² Certain beiges and grays have proven useful as one-coat systems despite this handicap, if care is taken in regard to baking schedules and tank control. There are a number of applications in the general industrial area where corrosion resistance is deemed important, or where there are some other special product requirements that are well suited to cationic technology. Cationic systems are usually more costly than the older conventional anionic systems, a fact which has inhibited a broad scale invasion of the industrial market.

A relatively new area is the introduction of acrylic cationic systems cured with blocked aliphatic isocyanates where excellent durability or light colors, or corrosion resistance, superior to anionic acrylics, is desired. An example of this is the one-coat application to agricultural implements. While there is a substantial sacrifice in corrosion resistance over the cationic aromatic epoxy systems, it is deemed satisfactory for the end uses involved. A technical challenge is a highly durable system with the corrosion resistance of the aromatic epoxy capped isocyanate cured product.

An interesting sidelight to cationic coatings is that their field performance often is far superior to anionic systems even when panel work would indicate a much more modest differentiation. Air conditioners coated with an epoxy cationic system, while showing chalking due to the epoxy, were excellent in field corrosion tests at very severe sites, such as Daytona Beach, FL, as compared to control experiments run with anionic systems. Field tests on automobiles, both in proving ground and in commercial use, have shown a very substantial superiority over the older anionic systems. This fact accounts for the very rapid penetration and shift to cationic systems by the automotive industry.

Some statistics on the use of cationic electrocoat systems may be of interest. In the U.S., approximately 64 tanks in the automotive industry are in operation and only one is anionic. About two-thirds of automobiles produced in the U.S. are electrocoated. Outside of the U.S., 40% of the electrocoated automobiles are being coated with cationic systems and the situation is changing rapidly. Eleven out of 24 appliance electrocoat tanks in the U.S. are cationic systems, but only a few appliance cationic tanks are in operation outside the U.S. In the industrial area, there are about 30 cationic systems operating in a variety of end applications. There are a few acrylic one-coat tanks in operation, coating agricultural machinery and also one tank coating microwave ovens.

There are some special problems in introducing cationic electrocoat systems. Fortunately, electrocoat compositions for primers are available that can be used in systems designed for anionic electrocoating without the necessity of repiping to corrosion resistant materials. The corrosion rate is so low that steel piping, pumps, etc.,

can still be used. Tanks, however, are ordinarily lined. The current acrylic systems, however, do require corrosion resistant equipment especially when close color control is needed for the final film. The high throw corrosion resistant materials used as primers require the use of membrane boxes which is ordinarily a new installation cost. Ultrafiltration can prevent special problems.

ULTRAFILTRATION

Ultrafiltration has become virtually essential for the economic utilization of electrocoating.^{6,7} The same truth, of course, extends to cationic systems. The benefits are increased efficiency on the order of 98-99% of the paint used as compared to previous levels of 70-80%. This efficiency also is of great aid in controlling volatile organic emission. Ultrafiltration also avoids increasingly difficult waste disposal problems that would exist without it. A third advantage is the possibility of using ultrafiltration for bath control. If there should be any contamination of the bath or any accumulation of undesirable species, ultrafiltration provides a means that did not previously exist for getting rid of these contaminants. Another previously unsung advantage is the use of laboratory ultrafiltration for diagnosis of problems in the bath that can exist in these complex systems. With ultrafiltration, the continuous phase can be separated from the colloidal dispersion of resin, pigments, and other components to the point that minor constituents, which could be causing problems, can be isolated, identified, and appropriate action taken.

The discovery of ultrafiltration was based on an observation of proposed uses of ultrafiltration in pretreatment of sewage waste. It was found, contrary to the prediction of many, that it worked well with anionic paints. The molecular weight of the resin systems used in these paints was not high enough to account for their rejection of the membrane and led to the unexpected observation that despite this theoretical prediction of inoperability, the system worked well. Since that time, with the benefit of hindsight, it has been rationalized on the presence of the resin in micelles large enough to be rejected by the membranes, rather than having a true solution of the polymeric species involved. Ultrafiltration is distinguished from reverse osmosis in that it will allow certain small molecules, which are deleterious, to pass into a stream which can be further treated or discarded, as compared to a total rejection of almost all the components of the bath that can exist in reverse osmosis. From a practical standpoint, ultrafiltration rates and pressures are so vastly superior to reverse osmosis that it is a readily used process in the hundreds of installations of electrocoating. The time span between the laboratory discovery and the first commercial use of ultrafiltration on electrocoating tanks was very brief. A period of a few weeks elapsed between initial laboratory success and a commercial installation at General Motors Company. Fortunately, the sewage program resulted in modules available from Dorr-Oliver that were already engineered and adaptable for quick trial.

Unfortunately, cationic electrocoat paints did not

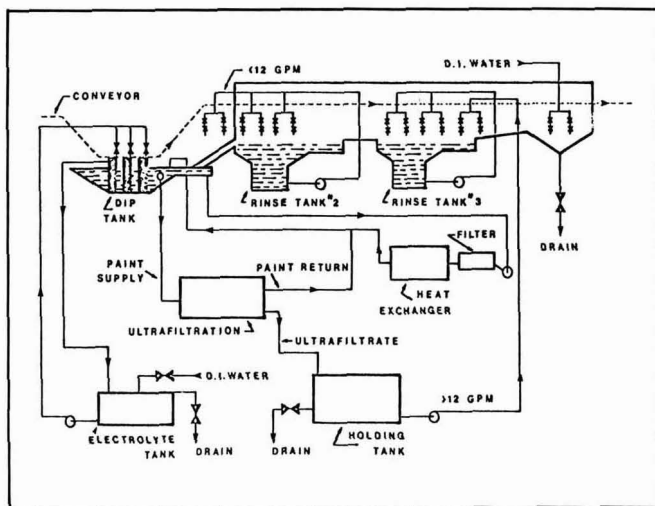


Figure 2—Typical commercial automotive cathodic electrodeposition installation

work well in the ultrafiltration membrane systems that were highly successful in anionic paints. There was a time of real crisis in the early days of cationic systems to find a membrane that would do the job without fouling after a few days or weeks. Fortunately, in a cooperative program with PPG Industries, Inc., one of the membrane suppliers, Abcor, discovered a membrane system that would work.⁸ Today, in addition to the Abcor equipment which is a large tube system, there is other operable ultrafiltration equipment available that is working well. The other domestic type from Romicon is a smaller hollow fiber type that is often equipped with automatic backwashing and cleansing cycles. There are also some systems devised abroad, both hollow fiber and flat plate types which do an acceptable job. Membrane technology has now advanced to the point that the ultrafiltration of cationic systems is well in hand.

Many different modes of operation have been proposed for ultrafiltration. In the early days, the ultrafiltration rinse water was considered a possibility, with the concentrate returned to the tank and the clear permeate used for additional rinsing. But, the usual mode today is to ultrafilter the bath itself and return rinse water, often after several stages of rinsing, back to the tank. In some installations, the so-called straight through system, the bath material is simply pumped through the ultrafilter with the appropriate separation of permeate and bath components. Other installations use a system where a smaller portion of the bath is continually made up for the loss of permeate and recycled through the ultrafilter at high rates. There are some economics of design in using this latter system. Rinse systems are variable but the usual sequence is to have several rinse stations, using either clear permeate or some deionized water or a combination of the final rinse. The rates of ultrafiltration on a commercial tank will usually be in the range of 10 to 30 gal/ft² of membrane per day.

The diagram of the electrocoating process, shown in Figure 2, shows a typical arrangement of the electrocoating tank and the auxiliary equipment needed for

rinsing and ultrafiltration. Again, ultrafiltration has achieved worldwide use and is an integral part of the electrocoating process.

MEMBRANE BOXES AND ELECTRODES

In the early days of anionic electrocoat systems, electrodes were often made of carbon. These were clumsy, heavy, and prone to breakage. Most electrodes today use appropriate grades of stainless steel and, if the anolyte concentrations are controlled properly, prove to be a reasonable and effective anode material. If one is willing to sacrifice some of the desirable attributes involving very high throw systems, it is not technically impossible to design systems that will incorporate well enough in the bath to use an anion deficient feed material to control the bath. Another disadvantage to such systems is that the dispersion step of going from a non-aqueous to an aqueous system tends to be left in the customer's hands and if done improperly can cause severe practical problems in settling and other bath control problems. Electrode boxes will have, of course, a membrane between the bath and the anode. Both ion-selective and nonion selective membranes have been successfully used in commercial installation. The required characteristics are enough physical strength in the membranes to give a practical utility and the ability to pass the anion without passing essential or significant quantities of any bath component. The ionic type, of course, accomplishes this, but in addition, certain microporous materials such as microporous polypropylene or other microporous polymeric materials will work without the necessity of using ion-selective membranes.

METAL PRETREATMENT

In the initial work on cationic systems, these materials were applied to pretreatments and substrates that had been optimized for anionic systems. In general, results were good even with this disadvantage. In fact, in testing

over a wide variety of substrates of various qualities, cationic systems would usually demonstrate their inherent advantage. Since the advent of cationic electrocoating, however, pretreatments have been designed that give an optimum performance of the total system. It is strongly recommended that cationic systems be given the maximum chance to demonstrate their properties by the selection of the most appropriate pretreatment. If the very best corrosion resistance is needed and required, a chrome rinse pretreatment will give the highest order of performance.

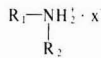
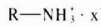
Studies of pretreatments for use under cathodic systems have highlighted the importance of the type of metal cleaning employed;⁵ the beneficial effect of passivating rinses;⁹ the effect of phosphate structure and morphology when passivating rinses are omitted;¹⁰ and the effect of pretreatment porosity on salt spray performance and its relation to metal surface contamination.¹¹ The need for good metal cleaning and the nature of the steel are not problems that have been repealed by cationic electro-deposition.

CATIONIC POLYMERS

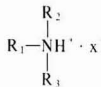
Cationic polymer development lagged behind that of anionics until these stumbling blocks were overcome: development of saponification resistant, acid soluble polymers; cure of the highly basic film; equipment corrosivity of acidic baths; and the development of high throw power materials.

The cationic groups required for water dispersibility can be introduced in several ways.

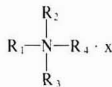
- (1) Primary and secondary amines solubilized with acids:^{12,13}



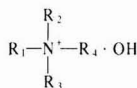
- (2) Tertiary amine solubilized with acids:¹⁴⁻¹⁶



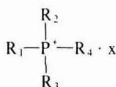
- (3) Quaternary ammonium acid salts:¹⁷⁻²⁷



- (4) Quaternary ammonium hydroxides:²⁵



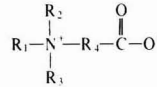
- (5) Quaternary phosphonium acid salts:²⁶⁻²⁸



- (6) Ternary sulfonium acid salts:²⁹⁻³²

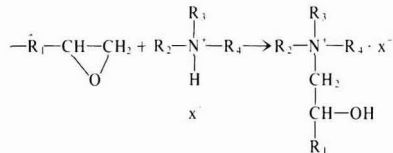


- (7) Quaternary ammonium-carboxylate:³³⁻³⁴



The following examples of cathodically electrodepositable resins are representative but not complete.

EPOXY BASED RESINS: As in anionics, it is desirable to use epoxide resin backbones for cathodic systems where good corrosion resistance is necessary.^{35,36} Typically, an epichlorohydrin-bisphenol A diepoxide is reacted with a base to form the desired functionality. For example, tertiary amine acid salts will react to form quaternary ammonium salt groups.



To form secondary amines, tertiary amines, quaternary ammonium hydroxides, quaternary phosphonium salts, or ternary sulfonium salts, the diepoxide is reacted respectively with primary amine, secondary amine, tertiary amines and water, tertiary phosphine salt, or organic sulfide and acid and water.

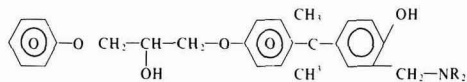
Other means are required to introduce primary amine functionality into an epoxy based system. Useful methods are reacting excesses of diprimary amine with diepoxides and blocking primary amines with ketones before reacting them with epoxide through other functionalities.^{37,38}

The commercially significant epoxy cationics are those with quaternary ammonium salts or amine salts. Good coating and film properties are available with high bath pH and low equipment corrosivity.

Due to their extremely high film alkalinity, these systems crosslink sluggishly with the aminoplast and phenoplast resins used in anionic systems. An effective means of crosslinking is with blocked isocyanates which are stable at bath temperatures but unblock at reasonable baking temperatures.^{13,39}

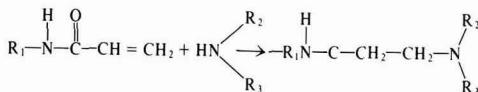
ADDITION POLYMERS: Cationic acrylic or vinyl copolymers can be prepared by inclusion of amine-containing monomers such as dimethylaminoethyl methacrylate,⁴⁰ or by inclusion of glycidyl monomers such as glycidyl acrylate or methacrylate which can be subsequently reacted with amine.⁴¹ Suitable one-coat systems with good durability can be produced. The preparation of amine containing polymers by the reaction of imines with carboxyl containing polymers was also described.⁴²

MANNICH BASES: Self-crosslinking cationic resins can be prepared from epoxide-phenolic resins in which terminal phenols are reacted with formaldehyde and a secondary amine.^{15,43}



This is a specialized method of providing tertiary amine groups.

MICHAEL ADDUCTS: Another route to tertiary amines is the addition of secondary or primary amines to acrylic double bonds derived from ester or amino acrylate functionality. The resultant amines are reversible to liberate volatile amine under baking conditions.¹⁶



SULPHONIUM-STABILIZED POLYMERS: Nonionic polymers can be stabilized by N,N' -tetramethyl-*S*-dodecylisothiuronium salts used as emulsifiers, or by copolymerization with *S*-(vinylbenzyl)isothiuronium salts.⁴⁴

ELECTROPOWDER COATING: A recent development is the use of curable powders dispersed in cathodically depositable epoxy-amine resins. Film build and flexibility are excellent, while throwpower and sandability is poor.⁴⁵

While the above description gives the type of functional groups used to make cationic polymers for electrocoating, the real challenge is in introducing these groups in such a way and at such levels that the backbone polymer will give the requisite colloidal stability in the bath, appropriate solubility at reasonable pH levels for practical use, and the ability to insulate upon electrocoating so that high throwpower materials can be achieved. The reactions must also be run efficiently enough so that the amounts of water soluble, low molecular weight cationic species are small. Low molecular weight species are generally very harmful as they can cause low rupture voltage, distortion of the film due to rupturing, and, very often, patterns in the electrocoated appearance. While ultrafiltration will help this aspect, it is desirable not to have to do excessive ultrafiltration.

Pigmentation

Pigmentation of cathodic electrodeposition baths involves the same considerations and constraints which were determined to be significant to the success of anodic systems.

Of primary importance is the selection of pigments low in content of soluble ionic constituents which adversely affect bath stability, corrosivity and conductivity, as well as film performance.

Obviously, cationic baths can present different pigment reactivity characteristics than anionic systems due to differences in composition and/or pH. Like anodic compositions, however, choice of pigmentation involves consideration of pigment dispersibility and resistance to

flocculation and settling, as well as film color, gloss, resistivity, flow, and dependent upon end use, corrosion resistance and exterior gloss retention. The constraint of attaining adequate film flow at high film solids as well as suspension of pigments in a low viscosity environment, necessitates formulation of electrodeposition baths at pigment loadings of 0.5/1.0 or lower in pigment to binder ratio by weight.

Coarse, dense, and poorly dispersed pigments predictably increase the degree of settling encountered on flat, horizontal areas of objects being coated, especially if the degree of bath agitation is low. Unfortunately, when this occurs, the resultant horizontal areas are usually degraded in both film smoothness and gloss.

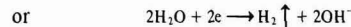
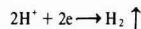
Pigment dispersion in a cationic grinding media should provide the necessary electrical charge distribution to facilitate electrophoretic movement toward the cathode, as well as assist suspension. Unfortunately, like anodic systems, the difference in transfer efficiency between different pigments, as well as between pigment and binder miscelles, dictates that feed formulations be adjusted to maintain the desired dynamic equilibrium of participating constituents.

The main binder constituent may often serve as the pigment dispersant in cathodic electrodeposition compositions. However, other considerations such as grinding efficiency and/or stability can be good reason for employing a specifically designed pigment grinding vehicle.⁴⁶

KINETICS AND ELECTROCHEMISTRY OF CATHODIC ELECTRODEPOSITION PROCESS

Electrodeposition does not start immediately upon the application of a voltage of the flow of electrical current.^{47,48} A finite time is required to establish the necessary conditions for film deposition in the boundary layer surrounding the cathodic part upon which the film deposition takes place.

At the cathode the primary electrochemical process is either.



The first reaction is favored in acid solution, the second predominates in neutral or alkaline solutions.

The rate of formation of hydroxyl ions at the cathode is given by the equation

$$V_{OH^-} = j/F$$

where j is the current density and F is Faraday's constant.

The hydroxyl ions produced at the cathode can diffuse, migrate in the electrical field around the electrode, and chemically react with arriving resin micelles. The resin micelles and pigment particles in the bath simultaneously migrate to the cathode, diffuse, and chemically react with the hydroxyl ions. In the case of the resin micelles and pigment, the diffusion flux is, however, much less than the migration flux.

The deposition of a film on the cathode does not occur until the hydroxyl ion concentration achieves a critical value.

In the absence of migration and chemical reaction, it can be shown that in an unstirred electrolyte under constant current density conditions, the concentration of hydroxyl ions at the cathode surface will increase as the square root of time according to the equation.

$$C_{OH^-} = C_0 + \frac{2j}{F} \left(\frac{t}{\pi D_{OH^-}} \right)^{1/2}$$

where t is time, C_{OH^-} the hydroxyl ion concentration at the electrode, C_0 the hydroxyl ion concentration in the bath, j is the current density, F is Faraday's constant, and D_{OH^-} is the hydroxyl ion diffusion coefficient.

If a critical hydroxyl ion concentration is required for film deposition, then it follows that deposition will occur only if the product

$$jt^{1/2} = \frac{1}{2}(\pi D_{OH^-})^{1/2} F (C_{OH^-} - C_0)$$

achieves a critical value. Constant current density experiments confirm this expectation. For a given system, the product of current density times the square root of the time required to form a film on the cathode is a constant.

The same relation can be used to estimate the hydroxyl ion concentration or corresponding pH at the cathode required for electrodeposition. Typical pH values necessary for cathodic electrodeposition range from 12-14. These estimates derived from constant current density electrodeposition experiments are also confirmed by the amounts of base required to precipitate an electrodeposition bath.

When the boundary layer conditions are sufficient for the formation of a film then the deposited film grows according to Faraday's law. The rate of film growth is proportional to the current density at the cathode.

$$\frac{d\delta}{dt} = cj$$

The rate of film growth depends on c , the coulombic efficiency in cm²/coulomb, and the current density through the film.

The film conduction characteristics have a very important influence on film growth. The most general relationship between current density and field strength across the deposited film is given by the equation:

$$j = A \sinh \left(B \frac{V}{\delta} \right)$$

where A and B are characteristic of the film, j is the current density, and the ratio of voltage to film thickness, V/δ , is the field strength.

At sufficiently low field strengths the hyperbolic sine becomes equal to its argument and

$$j = AB \frac{V}{\delta} = \sigma_F \frac{V}{\delta}$$

The current density becomes proportional to the field strength and the product AB is the film conductivity.

At higher field strengths the film conduction characteristics are nonohmic with an exponential dependence of current density on field strength.

$$j \cong \frac{A}{2} \text{EXP} \left(B \frac{V}{\delta} \right)$$

At high field strengths the hyperbolic sine function is approximated as an exponential function.

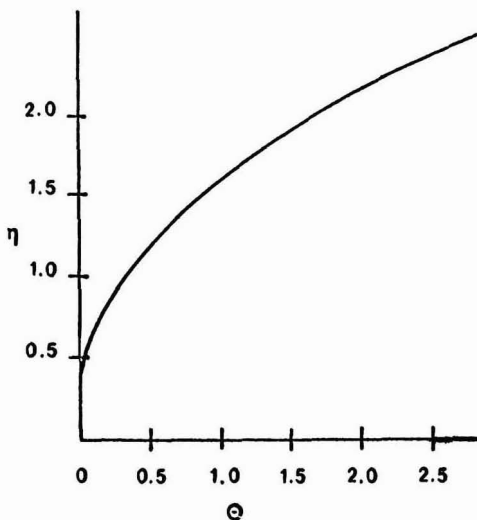


Figure 3—Relation between reduced film thickness, η , and reduced time, Θ for the electrodeposition of a film with non-ohmic conduction characteristics and no film dissolution in the electrodeposition bath

At intermediate field strengths film conduction data is frequently best fitted with a hyperbolic sine function.

The coulombic efficiency has been related to the chemical equivalent weight of the bath composition by the equation:

$$C = M/\rho F$$

where M is the number of grams of resin per equivalent of solubilizing salt groups, ρ is the film density, and F is Faraday's constant.⁴⁹ This relation is valid for the material deposited on the electrode but may not correspond to the total bath composition since the electrodeposition of all bath components are not necessarily in the same ratio as they exist in the electrodeposition bath.

The film growth equation can be integrated either analytically or numerically and the electrodeposition film growth data accurately fitted to the particular film growth model that is operating in the given system.

For example, in the case of ohmic film conduction, the film thickness under constant voltage electrodeposition conditions will increase as the square root of the deposition time according to the equation.

$$\delta = (2C \sigma_F V)^{1/2} t^{1/2}$$

In the case of nonohmic conduction, the kinetics are more complicated and a numerical solution of the film growth equation is necessary. If we define a dimensionless film thickness, ξ , and a dimensionless electrodeposition time, θ , by the following equations:

$$\xi = \frac{\delta}{BV}$$

and

$$\theta = \frac{CA t}{BV}$$

Table 1—Comparison of Calculated and Experimental Ford Throwpower at 0.17×10^{-3} CM for a Pigmented Cathodic Primer

Voltage (Volts)	Time (Sec)	Calculated Throwpower (CM)	Experimental Throwpower (CM)
50	90	8.6	8.9
100	90	13.0	12.4
200	90	17.8	19.0
250	90	19.2	20.6

then the nonohmic film growth equation becomes:

$$\frac{d\xi}{d\Theta} = \sinh\left(\frac{1}{\xi}\right)$$

This equation can be integrated numerically to give a table of reduced film thickness, ξ , versus reduced electrodeposition time, Θ . The numerical solution is shown in Figure (3). At long times the solution approaches the form

$$\xi = \sqrt{2\Theta^{1/2}}$$

At short times there is a very rapid film growth which slows and very quickly assumes an approximately $\Theta^{1/2}$ increase.

Other complications can also occur which influence the kinetics of film growth. If the film redissolves in the stirred electrodeposition bath at a significant rate during the time of electrodeposition, then the film growth equation must be modified to include the effect of film dissolution.

The kinetic film growth equation becomes

$$\frac{d\delta}{dt} = C(j - jd)$$

where jd is the dissolution current density or current density just required to counterbalance the rate of film dissolution. Film growth thus ceases when the current density is equal to jd . In this situation the electrodeposition process stops and the limiting film thickness is given by

$$\delta_{\infty} = \sigma_F V / jd$$

in the case of ohmic film conduction or

$$\delta_{\infty} = BV / \sinh^{-1}(jd/A)$$

for the nonohmic case. These cases can also be analytically or numerically integrated to give film growth time curves.

Occasionally porous films are also encountered. If the deposited film does not coalesce to form a continuous layer, most of the film conduction takes place through the pores in the film. This type of deposition has been reported for electrodeposition latex films and can also occur in cathodic electrodeposition. In this case the current density is given by the equation

$$j = j_0(1 - \alpha)$$

where α is the fractional surface coverage of the electrode and j_0 is the current density in the pores of the film. At constant voltage electrodeposition the cathode surface coverage is an exponential function of the time

$$\alpha = 1 - e^{-j_0 k t}$$

where k is the number of cm^2 covered per coulomb.

Table 2—Comparison of the Salt Spray Corrosion Resistance Of Anodic and Cathodic Automotive Primers

Substrate	Pretreatment	Salt Spray Exposure	Scribe Creep	
			Anodic	Cathodic
Steel	None	336 hr	3/16"	1/16"
Steel	FE Phosphate	336 hr	1/16"	1/64"
Steel	ZN Phosphate	336 hr	1/32"	1/64"

The kinetics of growth of electrodeposition films can assume a variety of forms depending on the nature of the electrodeposited film. Electrochemical measurements are thus useful tools to characterize film growth kinetics, to diagnose film growth mechanisms, and to provide a rational basis for optimizing the film growth kinetics for particular applications.

THROWPOWER

A major advantage of the electrodeposition process is its ability to coat recessed areas, cavities, channels . . . in fabricated metal products. The ability of a coating system to deposit films in recessed areas is called throwpower.

In the U.S., the two most widely used methods to measure throwpower are the Ford Cell Test⁵⁰ and the GM Cell Test.⁵¹ Furuno⁵² and Pierce⁴⁸ have discussed throwpower tests and the geometric and electrochemical factors which influence those tests. The results of those analyses permit the calculation of throwpower from electrochemical data obtained on flat panels provided the geometry, dimensions, voltage, and time of the throwpower experiment are known.

The Ford type cell, consists of a piece of $3/4$ " standard gas conduit which is immersed to a depth of 10–12 in. in a stirred container filled with electrodeposition coating. Inside the tube is a strip of metal shim stock running the length of the tube and electrically connected to the tube. A $5/16$ " metal strip was employed in the work reported here rather than the standard $1/2$ " metal strip specified in the Ford Test Method.⁵⁰ A standard $4" \times 12"$ test panel is also electrically attached to the throwpower tube. The inside diameter of the metal conduit is $5/8$ ".

A constant voltage is applied for a specified time, typically 60–120 sec. The cell is removed from the tank, rinsed, and taken apart. The strip is baked and the thickness of the electrodeposited film is measured.

A typical profile of the deposited film is wedge-shaped. The length of strip coated is the throwpower of the coating under the specified conditions. Because of the difficulty in precisely locating the point at which the coated regions ends, the throwpower is frequently taken as the point at which the wedge-shaped deposit has a specified film thickness, typically a 0.1 mil.

Furuno⁵³ has shown that the throwpower can be related to the geometry of the test cell and coating properties by the equation:

$$L = \left(\frac{2A}{P}\right)^{1/2} \left(\frac{\sigma_B V}{j}\right)^{1/2}$$

where A is the crosssectional area of the cell, P is the perimeter of the cell, σ_B is the bath conductivity, V is the

Table 3—Comparison of Substrate Dissolution During Anodic and Cathodic Electrodeposition

Substrate	PPM FE		PPM ZN	
	Anodic	Cathodic	Anodic	Cathodic
Cold Rolled Steel	2167	55	—	—
EP-10 FE Phosphated Steel	308	42	—	—
EP-2 ZN Phosphated Steel	249	30	13300	83

V = 90 Volts ; t = 90 Sec ; Anderson, et. al., JOURNAL OF COATINGS TECHNOLOGY, 50, No. 646, 38-45 (1978).

applied voltage, and j is the current density at the coated surface of the tube at the end of the deposition experiment.

The throwpower at some specified film thickness, δ_s , can be calculated provided the coating film thickness on the flat panel or outside of the tube at the end of the experiment is known. The throwpower at some specified film thickness, δ , is given by the equation:

$$\rho = L \cdot \left(\frac{\delta - \delta_s}{\delta} \right)^{1/2}$$

where L is the total throwpower, δ is the film thickness on the flat panel, and δ_s is the specified film thickness typically taken to be 0.1 mil.

Table 1 is a comparison of some experimental and calculated Ford Cell throwpower results. The calculated values were obtained using electrochemical data obtained from flat panel experiments. The throwpower was determined at the point at which the film thickness was 0.17×10^{-3} cm. The agreement between the calculated and experimental throwpower is reasonably good considering the difficulties in measuring throwpower and practical difficulties arising from such factors as the surface roughness of the substrate.

Besides providing good estimates of throwpower, the proceeding equations provide a guide to the factors that must be varied to increase the throwpower. The total throwpower can be increased by increasing the bath conductivity and the applied voltage or by decreasing the final current density. The throwpower at a specified film thickness can be increased by increasing the film thickness of the electrodeposit provided the total throwpower is not decreased. Since the film thickness also increases with voltage, this suggests that operation at the highest voltage possible, short of film rupture, will give the highest throwpower for a specific system.

SYSTEM PERFORMANCE

The move from anionic to cathodic electrodeposition which began in the early 1970's in the appliance industry and later spread worldwide to the priming of automobiles, was prompted largely by the superior corrosion protection offered by specific epoxy based cationic systems.^{54,55} Table 2, taken from reference,⁵⁵ illustrates the typical salt spray performance superiority offered by a widely used cathodic automobile primer. These accelerated test results were also substantiated on test cars

Table 4—Typical Properties of a One Coat Cathodic Agricultural Equipment System

Film Thickness	1.3 ± 0.2 MIL
Curing Schedule	20 Mins at 275-300° F Metal Temperature
60° Gloss Range (ASTM B523-67)	30-90%
20° Gloss Range (ASTM D523-67)	20-30%
D O I:	≥ 70
Pencil Hardness (ASTM D3363-74)	≥ F
Mar Resistance:	Good
Crosshatch Adhesion (ASTM D3359-74)	95-100%
Flexibility-Conical Mandrel Bend (ASTM D522-60)	Fair
5% Salt Spray Resistance (ASTM B117-73)	168-339 Hr
Humidity Resistance (ASTM D2247-73)	250 Hr
Water Soak Resistance (ASTM D870-54)	250 Hr
Steam-Alkali Resistance	Pass
Florida Exposure	60-80% Retention at 9-12 Months
Metal Pretreatment	Seven Stage Zinc Phosphate- Chromic Acid Rinse Equivalent to Parker EP-2

subjected to test track exposure cycling of salt water, temperature, and humidity.⁵⁶ Automotive standards of film smoothness, hardness, edge coverage, chip resistance, and topcoated Florida exposure durability, as well as extended in-plant stability and ease of operation, also were met by this system.⁵⁶ Conversion of existing anionic installations was facilitated by the fact that the offered cathodic products did not require changes in equipment due to differences in bath corrosivity.

Two factors which contribute significantly to the outstanding corrosion protection attainable by specific cathodic systems are reduced substrate dissolution, and polymer structures which are particularly resistant to hydroxyl ion attack. Electrochemically, the cathode reaction does not involve substrate dissolution as does the anode, but the highly alkaline boundary layer and cathodic deposit can lead to secondary chemical reactions, especially in case of amphoteric metal substrates. The amount of substrate dissolution under cathodic deposition, however, is small in comparison to anionic deposition. Table 3, taken from the work of Anderson, et al.,⁵⁷ illustrates this fact. Also to be noted is that in either case, metal pretreatment decreases the degree of substrate dissolution, and this therefore, suggests good metal pretreatment to be essential for both types of electrodeposition.

Studies of the cathodic disbonding of coating systems recently amplified by results on automotive primers, including cathodic systems,⁵⁸ show that superior corrosion resistance, as reflected by salt spray exposure, is directly related to increased resistance to alkali displacement at the cathodic corrosion sights.

In addition to the appliance and automotive fields, high gloss acrylic based cathodic electrodeposition coat-

ings, displaying exterior gloss retention improvement over their high carboxyl containing anionic counterparts, are currently being commercially introduced in other areas. Typical properties of a system designed for one-coat usage on agricultural equipment are illustrated in Table 4.⁵⁹

Notwithstanding the advantages evident for specific cathodic electrodeposition formulations illustrated above, anodic systems remain competitive in many applications, and will continue to be used because of the inherent merits of the coating process itself.

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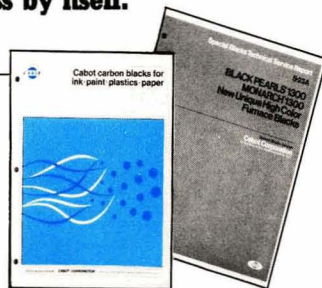
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Evaluation of Linings for SO₂ Scrubber Service

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Gilbert/Commonwealth*

Lining materials to protect steel surfaces from corrosion were evaluated utilizing the Atlas Test Cell. Collected gas condensate from within an operating flue following a SO₂ Scrubber Unit was analyzed and used as the media within the cell. This synergistic test correlated closely with field experience and appears to be a very effective method to evaluate coating materials. Microscopic observations of both coating and steel were made after completion of the test.

INTRODUCTION

In 1970 Congress enacted the Clean Air Act, promulgating a vigorous attack on air pollution by all segments of industry. Emissions by industrial installations, such as electric power plants, paper mills, steel mills, and other fossil fuel facilities, have been carefully monitored. Gas scrubbing systems have been designed to mainly control SO₂ emission. It has been shown that controlling SO₂ presents a severe problem for corrosion protection of all surfaces within the system.

Some of the first built units utilized carbon steel lined with various types of coating materials in an attempt to prevent corrosion. Each unit differs from another and there are practically no ground rules as to why some areas remain intact while others fail rapidly. The severity of the problem appears to center around the temperature of the gas being emitted. Temperatures above 210°F do not appear to be as severe as those units operating with gas emissions below the condensing temperature of

water. The use of reheat to increase the temperature is a costly operation, therefore, materials must be found or better materials substituted to resist these gas condensates at operating temperatures of 130° to 190° F.

Billions of dollars have already been invested in various SO₂ scrubber systems. Numerous papers have been presented and a wide variety of materials have been used and tested for this service.¹⁻⁸ Some of the major problems facing the power industry have caused severe economical strain usually related to outages, down time, and labor costs. Materials have been a serious problem in the corrosive environment within the SO₂ scrubber system. The most severe corrosive areas are usually downstream of the scrubber, outward toward the breeching and flues. Wherever condensation occurs, such areas are under a constant rain of acidic water confined within the system.⁹ Limestone is used to neutralize the emitted SO₂ in many scrubbers.

Usually the water and lime slurry creates a pH inside the venturi area ranging from as low as 4 to a high of 11, with standard operating conditions of about a pH of 6 to 7. As the gases flow out the system, water evaporates until the acidity of the droplets and the condensate lowers to a pH of 1.0 to 1.5. Inside the flue, the side walls condense the gas and water runs down causing the very low pH condition.

Not much information has been published concerning the contents of these gas condensates which are found in coal fired units. A program was initiated to collect the gas condensate at various heights of the flue and run an analysis of this condensate. Not all elements were identified, however, acidity, Cl, SO₂, and NO₂ were monitored. *Table 1* contains the analysis of some 20 of these condensate samplings which were taken from various elevations of the flue and from the drain water. Total organic carbon was highest during start-up. Organics were not further identified.

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Table 1—Analysis of Flue Gas Condensate and Drain Water

		Samples									
		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Acidity	mg/l CaCO ₃	335	2990	836	1232	2192	342	2560	292	2480	314
Chloride	mg/l Cl	9	98	10	28	433	5	151	6	160	7
Nitrates	mg/l NO ₃ N	4.70	81.3	9.66	16.3	50.6	3.00	81.3	3.00	83.5	2.14
pH		2.7	1.7	2.0	1.9	1.8	2.4	1.8	2.4	1.7	2.3
Solids, Total	mg/l @ 105°C	457	6780	1128	1963	9710	456	6783	402	6735	378
Solids, Suspended	mg/l @ 105°C	43.5	148	41.5	114	274	39.0	392	14.5	219	27.3
Solids, Vol. Suspended	mg/l @ 550°C	18.0	54.0	18.5	34.0	42.0	16.5	56.0	7.0	32.0	12.0
Sulfate	mg/l SO ₄	389	5509	913	1564	7706	411	5712	341	5814	372
TOC Total Org. Carbon	mg/l	14	29	12	12	12	11	16	6	17	10
Odor		None	Present	None	Present	Present	Present	Present	Present	Present	Present
		11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
Acidity	mg/l CaCO ₃	1500	1756	1772	816	1816	372	517	428	2068	102
Chloride	mg/l Cl	24	238	236	27	12	8	8	20	34	102
Nitrates	mg/l NO ₃ N	28.0	37.4	37.4	13.6	28.8	3.39	1.94	4.58	22.5	1.87
pH		1.6	1.8	1.8	1.9	1.6	2.1	2.0	2.2	2.2	5.8
Solids, Total	mg/l @ 105°C	2778	6540	6526	2615	3086	473	758	2690	5482	1676
Solids, Suspended	mg/l @ 105°C	233	529	510	277	501	50.3	95.3	180.7	122	73.0
Solids, Vol. Suspended	mg/l @ 550°C	44	44	43	53	101	14.5	18.7	36.7	25.3	10.3
Sulfate	mg/l SO ₄	2265	4952	4884	11969	2248	434	679	2003	3617	668
TOC	mg/l	25	15	17	32	51	13	13	29	200	9
Odor		Present	None	Present	Present	Present	None	None	Present	None	No identifiable Odor
		Flue 2b drain	Flue 2b Elevation 377'		Flue 2A drain		Flue 2a Elevation 377'		Flue 1b drain		
Sample		2, 5, 7, 8	1, 3, 4, 6, 8, 10		12, 13, 19		11, 14, 15, 16, 17, 18		20		

All samples taken on different days over 6 month period.

Chlorides, nitrates, and sulfates varied considerably. Chlorides were highest in the drain samples and sulfates reached a level of 12,000 Mg/L. The pH varied from 1.5 to 5.0.

In analyzing the type of stack lining failure which has occurred, there is a definite progression of corrosion. A spray applied polyester lining showed early signs of breakdown. A chemical analysis of this product revealed that over 100 ppm of water-soluble halogens were present. This would speed up corrosive attack on steel substrates.

In SO₂ scrubbers, coatings often are blistered after less than one year service. Low pH and elevated temperatures cause premature corrosion to occur.

Protective coatings act as a barrier. They prevent moisture and oxygen and other chemicals from attacking the steel substrate. Most coating films, however, permit chemicals, moisture vapor, and oxygen to permeate them and attack the steel. This phenomenon is accentuated at temperatures between 150°F and 210°F. Gaseous penetration occurs not only thru pinholes and other micropores, but also thru the general coating film. The movement of penetrants through the coating film is fostered principally by osmotic and electro-osmotic pressures and the constant thermally induced movements and vibrations of the coating film molecules.

STAGES OF UNDERFILM CORROSION

I: Spot Rusting and/or Blistering

Early stages of corrosion are often left unattended. They have been described many times as rust spotting on the coating. The standards for determining and evaluating degree of rust spotting are found in Steel Structures Painting Council Vis-2 or ASTM D 610-68. One rust spot found in one square foot may provide a 9+ rating, but 3 or 4 rust spots drop the rating to 8. The fact that the rust spots go unattended provides the mechanism for further corrosion to take place.

Early stages of corrosion can be recognized as blistering (See Figure 1). Frequently, blistering occurs without external evidence of rusting or corrosion. The mechanism of blistering is attributed to osmotic attack or a dilation of the coating film at the interface with the steel under the influence of moisture. Water and chemical gases pass thru the film, dissolve ionic material either from the film or the substrate, causing osmotic pressure greater than that of the external face of the coating. This establishes a solute concentration gradient with water building up at these sites until the film eventually blisters. Visual blistering standards are found as ASTM D 714-56.

Blistering is also dependent upon electrochemical reactions. Water containing corrosive ions diffuses thru a

coating also by an electro-endosmotic gradient. After corrosion has started, moisture is pulled thru the coating by an electrical potential gradient between the corroding area and the protected areas that are in electrical contact. Therefore, osmosis starts the blistering, and as soon as corrosion begins, electro-endosmotic reactions greatly accelerate the corrosion process. By adding heat and acidic chemicals the breakdown occurs most rapidly. At temperatures of 150° F to 200° F, the chemical reaction is accelerated. Thus, steel will literally dissolve in a chemical environment at these temperatures. Moisture is ever present and often condenses on the surface behind the blister. This condensation offers a solute for gaseous penetrants to dissolve. In acidic environments, the water pH behind the blister can drop as low as 1.0 to 2.0, therefore, the steel is subjected to severe attack.

II. General Rusting

After one rust spot has been observed or a few blisters are found, the condition advances to general rust spotting. The second stage of corrosion can be described as general rusting. This most frequently is seen as red iron rust, Fe₂O₃. However, within SO₂ scrubber systems, which do not have sufficient oxygen during normal operation, the rusting is usually black Fe₃O₄ (See Figure 2). This converts to Fe₂O₃ eventually as the unit is shut down and more oxygen is available. The second stage of rusting may therefore be more accurately described as a number 5 or number 3 rusting condition according to SSPC Vis-2.

III: Coating Disbondment

The next advanced stage of corrosion is the total disbondment of the coating resulting in direct exposure of the steel to the environment, as shown in Figure 3. No longer is the coating protecting the steel substrate, therefore, corrosion can now occur at an uninhibited rate. The acidic conditions within the SO₂ scrubber system will quickly corrode the steel at these elevated temperatures, especially with plenty of moisture present. Disbondment occurs because of chemical attack on the substrate, forcing the coating off. One might think of disbondment as one very larger blister.

IV: Pitting

Once the coating has been removed and no longer acts as a protective barrier, the steel is left to be directly attacked (See Figure 4). This attack most frequently is not uniform but rather localized into many electrolytic cells. Each cell with an anode and cathode, an electrolyte (moisture and acid), and the steel surface provide the perfect mechanism for pitting to occur, the concentration cell. Pitting develops when the anodic (corroding) area is small in relation to the cathodic area. These concentration cells develop where oxygen or conductive electrolyte concentrations in water differ. Mill scale, for example, is cathodic to steel, therefore, areas surrounding mill scale would be eaten away and pitted first. In a short time, the pitting will undercut the mill scale and flaking occurs. Pitting will cause structural failure from

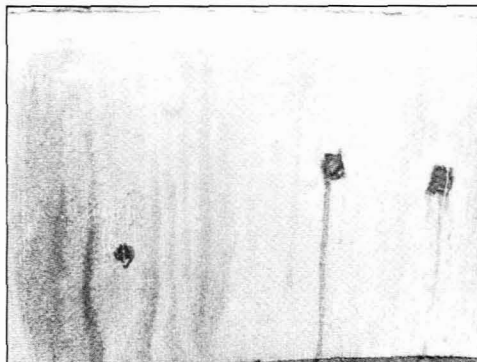


Figure 1—Early signs of corrosion blisters in polyester lining are the size of half dollars. Water, pH of 2.5 is entrapped. This 40 mil lining began to show corrosive attack of the steel after only six months service



Figure 2—In the second stage of corrosion, black iron oxide or iron sulfide appears thru weakened lining



Figure 3—In the third stage of corrosion, the polyester lining has lost adhesion. Spot corrosion or rusting appears beneath the coating



Figure 4—The fourth stage of corrosion shows severe pitting and loss of steel. The lining has completely lost adhesion. Red rust is noted

localized weakening effects while there is still considerable sound metal remaining.

V: Flaking of Steel and Development of Holes

As the corrosion cell becomes more active, the rust and pitting become more advanced. Deep pits in steel may eventually penetrate completely, causing holes to occur. Such penetrations generally result in structural loss and replacement of the steel at considerable expense to the owner. Within the corrosion cell, pitting has occurred to such a degree that undercutting, flaking, and delamination of the steel is noted. Most of these pits have a conical configuration.

After the small hole develops, the electrolyte can now seek other fresh surfaces on the reverse side. This enables corrosion to occur on both front and back surfaces as shown in *Figure 5*.

VI: Complete Loss of Steel

As the chemicals present condense on the unprotected substrate, corrosion occurs at its most rapid and aggressive rate. Large gaping holes are found, causing considerable structural damage. These holes are rapidly enlarged because the electrolyte is ever present on both front and back surfaces of the steel. Costly repairs are necessary including the replacement of steel and welding of large plates to the surface (See *Figure 6*). Complete inspection is required to determine functionality of the structure.

The necessity for some meaningful test program to evaluate materials for flue liners became quite apparent when the industry was surveyed. Many lining failures



Figure 5—In the fifth stage of corrosion, considerable loss of steel and delamination has occurred. A small hole completely thru liner permits the corrosive media to attack both front and back surfaces of the steel liner

have occurred throughout the country. None of the coating and materials people would guarantee the performance of their lining for more than one or two years service. Since few of these lining suppliers had any test data or meaningful field experience, the Atlas Test Cell program was initiated.

A-36 steel panels or A-242 Mayari R type steel $\frac{1}{4}'' \times 7'' \times 8''$, were used. In each case, application of the coating material was done according to the coating manufacturers' specific instructions. Their representatives were present at the time these panels were prepared. Some of the panels were coated at the jobsite, others in the laboratory.

The "Atlas Test Cell", shown in *Figure 7*, is an opened faced glass cell, described in NACE (National Association of Corrosion Engineers) TM-01-74, "Laboratory Methods for Evaluation of Protective Coatings Used as Lining Materials in Immersion Service." Each cell was half filled with gas condensate collected from a large number of daily samples taken at various times from the chimney of an operating power station. The concern for the variety of chemicals found in the gas condensate stimulated this test program. The main purpose of the Atlas Test Cell program was to evaluate coating materials for this service. A realistic secondary purpose was to develop a laboratory procedure which would be an effective method to evaluate all materials for this service. This would mean that coating materials could be screened by using the Atlas Test Cell technique. Recommendations could therefore be made based upon results found in the laboratory.

The liquid gas condensate contains chloride, sulfate, nitrate, and organic carbon in quantities significant enough to severely damage organic coatings and steel surfaces. It is believed that this synergistic test is more effective than merely evaluating for a few specific chemicals. The combinations found in the collected samples are very damaging to steel and seem to penetrate nearly all coatings below a 40 mil thickness (See *Figure 8*).



Figure 6—Final stage of corrosion causes a hole about 1 ft × 2 ft thru the ¼" thick A-242 type steel. A plate will be welded over this area and new lining applied

DISCUSSION

After 30, 60, and 90 days, the cells were opened and observations made. The visual condition of each panel was noted. The cells were reassembled using the identical media. No replacement solution was added. This procedure was changed in later work. The media can be replaced each 30 days if desired. This would allow for any losses or changes in pH which might occur due to reaction within the cell. In any case, some tests ended after 180 days with the very same solution with no volume addition. No water was added to maintain the liquid level. In fact, the liquid level dropped due to slight losses during the test. Some tests were discontinued after 30 or 60 days.

All cells were adjusted to a constant temperature of 165°F. This 165°F temperature was chosen because it is close to the average gas temperature within the chimney where the condensate gas was collected. Alternate testing was done on some systems at 195°F.

Some systems failed after 30 days testing. After the 180 day period, the remaining cells were opened. The liquid level retained in each cell was measured and the solution was analyzed as to the chemical composition.

Each panel was photographed and visually examined for blistering and rust immediately after dismantling. ASTM D 714-56 (Reapproved 1974) "Evaluating Degree of Blistering of Paints" was used to report blister size and frequency. Rusting was reported as severe, moderate, or slight before and after microscopic examination of the steel substrate.

The visual observations made on each of the panels are therefore substantiated by the chemical analysis of their respective solutions.

Microscopic Examination

After testing, the panels were cut in half vertically with a band saw and a cut edge was polished. Photomicrographs were taken which show the condition of the interface of the coating and steel exposed to both the liquid and vapor phases. A small area of the liquid or vapor phase was physically broken open, removing the coating

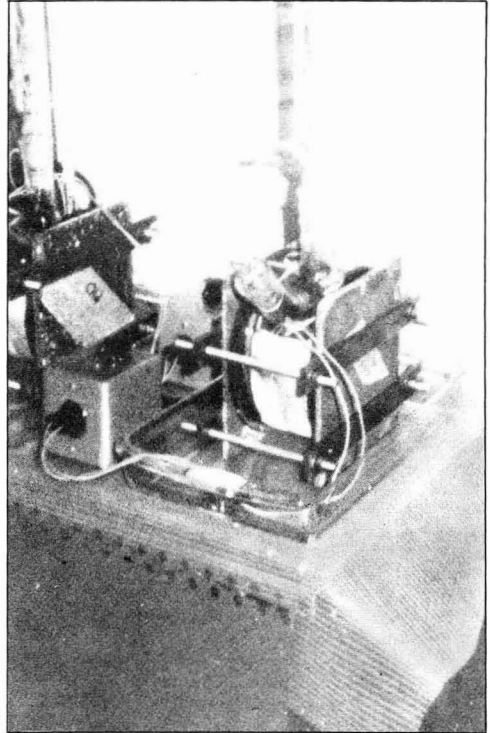


Figure 7—Atlas Test Cell. Two coated panels are under testing



Figure 8—A 40 mil epoxy-amine system failed by delamination within 30 days

Table 2—Atlas Test Cell Data for SO₂ Condensate Gas Evaluation of Lining Materials for Chimney Flues

Coating Material	mils Film Thickness	Visual Observations Liquid Phase				Visual Observations Vapor Phase				Microscopic Observations Liquid Phase				Microscopic Observations Vapor Phase				Performance Rating
		Days				Days				Days				Days				
		30	60	90	180	30	60	90	180	30	60	90	180	30	60	90	180	
Fluoropolymer	40		2D	2D			8F		S,R	S,R			E	E	E	7		
Fluoropolymer	40		E	E			E	E	E	E			E	E	E	10		
Fluoropolymer	40		E	E			E	E	E	E			E	E	E	10		
Fluoropolymer	40		E	E			E	E	E	E			E	E	E	10		
Fluoropolymer	40		E	E			E	E	E	E			E	E	E	10		
Chloro Polyester (Spray) ^a	40		2MD	2D			2M	2MD		S	R,S				S,R	0		
Bromo Polyester (Spray) ^a	40		E	C.C.			E	C.C.		C.C.	R,S				S,R	0		
Chloro Polyester (Trowel)	80		E	8D			E	8D (Surface)			S,R				SR	8		
Bromo Polyester	80		E	8D (Surface)			E	8D (Surface)			S,R				S	8		
Polyester 4 Trowel	120			E,C.C.			E				S,R				S	8		
Polyester 1 Trowel	120			C.C.			4-6MD (Surface)				E				E	10		
Epoxy/Polyamide Spray	30			4M	4M,D,C.C.			4MD			S,R				S,R	4		
Epoxy/Polyamide Trowel	125			6M	6D,C.C.			6M			S,R				S,R	2		
Epoxy/Amine	50	C.C.				D-1			R,S	C.C.			R,S			0		
Epoxy/Amine	50	D-2				D-1			R	C.C.						0		
Vinyl Ester (metallized)	40		2F	2F,C.C.				2F,C.C.			S				S	6		
Vinyl Ester (metallized)	40			2F,C.C.				2F,C.C.			S				S	6		
Vinyl Ester	40			4F				4F			S,R					5		
Coal Tar Epoxy	20	D-8				D-8			R,S				R,S			0		
Coal Tar Epoxy	20	C.C.				D-6			R,S				R,S			0		
Asphaltum	2	4MD			4MD								R			0		
Asphaltum	2	F8			4MD								R			0		
Cement, Chem. Resistant	1½ inches		E	E		A		A	S,SR		A		A		A	9		
Cement, Chem. Resistant	1½ inches		E	E		A		A			A		A		A	9		
Modified Inorganic	20		E	E				ST			SR		ST		ST	9		
Modified Inorganic	20		E	E				ST			SR		ST		ST	9		
Asphalt Urethane	125	4MD				4MD			S,R		S,R					5		
Foam Boro Silicate Block (closed cell foam)	2 inches			E				E	E		E		E		E	10		

(a) Control system which failed after 1 to 2 years service.
C.A. Corrosive Attack on surface.
Microscopic examinations, panel cut in half.
C.C. Chemical attack on coating.

2.4.6.8 ASTM D 714 Blistering
F,M,MD,D
A = Ablated
E = Excellent
S = Separation from substrate
R = Rust
SR = SI Rust
ST = Stain

down to the steel substrate. Photomicrographs were again taken to illustrate the condition of each area of the substrate. This was done because many of the coatings visually appeared to be intact, however, at the steel interface rusting had started.

Table 2 provides data regarding lining materials which have been tested in the Atlas Test Cell. Typical of Atlas Test Cell procedures, the media was analyzed before and after testing. Table 3 indicates the changes which occurred from the original test solution to that found at the end of testing. Cell A increased in chloride indicating water-soluble chlorides were extracted from the coating. The sulphate remained the same but total organic carbon was consumed either onto the coating or reacted with the contents or other extractants. The Fe concentration doubled, indicating attack on the steel panel. Cell B had a significant increase in pH which

accounts for the drop in sulphate. Total organic carbon (TOC) increased severely indicating a loss of lining material into the media. Fe also increased indicating attack on the steel substrate. The chloride content nearly doubled indicating the lining material contained significant water extractable chloride.

One technique used to identify attack on the steel substrate was to cut the panels in half and polish one edge. These edges were carefully examined under 25× magnification. Separation or delamination was easily determined, as shown in Figure 9. Rusting may have been observed (See Figure 10). Usually rusting was found after the coating was removed. Generally our findings of coating deterioration were confirmed after analysis of the gas condensate used as the Atlas Test Cell media.

By analysis of the test cell media after the test was completed, a rise in iron content was evident in several

Table 3—Partial Analysis of Flue Gas Condensate

	Original Test Solution Total Mg	Atlas Cells After Test 180 days Total Mg	
		Spray Applied Polyester (40 mils) (A)	Trowel Applied Polyester (125 mils) (B)
pH	1.9	2.3	4.9
Chloride	63.0	96.8	118.4
Sulphate	2393.0	2305.0	1855.0
Total Org.			
Carbon	60.8	8.3	206.0
Fe.....	58.0	110.9	95.3

cells, indicating corrosive attack of the steel substrate (See Table 3).

The first sample panel of the fluoropolymer blistered but no rusting was evident until the blister was opened and a cross section made by cutting the panel in half. Some slight rusting appeared and the obvious separation of the film was noted. This did not occur on the subsequent four panels, therefore, it was concluded that this spray applied fluoroelastomer would provide satisfactory service, (See Figure 11). This good record has been borne out under actual service conditions within the flues of two power stations for over a three year period. One additional station in England has been in service six years without failure.

The spray applied chlorinated polyester and brominated polyester coatings were considered to be control panels. These linings failed badly under actual service conditions. Representative panels were tested in the Atlas Cell and these coating materials failed, showing severe blistering and rusting after 180 days exposure, as shown in Figure 12. Large voids in the film (25–30 mils) were noted.

The heavier trowel applied chlorinated and brominated polyesters (80 mils) were better. They lasted 180 days in the test cell but, by cross section examination, and by mechanically removing the coating, some rusting was evident on the steel surface. These materials have provided good protection within the ductwork of an operating unit. They would not be recommended for use in chimney flues. Large voids (50 mils) were noted in the film. Heavy 120 mil trowel applied polyesters showed good results in the Atlas Cell Tests with only one panel exhibiting slight separation and rust after cross sectioning. This coating has performed well in ductwork of several operating units.

The epoxy/polyamide and epoxy/amine systems failed badly by showing separation and rusting. These systems would not be recommended for service.

The spray applied vinyl ester systems failed by exhibiting blister formation and separation when applied over metallized aluminum. When applied over steel, the coating showed few blisters and rusting of the surface after cross sectioning.

Coal tar epoxy, asphaltum, and an asphalt-urethane blistered severely. They all showed rusting of the steel after only 30 days testing (See Figure 13). One asphalt-



Figure 9—This trowel applied 125 mil polyester system shows delamination after 180 days test. 25X magnification also shows large void in the film. (A) Polyester laminate; (B) Steel

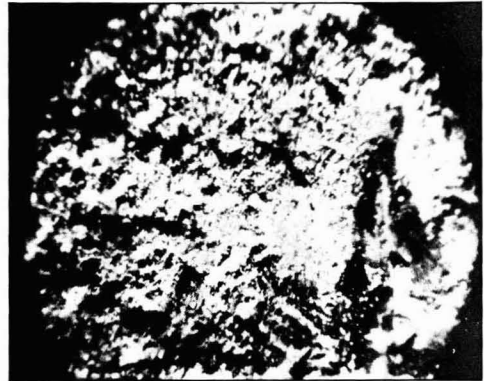


Figure 10—Considerable rusting is evident on the steel surface beneath the polyester coating. 25X magnification

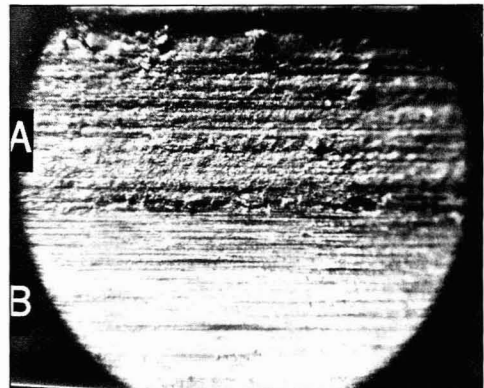


Figure 11—Fluoroelastomer is in excellent condition after 180 days test. Cross section view 25X magnification. (A) Fluoroelastomer; (B) Steel

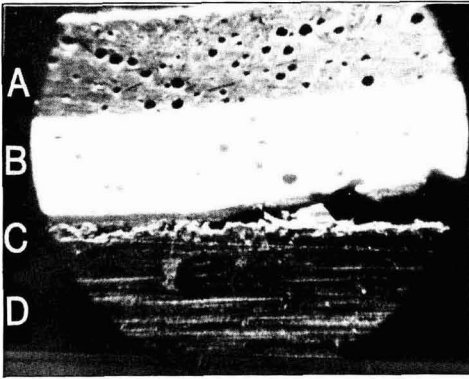


Figure 12—Brominated spray applied polyester failed by delamination after 180 days test. Cross section view 25× magnification. (A) Top Coat; (B) Intermediate; (C) Primer; and (D) Steel Substrate

rubber product could not be tested in the Atlas Cell because the 165° F temperature caused the material to flow, allowing leakage to occur. These products also burned severely in a fire resistance test.

Several chemical resistant cements were evaluated. These products were spray applied at 1½ to 2 inches thick. One product was too porous and could not be mounted in the Atlas Cell because leakage occurred thru the pores of the material. Tests inside the flue under actual operating conditions showed severe erosion and ablation of the material with rusting of the steel surface underneath the coating. The chemical resistant

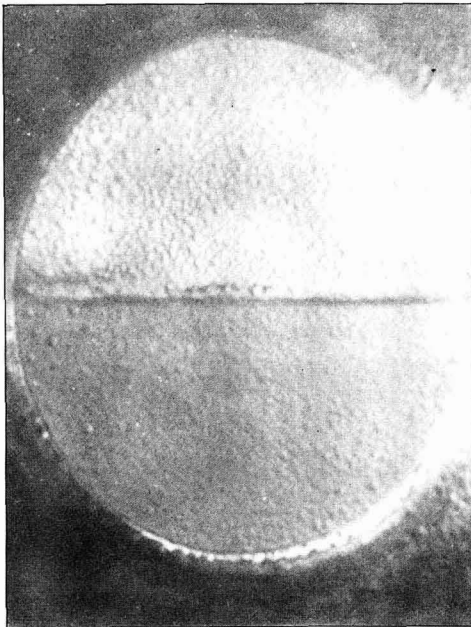


Figure 13—An amine cured coal tar epoxy is severely blistered after 30 days test. Upper portion is vapor phase, lower portion is liquid phase

cement tested in the cell showed a loss of material (about 50 mils) after 180 days (See Figure 14). It has good overall resistance. During the test, the texture of the surface changes from a hard material to a soft, easily damaged material.

A modified inorganic coating, based on an alkyl silicate with graphite or glass flake, showed excellent resistance to the corrosive media. A superficial stain was noted on the surface in the vapor phase. Examination of the steel substrate did not show rusting after cross section examination. The coating was subjected to a mandrel bend and only then could some minor rusting be observed. The gasket outline of the cell was noted.

A closed cell foam glass block system was found to be completely intact after 180 days testing. This system has performed well within the flue of one operating power station for two years. The foam glass blocks are easily damaged by any physical impact, therefore, great care must be taken upon installation of this material.

A flexible Furan was evaluated. This material is extremely flammable and therefore not recommended for chimney flues. This coating burned severely in two-foot tunnel fire resistance test.

Rubber lining materials were not evaluated in this program. Some specialty steels have also been evaluated.

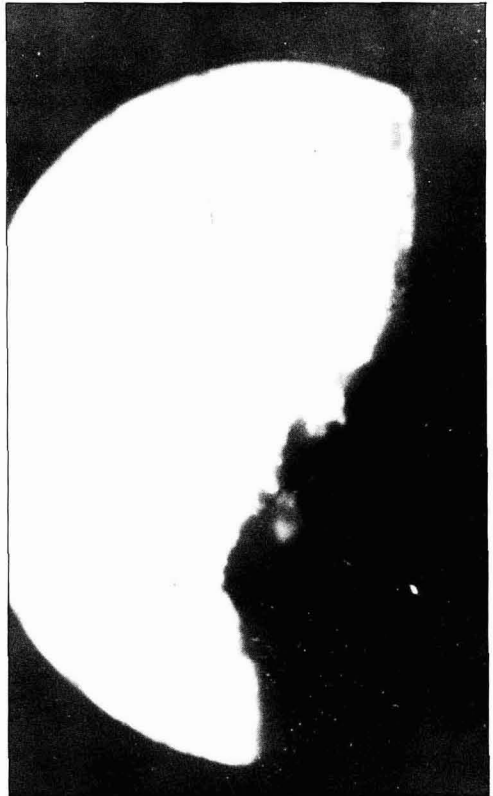


Figure 14—The surface of this acid resistant mortar has been ablated away losing about 50 mils of material. 25× magnification

A program has been initiated to analyze the flue gas condensates of various operating SO₂ scrubber units to establish the different types of corrosive environments found therein. Five stations in various locations are participating.

SUMMARY

The Atlas Test Cell is an effective means to evaluate coating materials used to protect steel surfaces for SO₂ scrubber service. The analytical and test data correlate closely with field experience and field test data.

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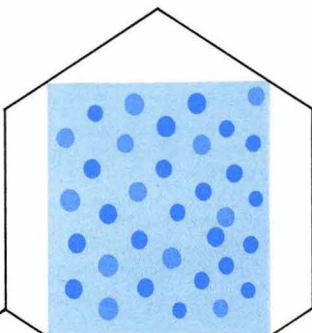
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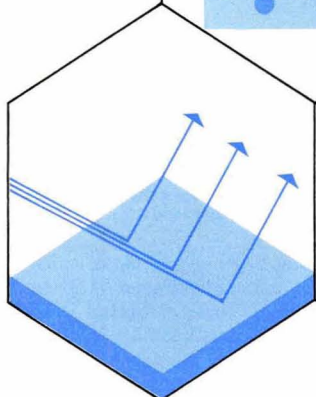
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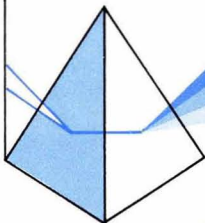
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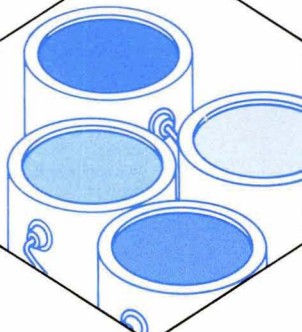
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Morphology of 'Water-Soluble' Acrylic Copolymer Solutions

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It has been previously proposed that "water-soluble" acrylic copolymers dissolved in cosolvent aggregate on dilution with water. The presence of aggregates has now been confirmed by microscopy and ultrafiltration. It has also been demonstrated that the aggregates are highly swollen with water and cosolvent. Viscosity is independent of molecular weight in relatively dilute, low cosolvent ratio systems. However, viscosity is very dependent on molecular weight at intermediate concentrations or cosolvent ratios even though the copolymer is completely aggregated. It is proposed that viscosity of such systems is dependent on aggregate phase viscosity.

INTRODUCTION

So-called "water-soluble" acrylic and polyester resins are widely used in industrial baking enamels. In general, such resins have acid numbers in the range of 50–100 and also are hydroxyl substituted. In coatings formulations, they are used with an amine and organic cosolvents along with a melamine-formaldehyde resin crosslinker. The coatings are diluted to application viscosity with water. As applied, they have a polymer concentration of about 20% and a volatile organic compound (VOC) content of the order of 250 g/L of coating excluding water.

It has been shown by many workers that the changes in viscosity on dilution with water and pH's of the systems are abnormal as compared to true polymer solutions. Hill and co-workers¹⁻⁴ have reviewed the

literature and studied the effect of several variables on the systems. In general, as water is added to a solution of a "water-soluble" resin in cosolvent and amine, the viscosity initially drops, then, on further dilution, levels off and then increases. With still further water addition, the viscosity drops very rapidly from a peak viscosity at intermediate concentrations. Hill, et al., propose that addition of water leads to aggregation of polymer molecules with the nonpolar segments and some accompanying carboxylic acid and hydroxyl groups in the interior of the aggregates and amine salt groups on the exterior of the aggregates. It has been suggested that the aggregates are highly swollen with cosolvent and water. When a sufficient volume of aggregates forms, the system becomes more crowded. This crowding more than offsets the decrease in polymer concentration leading to an increase in viscosity on dilution. Further dilution leads to a rapid decrease in viscosity. It has been suggested that this viscosity drop results from a decrease in crowding as more water is added to the continuous phase. It has also been suggested that the aggregates may shrink as the dilution continues. Both effects would result in decreasing internal phase volume. Viscosity changes rapidly with internal phase volume. The weight fraction of polymer in the range of precipitous drop is 20–30% in contrast to 50–65% in latex systems. Hill and Richards³ have noted that because of the swelling, the internal phase volumes of the water soluble polymer systems may also be 50–65%.

This proposal is consistent with the pH and viscosity behavior of the systems, but no direct evidence for aggregate formation has been obtained. Pierce has shown the presence of aggregates in the more dilute systems of quite different polymers used in electrodeposition coatings.⁵ Hill and Richards³ gave additional support to the proposed morphology by showing that the viscosity of diluted systems were independent of molecular weight. This would be expected if the resin were completely (or

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**Table 1—0.84 BMA/0.16 AA (Mole Fraction)
Copolymers in 2-Butoxyethanol**

Copolymer No.	\bar{M}_w	\bar{M}_n	\bar{M}_w/\bar{M}_n	Acid No.
1	14,000	6,000	2.3	67
2	19,000	8,000	2.4	68
3	25,000	11,000	2.3	68
4	45,000	18,000	2.5	70
5	71,000	29,000	2.4	70

almost completely) aggregated into a dispersed phase and it would not be expected if a significant amount was in solution. However, the comparison was based on a single pair of resins whose molecular weights were quite similar ($\bar{M}_w = 11,000$ and 19,000).

This work was undertaken to determine whether resins with greater differences in molecular weight would give fully diluted systems whose viscosities were independent of molecular weight. Furthermore, direct evidence for the presence of aggregates and, if possible, for the swelling of those aggregates with cosolvent and water was also to be sought.

EXPERIMENTAL

Viscosities were measured at 25°C using either a Ferranti-Shirley cone and plate viscometer with a shroud to minimize volatile loss or a Wells-Brookfield Model RVT cone and plate viscometer. Solids were determined gravimetrically at 105°C for 10 min followed by 105°C under vacuum for 2 hr, samples were diluted with dioctyl phthalate (DOP) to facilitate volatile loss. The weight losses were corrected for the minor loss of DOP blanks. Gas Chromatography (GC) analyses were run using a Varian Aerograph Model 90-P GC with a thermoconductivity detector. A 6' x 3/4" aluminum column packed with Porapak Q was used for separation. The column temperature was 105–110°C and the carrier gas flow rate was 0.09 L/min. A Carl Zeiss phase-contrast microscope with a Namarsky condenser was used.

Polymer Preparation

Acrylic copolymers made by polymerizing mole fractions of 0.84 butyl methacrylate (BMA) and 0.16 acrylic acid (AA) were used in all studies. This type copolymer was adopted as a standard by the Paint Research Institute subcommittee on water-borne coatings. Such a copolymer with $\bar{M}_w = 19,000$ has been designated PR-101. Other research supported by PRI, such as reported by Myers and Raju,⁶ has utilized PR-101. A typical polymerization procedure was as follows:

A 3-neck 2-L flask was charged with 260 mL of 2-butoxyethanol (BE). The flask was fitted with a stirrer, N₂ inlet, thermometer, reflux condenser, and dropping funnel. The flask and solvent were heated to 100°C using a stirred and temperature controlled oil bath. A solution of 46 mL (0.67 mole) of freshly distilled AA, 550 mL (3.46 mole) of BMA, 140 mL BE, and 10 g (1.8% of monomer weight) of 2,2'-azobisisobutyronitrile (AIBN) was added dropwise over a 4 hr period. The reaction temperature

was maintained at 100 ± 2°C under a N₂ atmosphere. After addition was complete, temperature was maintained for an additional 1 hr. Excess solvent and unreacted monomer were removed by vacuum distillation. The nonvolatile content of the copolymer solution was 67.4 wt % and the acid no. was 68.2. Molecular weights were determined by gel permeation chromatography (GPC) using polystyrene standards. The \bar{M}_w was 25,000, \bar{M}_n was 11,000, and \bar{M}_w/\bar{M}_n was 2.3.

A series of copolymers were prepared using different levels of AIBN to vary the molecular weights. Characteristics of the copolymers are given in Table 1.

For other work, a 0.84 BMA/0.16 AA mole fraction copolymer in tertiary butanol (t-BuOH) was prepared by a similar procedure except that the temperature of the reaction was at the reflux temperature of the solvent (78–83°C). The nonvolatile content of the product was 66.6 wt %, acid no. was 77, $\bar{M}_w = 45,000$; $\bar{M}_n = 16,000$; $\bar{M}_w/\bar{M}_n = 2.9$.

Water Dilution Experiments

Master batches were prepared of copolymers 1-5 using 75% of the equivalents of N,N-dimethylaminoethanol (DMAE) required to neutralize the carboxylic acid groups and sufficient additional BE to make 65% solids solutions including DMAE as part of the solids. (In all cases polymer concentrations include the neutralizing amine). The mixture was warmed and shaken on a Red Devil Paint Shaker then allowed to stand for two days before use. Water diluted samples were prepared by adding the appropriate ratio of master batch and water into a vial. The vials were capped, warmed on a steam bath and periodically shaken. About 15 min were required to give solutions which were visually uniform. The samples were allowed to stand 48 hr at room temperature before measuring viscosity.

For the experiments at constant polymer content, the partially neutralized copolymer solution was first diluted with the appropriate amount of solvent and shaken until homogeneous solutions were obtained. Then the appropriate amount of water was added and the diluted solutions shaken until uniform systems were obtained.

Ultrafiltration Studies

An Amicon 10 mL ultrafiltration cell with a Diaflo XM 100 A membrane was used. The manufacturer states that this membrane has a pore size of 5.2 nm and will retain molecules with a molecular weight over 100,000. A positive pressure of 28–32 psi of N₂ was used. The filtrate was collected through plastic tubing that just fit into a test tube using a small syringe needle to prevent back pressure build-up. Samples were analyzed for polymer content and in some cases for cosolvent/water ratio by gas chromatography.

Ultracentrifugation

After preliminary experiments failed with conventional centrifuges, samples were subjected to ultracentrifugation with a Beckman Model L5-65 ultracentrifuge at 23–25°C in closed polycarbonate cells at 35,000 rpm

(148,000 G). Samples of 21.2% polymer plus amine in 0.854 wt fraction water and 0.146 t-BuOH and with 0.875 wt fraction water and 0.125 t-BuOH separated into a clear supernatant liquid and a gelatinous semi-solid after 3.5 hr. The liquid was analyzed by gas chromatography. Lower water ratio systems (higher viscosity) showed no separation after 3.5 hr.

Head Space Analysis

A standard vapor composition curve was prepared by analyzing the vapor above a series of known solutions of t-BuOH in water. Fifty mL samples of solutions were placed in one liter bottles covered with a piece of aluminum foil tightly held in place with a rubber septum. The bottles were immersed up to the neck in a 25°C constant temperature water bath for a minimum of 24 hr. A gas tight syringe was heated for about 5 min in an oven (100–110°C) and then used to withdraw a vapor sample of about 5 mL. (The heated syringe was necessary to avoid condensation when the sample was expelled). The sample was immediately injected into a GC. It was found that all samples with t-BuOH fractions between 0.95 and 0.20 had a vapor composition within 0.01 of 0.85 t-BuOH. Hence the method is only applicable to determination of t-BuOH in solutions containing less than 0.20 t-BuOH in water. Based on 11 samples (each with six replicates) with less than 0.20 t-BuOH, the data fit the following equation:

$$Y = -26.8X^2 + 9.74X + 0.0341$$

where X is t-BuOH fraction in the liquid phase and Y is the t-BuOH fraction in the vapor phase. This equation was found to account for 98.5% of the variation in the analysis and had a 95% confidence limit width of less than 0.05 for solutions with a t-BuOH fraction of 0 to 0.2. Two polymer solutions whose overall t-BuOH fraction was less than 0.20 were analyzed. The liquid phase ratio was calculated from the analysis of the vapor phase.

RESULTS

Effect of Water Dilution on Viscosity

Copolymers 1–5 were neutralized with 75% of the theoretical amount of N,N-dimethylaminoethanol (DMAE) and diluted to 65% solids with 2-butoxyethanol (all polymer concentrations are expressed as % by weight of copolymer plus amine). The resulting solutions were then diluted with water to the desired concentration. The higher molecular weight copolymers gave viscosities too high to measure with available instrumentation at concentrations above 24%. Table 2 shows viscosity at 200 sec⁻¹ shear rate over the range of 16–24% solids.

At 18% and below, viscosity was essentially independent of molecular weight. These samples did not exhibit shear thinning over a range of 150 to 10⁴ sec⁻¹. This confirms the earlier limited observation of Hill and Richards.³ Those samples with solids of 20% and higher showed higher viscosities for higher molecular weight copolymers and were shear thinning. The degree of shear thinning at any given concentration increased as molecular weight increased. As shown in Table 2, at 20% the

Table 2—Viscosity (poise) at 200 sec⁻¹ as a Function of Molecular Weight and Concentration in Water Dilution. (Data at 12,000 sec⁻¹ Are Also Given for 20% Concentration)

No.	Copolymer \bar{M}_w	% Polymer					
		16	18	20	20 ^a	22	24
1	14,000	0.11	0.27	1.4	1.1	23	72
2	19,000	0.11	0.30	2.2	1.3	36	91
3	25,000	0.11	0.30	3.6	1.3	58	140
4	45,000	0.11	0.30	4.6	1.3	90	240
5	71,000	0.11	0.30	5.5	1.3	132	275

(a) These viscosities were determined at 12,000 sec⁻¹

viscosity of the systems were essentially equal at 12,000 sec⁻¹. Samples of the higher molecular weight copolymer systems above 20% wt solids gave erratic viscosity readings at high shear rates.

Effect of Cosolvent/Water Ratio On Viscosity at Constant Polymer Content

Interpretation of data such as that presented in Table 2 is made complex by the fact that two major variables are being changed: solids and cosolvent/water ratio. Further studies were made at constant polymer concentration with varying cosolvent/water ratios. Brandenburger and Hill⁴ had shown with a different acrylic copolymer that at relatively low polymer concentrations, maximum viscosity was obtained with an intermediate cosolvent/water mixture. They proposed that with high cosolvent/water ratios, the polymer was in true solution. As the ratio decreased, aggregates formed. Maximum crowding occurred at some intermediate level. With still lower ratios, apparently the aggregates shrank leading to smaller internal phase volume hence lower viscosities.

While 2-butoxyethanol is a desirable cosolvent for viscosity studies because of its low evaporation rate, we felt analysis of samples would be facilitated by using a more volatile cosolvent, tertiary butanol (t-BuOH). A 0.84 BMA/0.16 AA copolymer ($\bar{M}_w = 45,000$; $\bar{M}_w/\bar{M}_n = 2.9$; acid no. 77) was used in these studies. Solutions were prepared using 70% of the theoretical amount of DMAE. A series of solutions with 21.2% solids (polymer + amine) in various mixtures of cosolvent and water were prepared. (Except where otherwise stated, all cosolvent-water data are expressed as weight fraction cosolvent. Thus, a solution of 21.2% polymer plus amine in a mixture of 80% water and 20% t-BuOH is designated as having a weight fraction of t-BuOH of 0.2). Table 3 shows viscosity at 20 sec⁻¹ as a function of weight fraction t-BuOH in the t-BuOH/water mixture. Viscosity peaks at 0.30 t-BuOH.

Visual and Microscopic Observation

Samples with a weight fraction of 0.7 t-BuOH in the volatile components and higher were transparent. As t-BuOH decreased to 0.3, the samples became increasingly cloudy. At 0.3 and lower all samples were opaque.

Table 3—Ultrafiltration Data on Samples of 21.2% Polymer Plus Amine Solutions in Varying Ratios of t-BuOH/Water

Weight Fraction t-BuOH in Total Solvent (A)	Viscosity (poises) at 20 sec ⁻¹	Weight Fraction t-BuOH in Ultrafiltrate (B)	(A)-(B)	% of Original Polymer in Filtrate
1.00	0.82	N.A.	N.A.	100
0.80	0.88	N.A.	N.A.	100
0.743	N.A.	N.A.	N.A.	98
0.650	1.0	N.A.	N.A.	87
0.600	1.07	N.A.	N.A.	82
0.500	1.38	0.486	0.014	55
0.450	1.61	0.429	0.021	42
0.400	1.97	0.355	0.065	10
0.350	2.45	0.280	0.070	13
0.320	4.01	0.242	0.078	2.4
0.300	4.07	0.212	0.088	tr ^a
0.290	3.75	0.192	0.098	tr
0.271	3.33	0.190	0.081	tr
0.240	2.53	0.161	0.079	tr
0.219	1.32	0.139	0.079	tr
0.173	0.41	0.103	0.070	tr
0.146	0.30	0.082	0.064	tr
0.125	0.20	0.062	0.063	tr

(a) tr = trace (less than 0.1).

When allowed to stand, all samples with a t-BuOH fraction between 0.7 and 0.2 showed macrophase separation, that is, separated into visually obvious layers in contrast to the microphase separation resulting from initial aggregate formation. In general, the highest viscosity samples took long times to separate.

Before determining viscosities or doing other studies, samples were redispersed and then allowed to stand 6–12 hr before testing. The samples were examined using a phase contrast microscope with a Namarsky condenser. Above 0.7 t-BuOH, no particles could be seen. However, at lower t-BuOH contents, spherical aggregates were readily visible. In the range of 0.7–0.5 t-BuOH, a wide range of particle sizes were observed with some as large as 40–50 μm . As t-BuOH decreased further, particle size decreased and the field became more crowded. At low t-BuOH most particles were 1 μm or less. Typical photographs are shown in Figures 1–3. The picture at t-BuOH = 0.45 shows some spheres in the process of coalescing. Visually it was observed that when particles touched each other, they merged. Coalescence was not observed with the smaller particle size spheres at 0.3 and lower t-BuOH.

Ultrafiltration Studies

Samples with various t-BuOH contents were subjected to ultrafiltration with a membrane rated to retain particles with diameters larger than 5.2 nm. The solids of the ultrafiltrates were determined and the percentage of the polymer passing through the membrane calculated. The fraction of t-BuOH in the ultrafiltrate was determined by gas chromatography. Representative data are provided in Table 3. Above t-BuOH = 0.75, all of the polymer passed through the membrane. Between t-BuOH = 0.743 and t-BuOH = 0.3, decreasing percentages of polymer passed through. At 0.3 and below essentially none of the polymer was in the ultrafiltrate.

Thus the rheological properties, molecular weight effect on viscosity, microscopic observations and analyses of the continuous phase all are consistent and establish the validity of the hypothesis that the polymer is completely aggregated at low concentrations with low cosolvent/water ratios.

The ultrafiltrates were also analyzed for the ratio of cosolvent to water. Comparison of the weight fraction of t-BuOH in the ultrafiltrate (external phase) and the total weight fraction of t-BuOH given in Table 3 shows that there is a lower fraction of t-BuOH in the external phase, thus there is, as has been hypothesized,^{1–4} some degree of selective incorporation of cosolvent into the aggregates. As can be seen by examining the column of data showing differences in weight fraction t-BuOH between the total and the external phase, the difference increases until all the polymer is aggregated (0.30) and decreases as the total weight fraction t-BuOH is decreased beyond that level. This indicates that with increasing degrees of aggregation (0.50–0.30), t-BuOH is being removed from the external phase but since the difference decreases beyond the stage of full aggregation, presumably t-BuOH is being “extracted” from the aggregates. This is consistent with shrinkage of internal phase volume and decreasing viscosity.

It could be argued that considerable pressure is applied to the aggregates in the ultrafiltration process which might result in cosolvent and water being forced out of the aggregates. Therefore, two other methods which would apply higher and lower pressures were used to analyze the cosolvent/water ratio in the external phase. Ultracentrifuging of two samples with low weight fraction t-BuOH at 148,000 G for 3.5 hr separated a clear layer at the top. The bottom layer was a gelatinous semisolid. A thin milky layer remained between the two principal layers. The clear top layer was analyzed by gas chromatography. The higher cosolvent content samples did not separate even after 3.5 hr ultracentrifuging at 148,000 G. Also, as described in the experimental section, composition of the vapor in equilibrium with these samples in closed containers was determined. The equilibrium level of t-BuOH in the vapor was used to calculate the t-BuOH content of the external phase by comparison with a standard response curve for vapors in equilibrium with solutions of varying ratios of t-BuOH and water without polymer. As can be seen in Table 4, the three methods of analysis gave remarkably similar results. Since the vapor phase analysis involved essentially zero pressure on the aggregates and ultracentrifuging at 148,000 G much more pressure than ultrafiltration, ultrafiltration appears to be a satisfactory method for separating external phase for cosolvent analysis.

Estimation of Internal Phase Volume

Cosolvent and water content of the aggregate phase cannot be calculated from the composition of external phase unless the amounts of the two phases are also known. No procedure is available for direct determination of the amounts of the two phases. In one case, we have estimated the internal phase volume indirectly by viscosity studies. A sample of the 0.219 t-BuOH

"solution" of polymer was diluted to different extents with a solution of 0.138 t-BuOH, 0.861 water. This is the same composition as that of the external phase as determined by analysis of the ultrafiltrate. Presumably, dilution with the same composition of external phase would not lead to any change in the aggregates. Viscosities of the diluted systems were determined. Viscosity is a function of internal phase volume in two phase systems. A convenient equation showing the relationship is the Mooney equation (1).⁷

$$\ln \eta = \ln \eta_e + \frac{2.5 V_i}{1 - V_i} \phi \quad (1)$$

Where η is the bulk viscosity, η_e is viscosity of the external phase, V_i is internal phase volume, and ϕ is packing factor. In this form, the Mooney equation is applicable to dispersions of rigid spherical particles when there is no interaction between particles. Microscopy showed that the particles were spherical. In a crowded system, interaction might be expected. However, such interaction would be eliminated, or at least minimized, with dilution. It was shown that the samples do obey the Mooney equation. The internal phase volume before dilution was calculated to be 0.53 and the packing factor, ϕ , 0.78. The calculation procedure is given in the Appendix. The packing factor is high. High packing factors for spherical systems result from a wide particle size distribution which was observed microscopically. The internal phase volume of 0.53 in a sample with a weight fraction of polymer plus amine of 0.212 indicates substantial swelling with cosolvent and water.

Calculations of compositions of the internal phase require making density assumptions. The density of the polymer plus amine was assumed to be 1.1 and it was assumed that densities of mixtures were directly proportional to densities of the components. It was assumed that all of the amine was in the aggregates. (Since the pH of the solution was basic (pH 9.2), actually some of the amine was in the external phase.) Based on these assumptions, the volume compositions of the internal and external phases were calculated. The data are given in Table 5.

In view of the many assumptions, these data should be viewed as only approximate numbers. However, they do show that the aggregate phase is swollen with substantial amounts of both water and t-BuOH and that the aggregate phase contains a substantially higher fraction t-BuOH. Calculated as volume fractions of the volatile components, the total system was 0.26 t-BuOH, the external phase 0.17 t-BuOH, and the aggregate phase 0.39 t-BuOH.

Molecular Weight Dependence of Viscosity As Function of Cosolvent/Water Ratio

The viscosities of solutions of 18% of copolymers 1-5 in a range of 2-butoxyethanol/water mixtures were also determined. The data in Table 6 shows that viscosity at 40 sec⁻¹ is independent of molecular weight for those samples with 0.10-0.12 weight fraction BE but varied with molecular weight at other ratios.

Regardless of molecular weight, all samples show a peak viscosity at about 0.20 weight fraction BE. The loca-

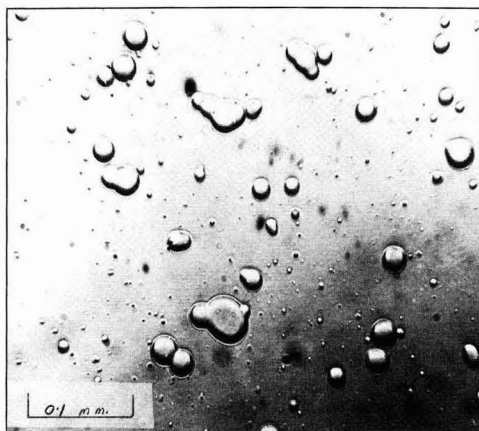


Figure 1—Microphotograph of aggregates in 21.2% solids solution of copolymer and DMAE in 0.45 t-BuOH and 0.55 H₂O taken using a phase contrast microscope

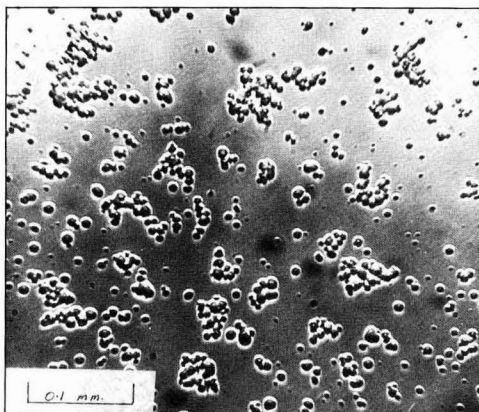


Figure 2—Microphotograph of aggregates in 21.2% solids solution of copolymer and DMAE in 0.39 t-BuOH and 0.61 H₂O taken using a phase contrast microscope

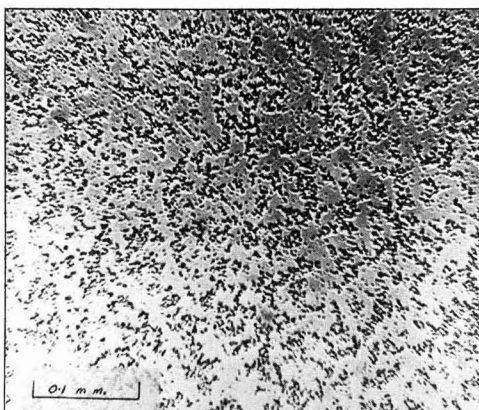


Figure 3—Microphotograph of aggregates in 21.2% solids solution of copolymer and DMAE in 0.24 t-BuOH and 0.61 H₂O taken using a phase contrast microscope

Table 4—Weight Fraction t-BuOH in External Phase As Determined by Three Procedures

Total t-BuOH	Ultrafiltration	Centrifugation	Vapor Analysis
0.146	0.082	0.083	0.084
0.125	0.062	0.064	0.068

Table 5—Estimated Volume Fractions in a Sample of 21.2% Copolymer in a Solvent with 0.219 Weight Fraction t-BuOH And 0.781 Weight Fraction Water

	Volume Fractions of Total	Volume Fractions in Each Phase
Aggregate Phase		
Polymer + Amine	0.19	0.35
Water	0.21	0.40
t-BuOH	0.13	0.25
	0.53	1.00
External Phase		
Water	0.39	0.83
t-BuOH	0.08	0.17
	0.47	1.00

Table 6—Viscosity (poise) at 40 sec⁻¹ of 18% Solutions Of Copolymers 1–5 as a Function of Wt Fraction BE In the Volatile Components

Copolymer No.	\bar{M}_w	Wt. Fraction BE						
		.10	.12	.18	.20	.22	.30	1.0
1	14,000	0.20	0.27	1.5	1.8	1.6	0.89	0.15
2	19,000	0.20	0.30	2.1	2.5	2.2	1.1	0.19
3	25,000	0.20	0.30	2.8	3.5	2.8	1.6	0.24
4	45,000	0.20	0.30	4.8	7.1	5.6	2.7	0.36
5	71,000	0.20	0.30	8.9	13.2	10.0	6.0	0.54

tion of the peak at 0.2 weight fraction cosolvent contrasts to the peak at 0.3 with t-BuOH as shown in Table 3. While some of the difference may be due to polymer concentration, the difference between solvents is probably the primary cause. The BE containing samples all showed substantially less light scattering than the t-BuOH containing samples. Ultrafiltration of the 0.12 2-butoxy-ethanol solution of the lowest molecular weight polymer gave a slightly hazy filtrate. Based on solids determination, less than 1% of the aggregates were of sufficiently small size to get through the membrane. Only traces of this copolymer passed through the membrane between 0.12 and 0.2 cosolvent. Also only traces of the higher \bar{M}_w copolymer were found in the ultrafiltrates at 0.20 and lower solvent contents. A substantial fraction of the highest molecular weight copolymer was retained by the membrane even when it was diluted only with BE. The membrane is rated as retaining molecular weights above 100,000, so partial retention was expected. Even though essentially all of the polymer was aggregated at 0.2 BE and lower, these samples were translucent in contrast to

the opacity of the t-BuOH fully aggregated samples. Presumably, the refractive index difference between internal and external phases was less. Observations with phase contrast microscopy were similar to those shown for the t-BuOH systems.

Log viscosity determined at 40 sec⁻¹ at the peak viscosity was very dependent on molecular weight, varying in a linear relationship with log \bar{M}_w . Solutions in straight BE showed a more normal relationship between viscosity and molecular weight; log viscosity increased approximately proportionately with the half power of \bar{M}_w .

The lack of dependence of viscosity on molecular weight at high water dilutions as shown in Table 2 and at low cosolvent/water ratios as shown in Table 6 is readily understandable. Latex viscosities are also independent of molecular weight. However, it is less evident why viscosity is highly dependent on molecular weight with somewhat less dilution or with cosolvent weight fractions up to 0.2 at constant polymer content, although these systems are also fully aggregated.

In order to explain why peak viscosity is not even higher than it is during water dilution of a variety of systems, it has been suggested that overall viscosity of these systems may depend on the viscosity of the internal phase as well as internal phase volume.^{1-4,8} Nielsen discusses the viscosity of emulsions and the dependence of their viscosities on the relations between internal and external phases.⁷ When an emulsion is exposed to shearing forces, the spherical droplets can be distorted and the viscosity drops as shear rate increases. The degree of distortion at any given shear rate is dependent primarily on the difference of viscosity of the internal phase and that of the external phase. Distortion under shear may change the "constants" in the Mooney equation.

$$\ln \eta = \ln \eta_c + \frac{K_E V_i}{1 - V_i} \phi$$

The shape constant, K_E , equals 2.5 for spherical particles. When spheres are distorted, K_E gets smaller and, as can be seen by the equation, viscosity will be lower. Also, the packing factor may get larger since distorted particles may pack more closely than spheres when aligned with the direction of shear. As can be seen by the equation, at high internal phase volumes, one would expect changes in ϕ to have the greatest effect on viscosity. Since internal phase viscosity of these systems would decrease with decreasing molecular weight, distortion of the spheres would increase as molecular weight decreases, resulting in lower viscosity of the overall system as molecular weight decreases. The effect would be most pronounced at high internal phase volumes. It would also be expected to be greater as overall viscosity increases since at a given shear rate more shear stress would be transmitted to the internal phase when the viscosity is higher.

Testing this proposal would require determining the actual viscosity of the internal phase, but we have not been able to devise any technique for the measurement. Indirect confirmation that internal phase viscosity increases with molecular weight was obtained by observing the degree of macrophase separation of the 18% solutions of the five copolymers in 0.12 BE/0.88 water. These solutions all have essentially equal viscosities, hence,

equal internal phase volumes and packing factors, hence, equal particle size distributions and densities. Yet after standing for four months, the lowest molecular weight solution was almost completely separated into two phases while only a trace of macrophase separation had taken place with the highest molecular weight solution. The intermediate solutions showed decreasing degrees of macrophase separation as molecular weight increased. It seems appropriate to attribute these differences to the effect of internal phase viscosity on the rate of coalescence of aggregates.

It is also possible that particle-particle interaction increases as molecular weight increases. Lin has suggested, in somewhat similar systems, that the shear thinning may result from breaking of "bridges" between aggregates.⁹ Perhaps bridges are more likely to form with higher molecular weight polymers. If this were a major effect, it is not evident why the peak of viscosity in Table 6 would be at the same cosolvent/water ratio with all molecular weights. Also, the linear relation between internal phase volume and $2.5/\ln \eta$, observed in the dilution experiment described earlier indicates that, at least in that experiment, little, if any, particle-particle interaction was present.

SUMMARY

It has been shown that viscosity is independent of molecular weight in relatively dilute, low cosolvent content "water-soluble" acrylic resin systems. By ultrafiltration, it has been established that essentially all of the polymer is aggregated. The aggregates have been observed directly by phase contrast microscopy. Analysis of external phases has established that the aggregated polymer particles contain a larger fraction of the cosolvent than the external phase. Fully aggregated systems show progressively less difference in cosolvent between the external phase composition and the total cosolvent/water composition as cosolvent/water ratio decreases. This agrees with earlier suggestions that aggregates shrink in lower cosolvent systems. It was shown that when a fully aggregated system was diluted with a cosolvent/water blend with the same ratio as in the external phase, the relationship between viscosity and internal phase volume obeyed the Mooney equation. Based on these data, it was established that the aggregate particles were swollen with substantial amounts of both cosolvent and water. Viscosity, on the other hand, is very strongly dependent on molecular weight at intermediate cosolvent/water ratios even though the systems are fully aggregated. It is suggested that this results from the dependence of overall viscosity on the viscosity of the internal phase.

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of using ultrafiltration made by Dr. Roger Christenson. We greatly appreciate the contributions of Dr. Loren Hill in planning the research, analyzing the data, and suggesting revisions and clarifications in the manuscript.

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APPENDIX

CALCULATION OF INTERNAL PHASE VOLUME FROM RHEOLOGICAL DATA

A sample of a solution containing 21.2% polymer plus amine in 0.219 t-BuOH and 0.781 water was progressively diluted with a solution of 0.139 t-BuOH and 0.861 water. The latter ratio has the same composition as that determined by analysis of the external phase. Viscosities at 20 sec⁻¹ of various dilutions are given in *Table 7*. Dilutions are expressed as mL of original solution divided by total volume after adding the additional increment of solvent (D). This definition of dilution is convenient since $V_i = D V_{i0}$ where V_{i0} is the internal phase volume of the original sample and V_i is the internal phase volume of the diluted sample. The experimentally determined viscosity of the t-BuOH/H₂O diluent of 1.78 cp compares with 1.76 calculated by the method of Rocklin.¹⁰

Table 7—Viscosities of Samples From Dilution Of 21.1% Copolymer $\bar{M}_w = 45,000$ in 0.219 t-BuOH/0.781 Water with 0.139 t-BuOH/0.861 Water

Sample Dilution D	η (cps)
1 (undiluted)	131
0.952	63.1
0.908	36.4
0.800	16.6
0.594	6.62
0.521	5.14
Diluting Solvent	1.78

The internal phase volume of the original sample is, of course, not known but can be estimated if the Mooney equation

is obeyed by plotting $2.5/\ln \eta_r$ vs $1/D$ as shown by the linear form of the Mooney equation.

$$\frac{2.5}{\ln \eta_r} = \frac{1}{(D V_{i0})} - \frac{1}{\phi}$$

Where η_r is the relative viscosity of the sample (η/η_e), V_{i0} is the internal phase volume of the undiluted sample, $(D V_{i0})$ is the internal phase volume of the sample and ϕ is the packing factor. Use of this equation assumes that the viscosity of the internal phase is sufficiently high so that the aggregates are not distorted in the viscosity measurement and that there is no interaction between particles. The validity of these assumptions can be tested by determining whether or not there is a linear relationship between $2.5/\ln \eta_r$ and $1/D$ as predicted by the equation. Using 2.5 for the shape constant, K_E is based on the assumption that the particles are spherical. This is reasonable based on microscopic examination. However, linearity of the plot does not test the assumption, it merely means that the shape constant stays constant through the dilution. Also, it is assumed that diluting with only a t-BuOH/water solution, which does not contain other components of the external phase of the original sample such as amine and the trace of polymer, gives equivalent viscosity effects. Most importantly, it is assumed that no changes in the aggregate particle size and particle size distribution resulted from the dilution; linearity of the plot would indicate that this assumption is valid.

The data in *Table 7* were shown by regression analysis to fit the following linear equation with a correlation factor of 0.999.

$$\frac{2.5}{\ln \eta_r} = \frac{1}{0.53 D} - \frac{1}{0.78}$$

Thus, the internal phase volume before dilution was 0.53 and the packing factor 0.78. This relatively high packing factor is to be expected for spheres with a wide distribution of particle sizes.

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Equations for Calculating Homolog Solubility Parameters

The Limiting Solubility Parameter

Charles H. Fisher
Roanoke College*

Simple logarithmic equations ($\sigma = b + m \log(x + k)$) were developed for relating homolog solubility parameters (σ) to number of carbons (x). These equations (k , adjustable parameter), which confirm Seymour's observation that σ is linear with $\log x$, can be used to evaluate published solubility parameters and to calculate new ones. The solubility parameters of some moderately polar homologs may be represented by simple linear equations ($\sigma = b + mx$). Equations are provided for relating homolog solubility parameters to several other properties. Some of the equations suggest the limiting solubility parameter (σ_{∞} for an n -alkane of infinite length) is approximately 8.8.

INTRODUCTION

The nature, importance, and usefulness of solubility parameters have been described, and several compilations of solubility parameter data have been published.¹⁻¹² Nevertheless, there is need for more solubility parameter data and for additional methods of assessing the accuracy of existing data. Solubility parameters (σ), the square root of the heat of vaporization per unit volume³

$$\sigma = (E/V)^{1/2}$$

are known to be related to chain length. Seymour³ showed that homolog solubility parameters (σ) are approximately linear with the logarithm of chain length (molecular weight, M , or number of carbons, x), thereby suggesting a method for correlating and calculating homolog solubility parameters. The principal purpose

of the present work was to facilitate the calculation of solubility parameters by developing equations and relating solubility parameters to molecular weight and to certain other properties.

DATA SELECTION AND HANDLING

For the most part, Hoy's data⁹ were used. A Hewlett Packard HP27 instrument was used to calculate least squares equations and correlation coefficients (r):

$$(\sigma) = b + m \log(x + k)$$

In these equations, b is the intercept, m is the slope, and k is an adjustable parameter. Two sets of equations were derived. In the first set, k values were selected to give approximately the best fit between literature and calculated values (*Table 1*). In the second set, k values were selected to give solubility parameters of approximately 8.4 for the C_{30} homologs (*Table 2*). These equations (*Table 2*) might be best for calculating solubility parameters of homologs of relatively high molecular weight.

The number of carbons is used in the present work to represent homolog chain length; presumably the molecular weight could be used equally well. The solubility parameters (Hildebrands) of the present work may be multiplied⁵ by 2.046 to obtain solubility parameters in S. I. units ($J^{1/2}/cm^{3/2}$).

EQUATIONS RELATING SOLUBILITY PARAMETERS TO NUMBER OF CARBONS

The work reported below provides equations for calculating homolog solubility parameters from the chain length, represented by the number of carbons (x). In agreement with Seymour,³ the solubility parameters of 31 homologous series were found to be approximately

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Table 1—Equations Relating Solubility Parameters (σ) to Number of Carbons (x) ($\sigma = b + m \log(x + k)$)^{a,b}

Eq.	n-Alkyl compounds	Carbon Range	Constant, k	Intercept, b	Slope, m	Corr. coeff., r	C ₃₀ value
1	n-Alkanes	5-15	0	5.46421	2.29444	0.9926	8.85
2	2-Me alkanes	4-10	-3.5	6.49222	1.33103	0.9991	8.39
3	3-Me alkanes	5-10	-4	6.74116	1.15599	0.9947	8.38
4	R cyclopentanes	6-16	10	3.88173	3.26044	0.9824	9.11
5	1-Alkenes	4-10	-3	6.66266	1.35623	0.9992	8.60
6	R benzenes	8-16	-7.9	8.64418	-0.187017	-0.9715	8.40
7	n-Alkanols	1-12	-0.5	13.4514	-3.53431	-0.9989	8.26
8	2-n-Alkanols	3-12	1	15.1041	-5.95134	-0.9948	6.23
9	n-Alkanals	3-6	-2.9	9.09512	-0.346766	-0.9985	8.60
10	n-Alkanoic acids	2-6	-1	12.9605	-1.92022	-0.9911	10.15
11	Anhydrides	4-8	-2.5	11.1009	-2.54880	-0.9999	7.43
12	Acetates	4-8	-3.4	8.84321	-0.312306	-0.9966	8.40
13	Et alkanoates	3-10	-2.2	9.41617	-1.46341	-0.9969	7.30
14	R alkanoates	4-12	-2.8	8.96494	-0.702018	-0.9999	7.96
15	Vinyl alkanoates	4-24	-3.5	8.90693	-0.471831	-0.9907	8.24
16	R phthalates	10-20	-7	12.0185	-2.80879	-0.9981	8.19
17	Me ketones	3-9	1	11.4311	-2.99526	-0.8970	6.96
18	Et ketones	5-8	-4.9	8.62423	-0.434948	-0.9961	8.02
19	ROR	4-12	10	4.73252	2.43132	0.9961	8.63
20	ROCH ₂ CH ₂ OH	3-11	-1.7	12.0168	-3.31742	-0.9895	7.20
21	ROCH ₂ CH ₂ OR	4-10	-2.7	8.69350	-0.577364	-0.9427	7.86
22	Glycol ether acetates	5-8	-4.5	9.55020	-1.17056	-0.9999	7.90
23	Diglycol monoethers	5-10	-4.8	10.3957	-1.06867	-0.9958	8.90
24	Diglycol diethers	7-12	-6.7	8.74484	-0.553460	-0.9996	7.99
25	Diglycol ether acetates	7-10	-6	9.90167	-1.41182	-0.9999	7.95
26	N-RR amides	3-6	-2.5	11.3500	-2.44796	-0.9844	7.83
27	RNH ₂	3-6	-2	8.87000	-0.697605	-0.9999	7.86
28	R ₂ NH	6-12	-4	7.79667	0.581337	0.9999	8.62
29	R ₃ N	6-12	4	5.55102	1.85431	0.9991	8.39
30	RCN	2-4	-1.7	10.9689	-2.18790	-0.9999	7.79
31	RCl	3-6	10	8.20256	0.159434	0.4770	8.46

(a) R = n-alkyl

(b) Values of k selected to give approximately the best fit (highest correlation coefficient).

Table 2—Equations Relating Solubility Parameters (σ) to Number of Carbons (x) ($\sigma = b + m \log(x + k)$)^{a,b}

Eq.	n-Alkyl compounds	Carbon Range	Constant, k	Intercept, b	Slope, m	Corr. coeff., r	C ₃₀ value
32	n-Alkanes	4-34	-3.5	6.91897	1.04378	0.9953	8.40
33	1-Alkenes	5-10	-4	7.03971	0.963051	0.9928	8.40
34	n-Alkanols	2-12	-0.8	13.1535	-3.26680	-0.9971	8.37
35	n-Alkanals	3-6	-2.6	9.20356	-0.567128	-0.9961	8.39
36	n-Alkanoic acids	2-6	4	17.5076	-5.96533	-0.9780	8.37
37	Anhydrides	4-8	-3.7	10.0485	-1.19736	-0.9915	8.35
38	R alkanoates	4-12	-3.9	8.60711	-0.309483	-0.9923	8.17
39	Vinyl alkanoates	4-24	-3.9	8.77513	-0.330697	-0.9724	8.31
40	R phthalates	10-20	-8.5	11.0950	-2.02792	-0.9965	8.39
41	Et ketones	5-8	-4.99	8.56351	-0.252049	-0.9908	8.21
42	ROR	4-12	0	6.92247	0.979976	0.9849	8.37
43	Glycol ether acetates	5-8	-4.9	9.28698	-0.640022	0.9871	8.39
44	Diglycol monoethers	5-10	-4.2	10.8747	-1.74659	-0.9780	8.41
45	Diglycol diethers	7-12	-6.99	8.58309	-0.239780	-0.9734	8.26
46	Diglycol ether acetate	7-10	-6.7	9.50597	-0.802201	-0.9909	8.41
47	N-RR amides	3-6	-2.75	11.0147	-1.83508	-0.9828	8.38
48	RNH ₂	3-6	-2.9	8.61832	-2.67594	-0.9748	8.23
49	R ₂ NH	6-12	-5.9	8.14011	0.182829	0.9678	8.39
50	RCN	2-4	-1.85	10.7666	-1.64861	-0.9983	8.39
51	RCl	3-6	-2	8.38167	0.016610	0.3273	8.41

(a) R = N-alkyl

(b) Values of k selected to give $\sigma = 8.40$ (approximately) for C₃₀ homologs.

linear with the logarithm of x . Adjustable parameters (k) were generally needed, however, to have good agreement between calculated and literature values (Tables 1 and 2).

The logarithmic equations (Tables 1 and 2) have several advantages:

(1) Solubility parameters for additional compounds may be calculated by interpolation and prudent extrapolation.

(2) The calculated solubility parameter values, at least for some homologous series, may be more accurate than the experimental and literature values.

(3) For any given homologous series, the calculated increments between adjacent homologs change smoothly and regularly.

(4) The preparation of figures with straight lines depicting the relation of solubility parameters to $\log(x+k)$ is facilitated.

(5) With the calculated values, it may be feasible to report solubility parameters in the second or third decimal place.

(6) As shown below, the logarithmic relation may be used to relate solubility parameters to other properties or functions that are linear with homolog chain length.

(7) The equations in Tables 1 and 2, occupying little space, can be used to calculate hundreds of solubility parameters.

As shown in Table 3, the σ values calculated by equations (31) and (51) for n -alkyl chlorides agree well with the literature values⁹ in spite of the low correlation coefficients. The following linear equation (52) also is suitable for calculating the solubility parameters of the n -alkyl chlorides (Table 3):

$$\sigma = 8.36500 + 0.005000x \quad (52)$$

(Corr. coeff., 0.500000)

The equation slopes (m) for the relatively non-polar homologs (Table 1) are positive, whereas the slopes for the polar homologs are negative. Hence, the slopes may be considered an approximate measure of polarity. The equations with low slopes (Tables 1 and 4) have intercepts (b) ranging from 7.8 to 9.1. The n -alkyl chlorides have the lowest positive slope (0.159434), whereas the n -alkylbenzenes have the lowest negative slope (-0.187017); the intercepts (b) for these two homologous series are 8.20 and 8.64.

The intercepts in Table 1 are approximately linear with the slopes. Equation (53), based on the data in Table 4, indicates the intercept for zero slope is 8.43. This suggests the ultimate or limiting solubility parameter is about 8.4.

$$b = 8.43106 - 1.08239 m \quad (53)$$

(Corr. coeff., -0.926487)

The solubility parameters represented by equations with low slopes (Tables 1-5) may be defined by simple linear equations (Table 5):

$$\sigma = b + mx$$

The agreement between calculated and literature values is good (Table 6).

The n -alkylcyclohexanes (Tables 5 and 6) are exceptional in that, in spite of low solubility parameter values,

Table 3— n -Alkyl Chlorides: Literature⁹ and Calculated σ Values

Carbons, x	3	4	5	6	30
Literature	8.39	8.37	—	8.40	—
Eq. 31	8.380	8.385	8.390	8.395	8.458
Eq. 51	8.382	8.387	8.390	8.392	8.406
Eq. 52	8.380	8.385	8.390	8.395	8.515

Table 4—Relation of Intercepts (b) to Slopes (m)

Homolog	Slopes	Intercepts	
		Table 1	Eq. 53
R ₂ NH	0.581337	7.79667	7.8018
RCl	0.159434	8.20256	8.2585
RC ₆ H ₅	-0.187017	8.64418	8.6335
Acetates	-0.312306	8.84321	8.7691
Aldehydes	-0.346766	9.09512	8.8064
Et ketones	-0.434948	8.62423	8.9018
Vinyl esters	-0.471831	8.90693	8.9418

Table 5—Equations Relating Solubility Parameters (σ) To Number of Carbons (x)^a

Homologs	Eq.	Carbon Range	Intercept, b	Slope, m	Corr. coeff., r
R ₂ NH	54	6-12	7.66071	0.0560714	0.9787
RCl	52	3-6	8.36500	0.0050000	0.5000
RC ₆ H ₅	55	9-16	8.79795	-0.0209639	-0.8699
Acetates	56	5-8	9.02214	-0.0492857	-0.9198
RCHO	57	4-6	9.45000	-0.0900000	-1.0000
Et ketones	58	6-8	9.20000	-0.1000000	-0.9853
Vinyl esters	59	4-6	9.83500	-0.1950000	-0.9990
Cyclohexanes	60	8-18	8.04265	-0.0123280	-0.9559

(a) $\sigma = b + mx$; data from Reference 9.

the solubility parameters decrease with increasing chain length.

As a matter of convenience, it would seem desirable, where feasible, to use simple linear equations (such as those in Table 5) for the moderately polar compounds. Logarithmic equations (Tables 1 and 2) could be used where the simple linear equations are not suitable. For some homologous series, the first few members may not be amenable to the equations.

Preliminary work, not herein described, indicates the molar-volume type of equation¹⁴ ($M/\sigma = b + mx$) and various reciprocal equations¹⁴ ($\sigma = b + m/(x+k)$ and $1/\sigma = b + m/(x+a)$) can be used to relate σ to x . In these equations, b is the intercept, m is the slope, and a and k are adjustable parameters. For some such equations, a and k may be zero.

Table 6—Literature^a and Calculated Solubility Parameters^b

Homologs	Carbons, x									
	3	4	5	6	7	8	9	10	12	14
R ₂ NH		8.04		7.97		8.15			8.32	
Eq. 54		7.89		8.00		8.11		8.22	8.33	8.45
RCl		8.39		8.37						
Eq. 52		8.38	8.39	8.39	8.40	8.40	8.41			8.44
RC ₆ H ₅ ^b				9.16	8.93	8.84	8.62	8.57	—	8.56
Eq. 55					8.65	8.63	8.61	8.59	8.55	8.50
Acetates		9.46	8.91	8.80	8.69	—	8.64			
Eq. 56			8.83	8.78	8.73	8.68	8.63	8.58	8.53	8.33
RCHO		9.44	9.09	9.00	8.91					
Eq. 57		9.18	9.09	9.00	8.91	8.82	8.73	8.64	8.55	8.19
Et ketones			9.45	9.06	8.59	8.52	8.39			
Eq. 58				8.70	8.60	8.50	8.40	8.30	8.20	7.80
Vinyl esters			9.05	8.87	8.66					
Eq. 59			9.06	8.86	8.67	8.47	8.28	8.08	7.89	7.11
RC ₆ H ₁₁ ^c				8.19	—	7.95	7.92	7.94	7.89	7.88
Eq. 60				7.97	7.96	7.94	7.93	7.92	7.89	7.87

(a) Solubility parameter calculated from equations in Table 5.

(b) The C₁₈ solubility parameter, 8.44.(c) The C₁₈ solubility parameter, 7.83.

RELATION OF SOLUBILITY PARAMETERS TO OTHER PROPERTIES

Because σ is related to the logarithm of homolog chain length (represented by number of carbons, x), it would be expected that solubility parameters can also be related to the logarithms of properties and functions that are linear with chain length. This expectation was confirmed by developing equations (61, 62, and 63) that relate solubility parameters of *n*-alkanes to molar volume (V_{20}), T^2 (T = boiling point, °K), and heat of vaporization (ΔH_v):

$$\sigma = 1.01658 + 2.94384 \log V_{20} \quad (61)$$

(Corr. coeff., 0.999258)

$$\sigma = 6.54587 + .00006012 \log T^2 \quad (62)$$

(Corr. coeff., 0.992931)

$$\sigma = 5.15190 + 2.39262 \log \Delta H_v \quad (63)$$

(Corr. coeff., 0.999993)

Table 7—*n*-Alkanes: Solubility Parameters (σ), Molar Volumes (V_{20}), Normal Boiling Points (T , °K), and Heats of Vaporization (ΔH_v)^{a,b}

Carbons, x	V_{20}	T , °K	σ^a	ΔH_v	σ , Calculated			
					Eq. 1	Eq. 61	Eq. 62	Eq. 63
5	115.21	309.27	7.02	6.316	7.068	7.085	7.121	7.067
6	130.70	341.94	7.27	7.541	7.250	7.247	7.249	7.251
7	146.55	371.63	7.50	8.736	7.403	7.393	7.376	7.404
8	162.61	398.87	7.54	9.916	7.536	7.526	7.502	7.536
9	178.73	424.00	7.64	11.100	7.654	7.647	7.627	7.653
10	194.90	447.32	7.72	12.277	7.759	7.757	7.749	7.758
12	227.52	489.48	7.91	14.648	7.940	7.955	7.986	7.941

(a) Solubility parameters from Reference 9, other data from Reference 13; $V_{20} = M/d^*$; and ΔH_v at 25°C.(b) The σ values of equation (1) were used to develop equation (61), (62), and (63).

The σ values calculated by these equations agree well with the literature values (Table 7).

The Hoy⁹ and Maffiolo⁶ solubility parameters for the *n*-alkanes (Table 8) are linear with densities¹⁵ (d_4^{20}) (equations (64) and (65)).

$$\sigma = 2.13302 + 7.76035d_4^{20} \quad (64)$$

(Carbons 5 - 15; $r = 0.985521$)

$$\sigma = 1.72003 + 8.26983d_4^{20} \quad (65)$$

(Carbons 7 - 36; $r = 3(0.9)134$)

The solubility parameters calculated by equations (64) and (65) agree well with the literature values (Table 8). The limiting solubility parameters (σ_∞) calculated from equation (64) and the limiting density ($d_4^{20} = 0.854$ for C_∞) is 8.76. The limiting solubility parameter (σ_∞) calculated from equation (65) and $d_4^{20} = 0.854$ is 8.78. The following σ_∞ values have been reported: 7.7,¹ 8.36,⁵ and 8.79.⁹ Because the C₃₆-*n*-alkane solubility parameter is 8.49 (Table 8), the proper σ_∞ value should be higher, possibly approximately 8.8. Knowledge of limiting properties can be helpful in developing equations relating homolog properties to chain length.¹⁴

SUMMARY

Logarithmic equations ($\sigma = b + m \log(x + k)$; b , intercept; m , slope; k , adjustable parameter) are provided for calculating solubility parameters (σ) from the number of carbons (x) for 31 homologous series. The slopes of these equations, some positive and some negative, appear to be an approximate measure of polarity. Even simpler equations ($\sigma = b + mx$) may be used to calculate σ from x for some moderately polar compounds. Equations are provided for relating *n*-alkane solubility parameters to molar volumes, boiling points, heats of vaporization, and densities. Some of the equations suggest the limiting

Table 8—n-Alkanes: Densities (d_4^{20}) And Solubility Parameters (σ)^a

Carbons, x	d_4^{20}	Solubility Parameters				Carbons, x	d_4^{20}	Solubility Parameters			
		Ref. 9	Eq. 64	Ref. 6	Eq. 65			Ref. 9	Eq. 64	Ref. 6	Eq. 65
5.....	0.62624	7.02	6.99	7.08	—	13.....	0.7564	8.04	8.00	7.97	7.98
6.....	0.65937	7.27	7.25	7.28	—	14.....	0.7628	8.11	8.05	8.02	8.03
7.....	0.68376	7.50	7.44	7.41	7.37	15.....	0.7685	8.19	8.10	8.06	8.08
8.....	0.70252	7.54	7.58	7.54	7.53	20.....	0.7887	—	8.25	8.23	8.24
9.....	0.71763	7.64	7.70	7.66	7.65	25.....	0.8012	—	8.35	8.35	8.35
10.....	0.73005	7.72	7.80	7.75	7.76	30.....	0.8097	—	8.42	8.42	8.42
11.....	0.74017	7.80	7.88	7.83	7.84	35.....	0.8157	—	8.46	8.48	8.47
12.....	0.74869	7.91	7.94	7.90	7.91	36.....	0.8169	—	8.47	8.49	8.48
						∞	0.854	—	8.76	—	8.78

(a) Densities, Reference 15.

solubility parameter (σ_∞ for an n-alkane of infinite length) is approximately 8.8.

ACKNOWLEDGMENT

This paper is dedicated with gratitude, admiration, and best wishes to Professor J. H. Hildebrand on the occasion of his 100th birthday.

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January 1982 Subcommittee Reports Of ASTM Committee D-1

The January 1982 meeting of ASTM Committee D-1 on Paint and Related Coatings and Materials was held on January 17-20 at the Hotel Monteleone, New Orleans, LA. In the three and one half days preceding the final report session and general meeting of Committee D-1, approximately 170 members and guests met in 156 scheduled meetings of D-1 subcommittees and working groups. The present membership of Committee D-1 is 503.

One of the highlights of the meeting was a talk by J. A. Thomas, Deputy Director of the Standards Development Division of ASTM, on "New Happenings at ASTM."

The D01.90 Executive Subcommittee authorized Sub. D01.94 on Awards and Memorials to consider establishing awards for 35 and 50 year D-1 members.

Subcommittee Officers appointed by Chairman S. B. Levinson were: Sub. D01.42 on Architectural Coatings—R. H. Rowland to replace R. S. Armstrong as Chairman; Sub. D01.44 on Traffic Coatings—R. L. Davidson to replace W. V. Moseley, Jr. as Chairman; and Sub. D01.55 on Factory-Applied Coatings on Preformed Products—F. Zurlò to replace F. J. Steslow, Jr. as Chairman.

D-1 Committee officers for the 1982-83 term are: Chairman—S. B. Levinson; Vice-Chairman (Administrative)—M. S. Abriss; Vice-Chairman (Technical)—S. Le Sota; Vice-Chairman (Liaison)—J. C. Weaver; Recording Secretary—H. M. Werner; and Membership Secretary and Treasurer—J. M. Behrle.

Highlights

The following projects of major interest to the coatings industry represent areas of new or special emphasis:

VOC Standards—D01.21.13—to proceed with an ASTM STP to compile methods relevant to regulatory changes on VOC compliance.

Halohydrocarbons—D01.21—to form a group to pursue the need for analytical methodology to enable compliance

procedures to be established for regulations concerning whole paint.

Air Pollution—D01.21.72—appeals for suggestions for sample preparation for a round-robin on lead and chromium type pigment dust determination.

Sustained Burning Tests—D01.22—to submit for ballot two methods recommended by the Coordinating Committee on Flash Point that could eventually affect transportation regulations.

Accelerated Weathering—D01.27.04—seeking information on means to write an improved practice for cyclic testing of coatings.

Enzyme Presence in Latex Paints—D01.28.02—working on a rapid method to check enzymes in paint, seeking new instruments and special polymers.

Filterable Solids of Latex—D01.33.26—looking for help on testing methods.

Water in Urethane Solvents—D01.35.02—discontinuing work on method for low levels of water due to lack of support.

Latex Paint Purchasing Guide—D01.41—to vote on controversial document for "off-the-shelf" paint purchases.

Zinc Rich Coating Tests—D01.48—reviewing specific tests for these coatings and initiating round-robins on some. Needs some group chairmen.

Hardboard Siding Problems—D01.52, Group B—soliciting help of board and paint producers on testing discoloration and loss of water resistance of water-based board coatings.

Labeling Artists' Paints for Toxicity—D01.57.08—expanded to redraft critical labeling practice for chronic hazards.

Next Meeting

June 20-23, 1982—Toronto, Canada (Sheraton Center or Harbor Castle Hilton)

January 23-26, 1983—Lake Buena Vista, Florida (Dutch Inn)

June 23-26, 1983—Nashville, Tennessee (Hyatt Regency)

New standards appearing in March 1982 Parts 27, 28, and 29, but not in 1981 edition:

D3960-81 Practice for Determining Volatile Organic Content (VOC) of Paints and Related Coatings.

D3969-81 Test for Zirconium in Paint Driers by EDTA Method.

D3970-81 Test for Cerium in Paint Driers by Oxidmetric Determination.

D3980-81a Practice for Interlaboratory Testing of Paint and Related Materials.

D3988-81a Test for Vanadium in Paint Driers by EDTA Method.

D3989-81a Test for Total Rare Earth Metals in Paint Driers by EDTA Method.

D4017-81 Test for Water in Paints and Paint Materials by Karl Fischer Method.

D4039-81 Test for Reflection Haze of High-Gloss Surfaces.

D4040-81 Test for Viscosity of Printing Inks and Vehicles by the Falling Rod Viscometer.

D4060-81 Test for Abrasion Resistance of Organic Coatings by the Taber Abraser.

D4061-81 Test for Specific Luminance of Horizontal Coatings.

D4062-81 Test for Leveling of Paints by Draw-Down Method.

New standards approved by the Society too late for inclusion in 1982 Parts 27, 28, and 29:

D4086-82 Practice for Visual Evaluation of Metamerism.

DIVISION 1 ADMINISTRATIVE

SUBCOMMITTEE D01.06 ISO/TC 35 ON PAINT AND VARNISH

J. C. Weaver, Chairman

The International Standards Organization (ISO) Technical Committee 35 (TC 35) on Paints and Varnishes has in 30 years produced about 155 ISO standards, many of which are close counterparts of D-1's nearly 500 standards. Sub. D01.06 plans to list and cross reference the TC 35 standards in the 1983 issue of Parts 27, 28, and 29. Much credit for this is due J. A. deWilde who is a D-1 member as well as secretary of TC 35 at NNI in the Netherlands.

TC 35's thirteenth and last plenary meeting in Paris, November 2-6, 1981, was attended by D-1 member Harry

Ashton. TC 35 welcomes informal D-1 interrelation even though voting protocol via ANSI is too costly and cumbersome for D-1. ISO/TC 35 standards adoptions are by one vote from each of the 24 participating member countries, very different from ASTM Regulations on balance of voting interests. TC 35 receives supplementary advice from the 31 observing country members, of which USA (ANSI) is one, as are Australia and Japan. ISO protocol does not prohibit informal cooperation in their working groups (WG's).

Committee D-1's working groups may select from *Table 1* those TC 35 subjects of interest and inquire via ASTM headquarters for address and correspondence details toward group cooperation. D-1 groups may then develop at the same time from these cooperative results the ASTM counterpart standard via ASTM Regulations. Two current examples are: (1) Sub. D01.23.14 is examining the pendulum hardness test used in Europe and now an ISO standard; and (2) Dean Berger, of Sub. D01.46, is working with

ISO/TC 35/SC 12/WG 3 on surface preparation techniques (for steel).

SUBCOMMITTEE D01.07 GOVERNMENT CONTACTS

R.F. Brady, Chairman

The chairman read a letter written in response to the request from T.L. Hinds of the Naval Construction Battalion Center in Port Hueneme, CA to convert 55 federal and 14 military specifications to ASTM Standards. The reply stated that ASTM will not convert federal documents to ASTM Standards and that, besides, ASTM does not write Standards, but people do, and asked that Mr. Hinds send a representative to the D-1 meetings to discuss his proposals and to participate in the work of D-1.

The chairman also summarized the current activities in the U.S. General Services Administration regarding laboratory closings, transfer of responsibilities for qualified products lists and changes in the specification-writing staff.

Alexander A. Chasan of the U.S. Navy Ship Research and Development Center has accepted the post of Vice Chairman, Sub. D01.07.

Table 1—Committee D-1 Interrelations with ISO/TC 35/Working Groups

STRUCTURE, at the end of the year from the Annual Report for 1981 of ISO/TC 35

SC	WG	Title	Secretariat or Convener	Sub Report
D01.55	7	Lacquers for food containers		
D01.16	1	Terminology	France	X
D01.16	1	Definitions and commentaries	France	
D01.31	2	General test methods for pigments and extenders	Germany	X
D01.31	1	Chromate and phosphate pigments	Germany	
D01.31	2	Zinc oxide pigments	France	
D01.31	3	Chrome oxide green pigments	Germany	
D01.31	4	Cadmium pigments	Germany	
D01.31	5	Aluminum pigments	United Kingdom	
D01.31	6	Solubility of dyestuffs	United Kingdom	
D01.24	7	Ease of dispersion	Germany	
D01.90	9	General methods of test for paints	United Kingdom	X
D01.27	1	Artificial weathering	United Kingdom	
D01.27	2	Resistance to humidity	United Kingdom	
D01.33	3	Drying time	Netherlands	
D01.26	4	Hiding power	United Kingdom	
D01.26	6	Gloss	Germany	
D01.23	7	Indentation tests	United Kingdom	
D01.23	8	Rapid deformation and falling weight	France	
D01.23	11	Evaluation of painted surfaces	Netherlands	
D01.23	12	Compatibility with surfaces to be painted	United Kingdom	
D01.21	14	Toxic content of paints	Germany	
D01.22	15	Flame retardance test	Germany	
D01.51	16	Powder coatings	Germany	
D01.26	17	Instrumental colour measurement	Germany	
D01.27	18	Salt spray tests	United Kingdom	
D01.42	19	Washability and scrub resistance	France	
D01.20	20	Abbreviated sampling procedures	United Kingdom	
D01.33	10	Test methods for binders for paints and varnishes	Germany	X
D01.29	12	Preparation of steel substrates before application of paints and related products	United Kingdom	X
D01.29	1	Surface profile	United Kingdom	
D01.29	2	Surface cleanliness	Sweden	
D01.29	3	Surface preparation techniques	Germany	
D01.32	13	Drying oils	Sri Lanka	X

DIVISION 1 ADMINISTRATIVE

SUBCOMMITTEE D01.16 DEFINITIONS

S. Le Sota, Chairman

The definitions for acid number, acid value, dirt, edge-tracking, natural spreading rate and stain have passed Society ballot. There were editorial changes in "natural spreading rate" and "acid number." Negatives on the definitions of "batch" and "soil" are still unresolved. The subcommittee has not been holding meetings, its work being done effectively by mail.

DIVISION 20 RESEARCH AND GENERAL METHODS

SUBCOMMITTEE D01.20 STATISTICS AND SAMPLING

H.E. Ashton, Chairman

The response to a survey of the D-1 membership to establish whether D 3925, "Practice for Sampling Liquid Paints

and Pigmented Coatings," should be extended to include sampling containers packed in units and sampling raw materials was disappointing. There were only two affirmatives, several negatives and over 50 abstentions on each of the two items. It was decided to drop the subject.

The Secretariat of ISO/TC 35 had expressed interest in having D 3980, "Practice for Interlaboratory Testing of Paint and Related Materials," studied by TC 35. Unfortunately, the document was not circulated with the request for approval of this undertaking, resulting in only three countries voting affirmatively. The item was dropped for lack of interest.

SUBCOMMITTEE D01.21 CHEMICAL ANALYSIS OF PAINT AND PAINT PRODUCTS

R.W. Scott, Chairman

Group 13, Coordination of VOC Standards, J.C. Weaver, Chairman, reviewed regulatory changes on VOC compliance since the June meeting. There is more need for clear explanation to state officials of ASTM's test methods and the proper use of them. A resolution was adopted to proceed with an ASTM STP to compile the relevant methods, with an introductory preface, under the leadership of D. Lawson and J.C. Weaver.

The group recommended to Sub. D01.21 further cooperative work to improve D 4017 (water by the Karl Fischer method) and to emphasize the problem with its use in water-borne paints in the proposed STP.

Exemption of three halohydrocarbons, dichloromethane, 1,1,1 trichloroethane and dichlorofluoroethane (Freon 13) in certain regulatory areas results in a need for analytical methodology to enable compliance procedures to be established for whole paint. Upon the request of Ms. Carol Niemi, of Dow Chemical, manufacturer of two of these products, Sub. D01.21 was asked to form a task group to pursue this problem.

Group 22, Analysis of Electrocoat Bath Samples, A.G. Yeramy, Chairman, reported that five methods will be combined under a "Standard Test Method for Analysis of Electrocoat Bath Samples." They are nonvolatiles, acid-base equivalence, pH, conductivity, and solvents by gas chromatography. The latter three are ready for a round-robin evaluation which will be initiated as soon as possible.

Group 25, Revision of D 2832, D.L. Campbell, Chairman, reported the reference to the use of D 93 (Pensky-Martens flash point) in determining the volatile content of drying oils will be deleted from that practice, because this method is not quantitative for solvent

content. Methods being developed for determination of volatile and nonvolatile content of inks will be added to the "Standard Practice for Determining Volatile and Nonvolatile Content of Paint and Related Coatings," as they are approved.

Group 26, Revision of D 2697, "Volume of Nonvolatile Matter in Clear or Pigmented Coatings," M.E. Sites, Chairman, reported reviewing of proposed revisions to D 2697 resulting in submission of a new revised copy to the Editorial Subcommittee prior to Sub. D01.21 balloting.

Group 42, AAS Analysis of Pigments, W.V. Moseley, Jr., Chairman, H. Fujimoto, Acting Chairman, reported a revised draft of "Test for Titanium Dioxide in Pigments Recovered from Whole Paint by Atomic Absorption Spectroscopy," incorporating comments and suggestions resulting from the recent subcommittee letter ballot, will be sent out for D-I letter ballot.

Group 46, X-Ray Analysis of Pigments, H. Neubold, Chairman, P. Kamarchik, Acting Chairman, reported the results of a preliminary round-robin for a generalized pigment analysis scheme based on X-ray diffraction were quite encouraging, with the exception of those from one laboratory, even though the quantitative analysis was only crudely standardized. Standards, samples, and a more specific method will be distributed for a round-robin prior to the next meeting.

Group 53, Trace Levels of Monomers in Paints, G. Cunningham, Chairman, reported that it was concluded that a method developed by H.D. Swafford, of Glidden, should be used immediately in the round-robin underway, since development of a more generalized method is still not finished. The samples for the round-robin will be vinyl acetate/n. butyl acrylate latex spiked by the individual participants to a known level of vinyl acetate and n-butyl acrylate. Consideration will be given to the possible addition of other monomers at the same time.

Group 71, Revision of D 3335, H.D. Swafford, Chairman, reported that only three out of seven collaborators have reported results to date of a round-robin started early in 1981 to evaluate a proposed alternative sample preparation technique for use with D 3335, "Standard Test Method for Low Concentrations of Lead, Cadmium, and Cobalt in Paint by Atomic Absorption Spectroscopy." All results received by the end of February will be statistically evaluated, any suitable revisions made to the method, including the alternative

sample preparation procedure, and then be submitted for a Sub. D01.21 ballot.

Group 72, Metals in Air Particulate, L. Di Carlo, Chairman, reported that as a result of the last round-robin on the determination of lead and chromium in lead-silico-chromate type pigment dusts, a fifth draft incorporating methods for determination of lead and chromium in lead chromate, as well as lead-silico-chromate type pigment dusts, will be submitted for Sub. D01.21 letter ballot.

The group has examined lead and chromium in two types of pigments. It is now concerned with lead and chromium in whole paints and is appealing once again for any suggestions for sample preparation for a round-robin, as well as methods of analysis.

Group 80, Exploratory Analytical Research, H. Fujimoto, Acting Chairman, D. Emerick has agreed to chair this group since L. Wineberry resigned because of work reassignment.

After a discussion on the purpose and merits of the group, it was decided to survey the Sub. D01.21 members as to the availability and/or accessibility of analytical equipment that might be used by the group. Suggestions for further study and development will also be solicited. Some suggestions to date are: (1) improvement of D 3792, (gas chromatographic method for determination of water in coatings) to cover both the high (70%) and low (less than 1%) levels; (2) HPLC for oligomer size exclusion analysis and trace monomers; and (3) any equipment that might fit a "need" regardless of price or limited availability.

In its main meeting the subcommittee agreed to immediately reactivate a task group to pursue additional round-robin work to validate VOC calculations by D 3960. Group 13's request to form a new task group to evaluate methods for the determination of halohydrocarbons in paints was also approved. As a result of W.C. Spangenberg's request for Sub. D01.21 to evaluate a method for the "Chemical Analysis of Calcium-Boro-Silicate," it was agreed to distribute the method to the Sub. D01.21 membership upon receipt of a precision statement and other pertinent information.

SUBCOMMITTEE D01.22 HEALTH AND SAFETY

H.A. Wray, Chairman

After discussion of comments and resolution of negatives resulting from the recent concurrent Sub. D01.22 and D-I letter ballot, the following items were approved for Society ballot: (1) D 3934, "Closed Cup Flash Point Specification of Liquids by the No-Flash Equilibrium

Method"; (2) D 3941, "Test Method for Finite Closed Cup Flash Point of Liquids by the Equilibrium Method"; and (3) D 1310, "Flash Point and Fire Point of Liquids by the Tag Open Cup Apparatus."

After discussion and withdrawal of several negatives it was agreed to submit for D-1 ballot two new methods, "The Sustained Burning of Liquid Mixtures by the Seta Flash Tester (Open Cup)" and "The Sustained Burning of Low Viscosity Liquid Mixtures by the Wick Test."

As the result of a request by the Coordinating Committee on Flash Points that D 3278 be considered for use with peroxides, a revision will be made to cover this request and will be submitted to committee ballot. It was also reported that at the last meeting of the Coordinating Committee, the U.S. Department of Transportation proposed definitions for "solids," including flammable solids, and "oxidizers."

SUBCOMMITTEE D01.23 PHYSICAL PROPERTIES OF APPLIED PAINT FILMS

M.P. Morse, Chairman

Group 10, Adhesion, H.E. Ashton, Chairman, reported that a revision of D 3359, "Adhesion by the Tape Test," has been drafted to inform the user of the source of tapes that meet the method specifications. It will be submitted to concurrent subcommittee and committee ballot.

Coated panels exhibiting differences in the medium range of adhesion are being prepared for evaluation of the utility of a "pull-off by tensile tester" adhesion test.

Group 11, Wet Film Thickness, H.A. Ball, Chairman, reported on the round-robin work to determine the accuracy and precision of the Weftig Gauge and the difficulty that was encountered in adjusting the gauges to a zero setting, which adversely affected the precision. The gauges gave film thickness values considerably higher than other types of gauges and even higher than the clearances of the draw-down blades used to apply the films.

Group 12, Dry Film Thickness, K.A. Trimmer, Chairman, reported D 1005, "Destructure Test for Film Thickness Measurements," which now specifies the use of a dial micrometer, will be revised to include hand-held micrometers.

Group 14, Hardness, Mar and Abrasion Resistance, M.P. Morse, Chairman, reported tests will be conducted to determine the utility of pendulum testers in measuring hardness of coatings.

Group 15, Slip Resistance, G.D. Ernst, Chairman, reported initiation of a round-robin test to evaluate static coefficients of

friction measurements performed with the Instron Tensile Tester using a leather-faced sled to compare with the results obtained from three other types of testing devices used to measure the frictional characteristics of flooring, shoe sole materials, and floor polishes. The activities of the group have been directed toward walkway slip resistant measurement. A questionnaire will be sent out to D-1 members to determine if measurements should be directed toward other coatings applications.

Group 8, Preparation of Uniform Films, M.P. Morse, Chairman, reported D 823, "Producing Films of Uniform Thickness . . . on Test Panels," is being extensively revised to up-date the method for automatic spray application, the deletion of the method for automatic draw-down (inclined plane draw-down), and to include a method for using wire-wound rods.

SUBCOMMITTEE D01.24 PHYSICAL PROPERTIES OF LIQUID PAINTS & PAINT MATERIALS

C.K. Schoff, Chairman

Group 19, Viscosity by Efflux Cups, C.K. Schoff, Chairman, reported the suggested changes to D 1200, "Viscosity by Ford Cup," resulting from the concurrent Sub. D01.24 and D-1 ballot will be incorporated in the method and be submitted to Society ballot. Comments from the subcommittee ballot on the proposed dip cup method will be incorporated into the next draft to be submitted for D-1 ballot.

Group 20, Rotational Viscosimeters, D. Howard, Chairman, reported that plans were made for interlaboratory testing of four Trade Sales paints to provide data for a precision statement for D 2196, "Standard Method of Test for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscosimeters."

Group 23, High Shear Viscosity, C.K. Schoff, Chairman, reported that the recent round-robin on the proposed method for high shear viscosity by ICI cone/plate viscometer was not successful due to incomplete directions given to the cooperators and surprisingly poor reproducibility. A new round-robin will be run. After a suitable precision statement is developed the method will be rebalotted.

In the main committee meeting it was reported that Burt Merriman, of DuPont was appointed Vice-Chairman of Sub. D01.24. Robert Huddleston, of Nordson, has agreed to chair a new Group 26 on Electrical Properties of Liquid Coatings.

SUBCOMMITTEE D01.26 OPTICAL PROPERTIES

C.J. Sherman, Chairman

Group 2, Color Measurement, C.S. McCamy, Chairman, reported that D 1729, "Visual Evaluation of Color Difference of Opaque Materials," after addition of several comments from the recent letter ballot, will be sent on to Society ballot.

Method D 3134, "Selecting and Defining Color and Gloss Tolerances of Opaque Materials and Evaluating Conformance," and D 2244, "Instrumental Evaluation of Color Difference of Opaque Materials," both received extensive comments on the same ballot. They will both be revised and rebalotted.

Group 6, Hiding Power, C.J. Sherman, Chairman, L. Schaeffer, Acting Chairman, reported that statements regarding the essential characteristics of the paint brush, and specific directions on the use of the brush will be added to the method D 344, "Relative Dry Hiding Power of Paints," as a result of the recent letter ballot. It will then be rebalotted.

Group 23, Retroreflectance of Horizontal Coatings, N. Johnson, Chairman, reported that the proposed method of test for Specific Luminance of Horizontal Coatings has passed Society ballot and has been designated D 4061. H.E. Ashton suggested that the method's precision statement be revised to conform with D 3980.

Group 27, Infrared Properties, R.F. Brady, Jr., Chairman, discussed both solar heat-absorbing coatings and camouflage coatings and decided to focus attention on the infrared properties of camouflage coatings in the spectral region from 400 to 2700 nanometers. A compilation of test methods for IR reflectance from military specifications will be circulated by the chairman to the group members for solicitation of comments for the preparation of a draft method for discussion at the next meeting.

SUBCOMMITTEE D01.27 ACCELERATED TESTS FOR PROTECTIVE COATINGS

E.A. Praschan, Chairman

The negative votes received on items on the D0104(81-4) letter ballot were discussed and acted upon. Two of the negatives were received on the proposed new standard for chalking evaluation. H. Ashton's negative was based on the fact that the final draft of the standard was not the one placed on the ballot, but that an earlier draft was mistakenly used. He was correct. The proposed standard will be rebalotted. A negative by D. Mac-

Gregor questioned the ability to use this method at any given inspection moment since moisture in any form will remove chalk. He suggested that the area under study should be protected from this moisture during the observation period. The subcommittee felt that many elements of weather contribute to the degree of chalking, that protection from some of these elements would be wrong and that the proposed method clearly states that readings should be made only after a period of clear weather and when the surface is dry. On this basis the negative was found not persuasive.

Group 11 will be reactivated with J. Robbins as Chairman to study possible technical changes to be made in a revised D 2485, "Coatings Designed to be Resistant to Elevated Temperatures." Since such changes will take time, an editorially revised draft will be prepared for the next D-1 ballot, the current standard being overdue for reapproval.

Group 2, Water Tests, G. Grossman, Chairman, reported a round-robin is being planned to compare the various methods for blistering (water immersion, 100% relative humidity, water fog, and Cleveland condensation). Preliminary screening of ways to induce varying degrees of blistering were conducted by R. Cassel and R. Williamson and were reviewed at the meeting.

Group 4, Light and Water Exposure Apparatus, S.M. Totty, Chairman, reported the consensus of the group to be that D-1 should develop a practice for the cyclic testing of coatings (UV light and condensation) using equipment described in Practice G-53. It is hoped that a draft of a proposed practice will be ready for discussion at the June meeting. A suggestion was made that the group continue to seek information on alternative cycles for D 822 and/or D 3361 that have proved useful.

Group 6, Detergent Testing, H.M. Leister, Chairman, reported the group felt that D 2248, "Detergent Resistance of Organic Finishes," could be strengthened by including information on the effect of agitation and frequency of change of bath solution. Work will proceed in these areas.

Group 9, Evaluation of Corroded Specimens, R. Williamson, Chairman, stated there was considerable interest in evaluating cyclic methods to reproduce the types of corrosion found in the field ("scab" corrosion). The chairman will solicit information on the subject and will also attempt to schedule a speaker on the subject for the June meeting.

Group 10, Accelerated Outdoor Weathering, M.P. Morse, Chairman, will make editorial revisions to the proposed Practice for Conducting Accel-

erated Outdoor Weathering Exposure Tests before submitting it to Society ballot.

SUBCOMMITTEE D01.28 BIODETERIORATION

D.L. Campbell, Chairman

Group 1, Package Stability, W.B. Woods, Chairman, discussed a new approach to evaluating the efficacy of package preservatives using a presumptive challenge test. A tentative protocol will be drafted and distributed with the hope of initiating a round-robin prior to the June meeting.

Group 2, Rapid Determination of Enzyme Presence, A.J. Desmarais, Chairman, reported that a copy of the "Test Procedure for Detecting Enzymes in Latex Paints" will be sent out with the minutes of the meeting for review and comment. A negative on this method is the fact that it requires 3 to 14 days to run.

The HMB 2000 unit was rejected as a means of determining the presence of hydroperoxidases because of poor precision, sensitivity, and reproducibility. Lumac Systems may have a unit with acceptable sensitivity in their ATP Photometer. The significance of these instruments is that they can measure the concentration of the precursors of the enzymes which could reduce the time required to determine the potential of enzymatic activity in a paint.

A third approach is to find a polymer that is highly susceptible to attack by enzymes. In theory, such a polymer would show a quicker loss in viscosity in the presence of lower concentrations of enzymes.

Group 3, Accelerated Tests, K.A. Haagenson, Chairman, reported that a revision was proposed to D 3273, "Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber," which would allow it to be used for the evaluation of exterior, mold-resistant Paints as well as for interior ones. A corrected revision will be circulated to Sub. D01.28 members prior to the next meeting for additional comments.

Group 4, Resistance of Paint Films to Attack by Algae, W.B. Woods, Chairman, reported that three laboratories agreed to participate in a study to evaluate an accelerated Petri dish test for determining the algal resistance of paint films. The initial study will involve challenging an unprotected paint film with an algal suspension. Data should be available from this study at the June meeting.

SUBCOMMITTEE D01.29 SUBSTRATE PREPARATION FOR COATING TESTING

S.D. Ozenich, Chairman

Group 1, Sandblasted Panels, H. Leister, Chairman, discussed the various elements that would be necessary in writing a practice for the preparation of sandblasted panels for testing. It was decided that hot-rolled low carbon steel with a minimum thickness of 1/8 inch seemed to be the best choice. It was also decided that high and low profile panels would be needed. KTA Associates will be contacted to obtain information on their tape pull-off device for measuring profile.

Other subjects discussed included possible differences in the use of reblasted previously used panels and the protection of the panels after blasting. The use of SSPC standards to define degree of blast will be checked.

DIVISION 30 PAINT MATERIALS

SUBCOMMITTEE D01.31 PIGMENT SPECIFICATIONS

C.W. Fuller, Chairman

Twenty-one specifications covering pigments, extenders, and test procedures were finalized and approved in 1981. This cleared a large backlog. Six specifications due in 1981 were balloted in November, 1981, and with editorial comments and negatives handled at this meeting, the subcommittee is up to date on its schedule.

Editorial comments on the November ballot items were carefully reviewed. The majority of them will be incorporated into the specifications. Editorial comments will also be added to three 1982 specifications prior to submitting them for Sub. D01.31 ballot.

Approval was given for the preparation of specifications for Micaceous Iron Oxide Pigment, Zinc Phosphate Pigment, and Calcium Boro Silicate Pigment. The preparation of these specifications would be contingent on documentation of necessity, that the products are nonproprietary and readily available. Sub. D01.21 would be requested to develop any new testing procedures that would be required.

SUBCOMMITTEE D01.33 VARNISH & RESINS, INCLUDING SHELLAC

A.C. Abbott, Chairman

Group 1, Varnishes, H.A. Ball, Chairman, decided that since the proposed

withdrawal of D 1643, "Tests for Gas Checking and Draft Test of Varnish Films," was negated because it is still referenced in existing documents, a proper precision statement will be added and it will be submitted to a concurrent D-1 and Sub. D01.33 ballot.

Group 6, Drying Time, H.M. Werner, Chairman, did not meet. However, the chairman reported that a review was made of several papers submitted by K.A. Earhart concerning the use of Gardner Circular Drying Time Recorders to determine whether they would show any evidence for reconsideration of test method development for this instrument. Nothing was presented to change the previous decision to drop the subject.

Group 23, Epoxy and Phenolics, P. Kamarchik, Chairman, reported that a round-robin will be initiated on a proposed new method for acid value of phenolics with participants from labs that commonly use it. Efforts by both PPG and DuPont to solubilize specimens in the toluene/methanol solvent system of the proposed method were unsuccessful.

Group 24, Nitrogen Resins, J.H. Smith, Chairman, reported that it is believed that D 1198, "Test for Solvent Tolerance of Amine Resins," should be expanded in scope to cover other resins, particularly high solids melamines. The need for other new test methods was also discussed, including a bisulfite titration for formaldehyde, GPC methods, and C^{13} NMR methods.

Group 25, Poly (vinyl chloride) and Poly (vinyl butyral), J.J. Brezinski, Chairman, reported that a proposed new "Standard Method for Testing Vinyl Chloride Resins" will be submitted to Sub. D01.33 letter ballot. It was also reported that the Society ballot negative by L. Kraft, of GSA, on the withdrawal of D 1156, "Test for Total Chlorine in Poly (Vinyl Chloride) Polymers and Copolymers Used for Surface Coatings," was withdrawn after information was given of another available method.

Group 26, Polymer Emulsions, O.E. Brown, Chairman, decided to repeat the round-robins on proposed standard tests for freeze-thaw and elevated temperature of latex vehicles after verifying several possible sources of experimental error were eliminated.

A draft of a proposed test for filterable solids of latices will be circulated to Sub. D01.33 members for comment, at which time other candidate methods will also be solicited.

SUBCOMMITTEE D01.35 SOLVENTS, PLASTICIZERS AND CHEMICAL INTERMEDIATES

L.R. Thurman, Chairman

Thirteen standards were submitted for Sub. D01.35 letter ballot, five for D-1 letter ballot, and 19 will be submitted for concurrent Sub. D01.35 and D-1 ballot.

Group 1, Hydrocarbon Solvents, S.A. Yuhás, Jr., Chairman, presented the results of the review of D 3734, "High Flash Aromatic Naphthas," and D 3735, "VM&P Naphthas." D 2935 (Apparent Specific Gravity) was recommended as an applicable document for D 3734. Modifications of D 3735 were recommended to include substitution of D 270 and D 1616 with D 130 and E 300, respectively. A separate category of Type IV exempt solvent was removed and replaced with a footnote to the specification.

Group 2, Oxygenated Solvents, T.H. Golson, Chairman, reported that work has been discontinued on the formulation of "Standard Test Method for Low Level Water in Urethane Solvents" due to lack of active member support. D01.35 will be surveyed to determine the degree of continuing interest.

A modified D 1296, "Standard Test Method for Residual Odor of Volatile Solvents and Diluents," will be revised to split residual and characteristic odor procedures and reporting sections. This will aid producers and users in specifying one or the other, depending upon the toxicity concerns of the volatile solvent or diluent.

Group 3, Chemical Intermediates, L.R. Thurman, Acting Chairman, reported that J.M. Kauffman resigned as chairman. A replacement will be appointed at the June meeting. A new standard for glacial acrylic acid will be balloted at subcommittee level, including a precision statement based on statistical data reviewed at the meeting.

Four GC methods will be ranked for inclusion in a round-robin for the purity determination of 2-ethylhexanol. The proposed test method and specification will be reviewed at the June meeting.

Carol Niemi, of Dow Midland, requested Sub. D01.35 to assume responsibility for chlorinated hydrocarbon solvent standards. S.A. Yuhás, Jr. agreed to review the requirements of these solvents for discussion at the next meeting.

DIVISION 40 PAINT PRODUCTS APPLIED ON SITE

SUBCOMMITTEE D01.41 CRITERIA FOR THE PURCHASE OF COMMERCIAL PAINTS AND COATINGS

R.A. Brown, Chairman

After a review by the chairman of the past work of the committee, a motion was made to submit to subcommittee ballot the current draft of the document, "Standard Guide for Purchasing Interior Flat Latex Paint," or a modified version of it. A vote of only subcommittee members defeated the motion. A motion was then approved to adjourn the meeting, there being no further business to bring before the group.

Further recommended action on the work of the subcommittee was subsequently requested from the D01.90 Executive Committee, resulting in the recommendation that, because of the small percentage of the Sub. D01.41 members present, the document be submitted to a Sub. D01.41 letter ballot of the full membership.

SUBCOMMITTEE D01.42 ARCHITECTURAL PAINTS

R.H. Rowland, Chairman

Group 2, Stain Removal, C.C. Tatman, Chairman, reported that an additional round-robin will be conducted with one stain, tea, eliminated, and one, cooking oil, added. An additional system, alkyl flat, will be incorporated.

Group 4, Wet Adhesion, F. Winkelman, Chairman, decided to initiate a round-robin with steel as the substrate, a gloss alkyd as the base coating, and a semi-gloss interior latex paint as the test coating. Variables to be addressed in future round-robins will be aging effects and the method for adhesion evaluation.

Group 7, Sag Resistance, L. Schaeffer, Chairman, reported that the statistical results of the round-robin showed the Anti-Sag Meter and the Baker Sag Liner correlated well with the brush-out method, with the Anti-Sag Meter being the more sensitive of the two. The method will be prepared in ASTM format for review by the group. Additional testing, employing dark-colored paints, will be made to determine applicability of the method.

Group 9, Color Compatibility, R.H. Rowland, Chairman, reported that a round-robin is planned to determine

precision on the previously balloted method, employing semi-gloss and flat latex and semi-gloss alkyd paints with two tinting colors, black and one other.

Group 13, Brushability, J. Desmarais, Chairman, reported that correlation between the results of the previous work on evaluation of high shear viscometry and a practical hand brush-out method will be attempted through a new round-robin. Five paints ranging from 0.6 to 3.0 pises (Haake) will be evaluated.

Group 16, Practical Opacity, R.S. Armstrong, Chairman, agreed that a large test surface should be used to evaluate hiding in a practical way, employing brush or roller equipment. A new proposed substrate was presented—a paper panel having three gray stripes of different reflectance values running the length of the roll of heavy paper. These stripes were overcoated with a flat lacquer. A round-robin will be run with this substrate. The cooperators will be supplied with paint, test paper, and rollers.

R.S. Armstrong is retiring as chairman of Sub. D01.41. R.H. Rowland replaces him, with F. Winkelman taking over as the new secretary.

SUBCOMMITTEE D01.44 TRAFFIC COATINGS

**E.B. Countryman,
Acting Chairman**

Group 2, Traffic Paints, E.B. Countryman, Chairman, discussed the various test methods under its jurisdiction. A statement was added to D 711, "Dry to No Pick-Up Time," regarding the 'O'-Rings between runs. A round-robin will be run on three types of traffic paints by eight cooperators to establish precision.

The chairman will submit past round-robin results to the appropriate ASTM personnel on D 1309, "Settling Properties of Traffic Paints on Storage," and D 869, "Evaluating the Degree of Settling of Traffic Paints," to establish precision statements.

The subcommittee voted to eliminate the photographs in D 821, "Evaluating the Degree of Abrasion and Erosion in Road Service Tests of Traffic Paints," since they are not valid.

It was decided to eliminate the numbers and retain the percentages under the photographs in D 913, "Evaluating the Degree of Chipping of Traffic Paints," because the numbers are not consistent with the reference statement in D 713.

A proposed revision of D 713, "Conducting Road Service Tests on Traffic Paints," was distributed for recommendations prior to submission for letter ballot.

Group 3, Night Visibility, J. Ritter, Chairman, decided to eliminate method D 1213, "Crushing Resistance of Glass

Spheres," and to submit D 1214, "Sieve Analysis of Glass," and D 1155, "Roundness of Glass Spheres," for letter ballot. A round-robin to establish precision will be initiated shortly.

A discussion was held on the approach to be used for performing field tests the afternoon and evening of January 19 on reflective stripes applied in New Orleans. Various reflectometers were used in the afternoon and visual ratings were made in the evening. The main purpose of this field test was correlation of the four commercial retroreflectometers. Visual ratings were also compared to the instrumental readings.

Group 5, Water-Borne Coatings, E.B. Countryman, Chairman, has been asked to consider TT-P-1952b, Paint, Traffic and Airfield Marking, Water Emulsion Type as a project.

In the main meeting the subcommittee decided to form a special working task group for D 711 to do the work not accomplished at this meeting so there will be no delay in presenting a revised method for letter ballot.

W.V. Moseley's letter of resignation as chairman of Sub. D01.44 was read. Subsequent to this meeting, Robert L. Davidson, of the Pennsylvania Department of Transportation, was appointed chairman.

SUBCOMMITTEE D01.45 MARINE COATINGS

L.S. Birnbaum, Chairman

The subcommittee voted to submit D 3623, "Testing Antifouling Panels in Shallow Submergence," to D-1 letter ballot for reapproval as published with the addition of the following footnote: "Subcommittee D01.45 has a revised rating procedure now being evaluated by round-robin."

Group 5, Algae Control, C.D. Stevens, Chairman, is developing a test method to evaluate antifouling coatings for algae control efficacy.

Group 6, Dynamic Testing, D. Laster, Chairman, has prepared panels to explore rotating drum devices at three locations for exposing antifouling paints.

Group 7, Antifouling Rating, C. Perez, Chairman, has started panel exposures in a round-robin to evaluate a revised rating system for shallow submergence over that given in D 3623.

SUBCOMMITTEE D01.46 INDUSTRIAL PROTECTIVE PAINTING

D.M. Berger, Chairman

Group 2, Surface Preparation, J.D. Keane, Chairman, reviewed negative votes on the D0104(81-4) letter ballot on D 1014, "Conducting Exterior Exposure Tests of Paints on Steel." Since several of the points were found to be persuasive, the group felt that a revised version should be submitted to Sub. D01.46 ballot.

Group 10, Topcoating Zinc Rich, met without a chairman present. It was reported that Mary McKnight, of the National Bureau of Standards, will report one year from the meeting date on data available from NACE and SSPC regarding the topcoating of weathered galvanized steel.

Group 4, Pull-Off Adhesion Test, A. Cunningham, Chairman, reviewed the results of the subcommittee ballot on the proposed test method. It was decided that a round-robin will be run on the method prior to any further balloting. The details of the round-robin test program were worked out. They will be circulated to the participants.

SUBCOMMITTEE D01.48 ZINC RICH COATINGS

R.H. Wakefield, Acting Chairman

Group 2, Determination of Cure, A. Cunningham, Chairman, clarified its scope to include both organic and inorganic coatings. A zinc rich coating will be defined the same as by the Steel Structures Painting Council (SSPC); that is, 74% minimum zinc metal content in the nonvolatile portion of the coating for inorganic zincs and 80% (correct figure to be checked) for organics. The group will investigate three methods to measure cure of inorganic zinc rich coatings. They are (1) a solvent rub test with water and with methyl ethyl ketone, (2) "Coin Test"—abrading the film surface for degree of polishing, and (3) crosshatch scribe method. A round-robin will be initiated when the methods of test have been prepared.

Group 3, Laboratory Evaluation of Zinc Rich Films, R.H. Wakefield, Chairman, reported that preparation of the draft method for circle test (bullet-hole test) of zinc rich coatings is progressing. The method will include the V-notch test in salt fog exposure as given in SSPC Specification 12.00-68T, "Guide to Zinc Rich Coatings."

Group 4, Void Space (Porosity) and Solids by Volume, met without a permanent chairman. The NACE Technical

Committee Report T-6A-36 (Draft 6, January 1981), "Determination of Theoretical Coverage of Inorganic and Organic Protective Coatings," was presented and discussed. The method is a revision of ASTM D 2697, "Standard Test Method for Volume Nonvolatile Matter in Clear or Pigmented Coatings." Doubt was expressed that this method will find wide applicability because of its complexity and its use of tungsten metal substrate and mercury immersion medium. Alternatives to mercury (nonwetting liquids) will be researched. There is a need to review work done and in progress by other associations as well as to review the literature for other possible methods of determining nonvolatile volume.

Group 5, Topcoating, has no chairman as yet. The methylethylketone rub test was discussed, specifically as used on inorganic primers to evaluate compatibility of vinyl topcoats. Inorganic zinc films passing 40 rubs with no, or little, coating removed will be compatible with vinyls; those primers which do not pass will not be compatible. Correlation was good and the specific formulation of the vinyl was not a significant factor.

Cyclic tests, such as freeze-thaw and immersion-drying tests, are showing promise to evaluate topcoat performance on zinc rich primers.

DIVISION 50 PAINTS FOR FACTORY APPLICATION

SUBCOMMITTEE D01.51 POWDER COATINGS

C. Grenko, Chairman

A proposed method for color determination by the platinum-cobalt procedure has been drafted and is being prepared for Sub. D01.51 ballot.

A proposed method for color determination of base resins, ground and unfused, using a Gardner Tristimulus Colorimeter is also being prepared for subcommittee ballot.

Development in melt viscosity determination promises to help the work in drafting a method for this property. There was discussion of two areas, application and film formation, that point toward future work. Not enough work has been done to draft a specification.

The subcommittee agreed to meet once a year in a single session.

SUBCOMMITTEE D01.52 FACTORY-COATED WOOD PRODUCTS

R.C. Marck, Chairman

Group B, Hardboard, S.B. Schroeder, Chairman, is studying inadequacies in existing test methods to determine discoloration of the paint films and loss of water resistance, as well as buckling of the hardboard when some water-based finishes are applied to hardboard siding. Cooperation and attendance of both hardboard and paint manufacturers is solicited for the June meeting in Toronto to develop a round-robin.

SUBCOMMITTEE D01.53 FACTORY-COATED STRIP METAL

E.E. Haney, Chairman

Group 1, Formability, W.H. Gunn, Chairman, discussed the results of the D0104 ballot for the "Standard Method on Formability Characteristics," incorporating comments that were made by H.E. Ashton and H.A. Wray. It was decided to evaluate the need for a ball indent test on painted galvanized steel.

Group 3, Pretreatments, R.L. Williamson, Chairman, reported that the next endeavor of the group will be to develop a method for the determination of iron and zinc phosphate coatings on steel. Seven cooperators have agreed to participate in a round-robin.

SUBCOMMITTEE D01.55 FACTORY-APPLIED COATINGS ON PREFORMED PRODUCTS

F. Zurlo, Chairman

All six methods needing approval in 1982 were reviewed and found technically satisfactory by Group 1 on Coatings for Wood Products. In the Sub. D01.55 meeting, precision and significance statements were added as needed. All six methods with these changes made will be submitted for Society ballot.

The draft of the new standard practice, "Water-Reducible Industrial Coatings," is in good condition. Final editing should be completed by the time of the June meeting, when a subcommittee vote is planned.

SUBCOMMITTEE D01.56 PRINTING INK

J.M. Fetsko, Chairman

Group 1, Viscosity, J.M. Fetsko, Chairman, reported that the new method for "Viscosity of Printing Inks in Vehicles by Falling-Rod Viscometer" has been designed

D 4040 and will appear in the 1982 *Book of Standards*, Part 27.

Group 6, Ink Tack, C. Shepard, Chairman, will be requested to have the Inkometer method ready for ballot as soon as possible.

Group 8, Smoke Testing of Heat-Set Inks, J. Coleman, Chairman, reported that the first round-robin indicated the test temperature of 270°F was more meaningful than 240°F. Laboratories having Smoke Testers will be requested to participate in a round-robin at the higher temperature, using ink samples that vary more widely in smoke than the first set.

Group 9, Tinting Strength (of printing ink pigments and dispersions), A. Scarlatti, Chairman, reported that a review of D 3425 showed several test deviations from prevailing practices in the printing ink industry. A round-robin will be conducted with pigments and corresponding flushes varying in strength and shade. Instructions will request that color and strength be evaluated visually and instrumentally from masstone/under-color drawdowns from weighed printing ink films.

Group 10, Water Take-Up by Litho Inks and Dispersions, G. Bien, Chairman, reported that 13 labs were in the round-robin in which three pairs of Lithographic Printing Inks were tested for water take-up by single point and pen point Mix-master methods. The most important finding was that using distilled water as the test fluid neither the rate nor the quantity of water take-up was meaningful in predicting press performance. A new round-robin in which specified fountain solutions will replace distilled water, and volumetric measurements of water take-up will be made at 2, 5, and 10 minutes. In addition, an effort will be made to solicit cooperators from labs which use the Lithographic Break Tester in conjunction with the Karl Fischer water determination.

Group 11, Nonvolatile Matter (of Heat Set Inks), B. Blom, Chairman, reported that 14 labs participated in the round-robin in which two inks containing high boiling petroleum oils were run for one hour at 105°C. The nonvolatile mean was 64% compared to 60% actual. At the request of J.C. Weaver, D 2832 will be examined to see if a paragraph on heat-set inks will suffice.

Group 12, Fineness of Grind, J. Cichon, Chairman, reported that ASTM requested a precision statement be developed for D 1316, "Test for Fineness of Grind of Printing Inks by the Production Grindometer." A round-robin will be conducted with a series of carbon black dispersions varying in degree of premix-

ing and roller milling. Measurements will include scratch end-points, gloss of draw-downs and visual assessment of speckles.

Group 13, Ink Mileage. B. Blom, Chairman, is heading a new task group that will conduct a limited round-robin to determine the utility of methods now in use.

Group 4, Lightfastness. R. Kinmouth, Chairman, will suggest revisions to update D 3424, "Evaluating the Lightfastness of Printed Matter." Efforts to upgrade the method will wait until the industry is surveyed for interest.

SUBCOMMITTEE D01.57 ARTISTS' PAINTS AND RELATED MATERIALS

J.T. Luke, Chairman

Group 2, Lightfastness of Pigments. H.W. Levison, Chairman, met in Hallan-

dale, FL on November 2 to review test data and exposed samples from a set of four lightfastness tests and to establish two categories of lightfastness ratings for fine artists' paints. Minor changes were made at this meeting to the first draft of "Test Methods for Lightfastness of Pigments Used in Fine Artists' Paints." It will be sent for editorial review.

Group 3, Tinting Strength of Paints. I. Shack, Chairman, distributed a paper by Ruth Johnston-Feller describing another approach to the problem of determining the tinting strength of commercial artists' paints for consideration as the basis for a test method.

Group 7, Physical Tests. H.W. Levison, Chairman, presented a report on flexibility studies accompanied by several pages

of data. The recommendation was that the attempt to develop a test method for flexibility be dropped.

Group 8, Labeling for Chronic Toxicity. W. Stopford, Chairman, reported that several negatives received on the concurrent ballot for the proposed "Labeling Practice for Art and Craft Materials for Chronic Hazards," were found to be persuasive. The practice was withdrawn for revision.

Draft 9 of the practice was considered at this meeting. The title was changed to "Standard Practice for Labeling Artists' Paints and Related Materials for Chronic Hazards." Other major revisions having been suggested, the task group was expanded to redraft the practice to circulate to the subcommittee for comment.

Society Meetings

Baltimore (Virginia Section) Feb. 24

A panel discussion and presentation featuring "VARIOUS STRAINING OR FILTERING METHODS," was given by James Horne and Edward Barnard, of American Felt and Filter, and Rudy Maroscher, of M&M Machine.

The use of filter bags in a pressure vessel, cartridges in a pressure vessel, and mechanical strainers such as the Vortisiv were discussed. Advantages of each system were detailed along with the special features of each that made it excel in certain applications. Specific applications and comparisons of similar competitive equipment were highlighted.

CARL B. MINCHEW, Secretary

Birmingham Jan. 14

"ORGANIZATION AND MANAGEMENT OF BRITAIN'S LARGEST PAINT FACTORY" was presented by Alan Sutherland, of I.C.I. Paint Division.

Mr. Sutherland outlined the structure of I.C.I. Paint Division at Stowmarket and slides illustrated the manufacturing site and some of the individual operations within the plant. Employment opportunities and industrial relations were discussed. Since the division supplies paints to a wide range of markets, a high degree of computerization was needed in the resins plant and big batch plant, explained Mr. Sutherland. In the future, computer use will continue to control operations in the plant, according to Mr. Sutherland.

Q. What degree of dependence is there on computers and what back-up is available?

A. Virtually all systems depend to a greater or lesser degree on computers, with high efficiency being achieved. No back-up is available.

Q. What difficulties are associated with laboratory services?

A. Most formulation work is done at Slough. Having two sites does cause problems, but the biggest problem, i.e. color-matching, is handled on site.

Q. How many Quality Control staff are on site?

A. Three work on raw material Q.C. and up to 30 people on finished products.

Q. What Q.C. tests are carried out at Stowmarket?

A. Mainly color, gloss, appearance, drying, and special specifications tests

are carried out. Colors are matched mainly by instrumentation, especially pastel shades, which are totally instrumentally matched.

Q. What is the working life for ball-mills?

A. It is difficult to make a case to remove them totally as they are a highly efficient, load-and-leave operation. Within 2 to 3 years perhaps half of the ball-mills will be replaced.

Q. Do any formulae come from Stowmarket laboratories?

A. Colors within a product line are formulated at Stowmarket but original lines come from Slough laboratories.

D.H. CLEMENT, Secretary

Birmingham Feb. 4

Wolfgang Kelch, of BASF U.K., Ltd., discussed "RECENT DEVELOPMENTS IN THE USE OF NICKEL AND CHROME TITANIUM PIGMENTS IN SURFACE COATINGS."

Mr. Kelch explained that nickel and chrome titan yellows have been known for several years but recent developments have opened up new applications. The pigments are not titanates but are complex oxides of titanium and antimony with either nickel or chrome. Tests to determine health factors, such as handling properties and the effects of ingestion, have shown these materials to be safe, explained Mr. Kelch.

Using comprehensive tables and graphs, Mr. Kelch described the properties of a selection of the Sicotan range of pigments, concentrating mainly on the nickel-based product, Sicotan L1012, and the chrome pigment Sicotan L1910. Mr. Kelch said that Sicotan L1012 had excellent heat resistance and would withstand heating (in a silicon medium) for one hour at 400°C, without change in color. This property would be of particular use in areas of manufacture where high temperatures were inevitable.

Both nickel and chrome titans have very high opacity compared with titanium dioxide, and it could be shown that, even with pigment volume concentrations up to 40%, the gloss of paints made from them was very high. The sicotans, therefore, were of particular use in the formulation of full gloss, high opacity stoving finishes, said Mr. Kelch.

Photoactivity of the chrome titan structure is particularly low; lower than the titanium dioxide rutile crystal, said

Mr. Kelch. Good exterior durability and gloss retention properties were seen as a result.

Q. When these products were used several years ago there was evidence in tests of chalking leading to loss of gloss without change in shade. Is this still the case?

A. There was severe loss of gloss due to chalking but not due to gloss reductions, which is different. Now, polishing of panels is taken into account.

Q. In the ceramic field, where they are better known, there are different types. These are always considered to be titanates. Is it correct?

A. No nickel or chrome titanates can be detected by chemical tests. Requirements in the ceramic field are different because of different gloss effects and the importance of opacity. One cannot increase chrome and opacity simultaneously.

Q. Do these products have uses in powders and what will abrasion during extrusion do to the color?

A. Yes, the pigments are of use in powders and there are no known difficulties of abrasion changing a color.

D.H. CLEMENT, Secretary

C-D-I-C Jan. 11

Dr. Richard Eley, of the Joyce Research Center, Glidden Coatings and Resins Division, SCM Corp., presented, "NEW METHODS IN COATINGS RHEOLOGY."

Dr. Eley defined rheology as the science of flow. In the coatings area, the material must flow on to an applicator or applying system; when it is applied it must flow whether it is rolled, brushed, sprayed, or dipped; when on a substance it must flow to produce a level film—coalescence must take place in the case of an emulsion and the film has to build to the required thickness with no sags or slumps; and with thermosetting systems the modules will charge as the coating goes from a liquid to a solid. According to Dr. Eley, a rheologist must relate the flow behavior of fluids to molecular properties and must relate flow properties on the molecular level to the desired product performance.

In the coatings industry, rheological science has become a valuable tool in roll coatings, spray coatings, in brush and roller applied consumer coatings, and

also in the study of the cure of a thermosetting film, explained Dr. Eley.

A number of parameters that are used in the rheological study of coatings were listed. They are shear viscosity, dynamic or visco-elastic viscosity, normal stress measurements in plastic flow and extruded polymers, elongational viscosity, and dynamic surface tension, which is a change in surface tension when the surface area changes, said Dr. Eley.

Dr. Eley then defined shear stress as the force measured in dynes, resisting the movement of two parallel planes with a fluid between them divided by the area of the plane. The shear rate is the relative velocity of the moving planes V_1-V_2 divided by the distance between them. Viscosity which is measured in poises is the shear stress divided by the shear rate, explained Dr. Eley.

Newtonian flow is when the viscosity of a fluid is constant no matter how rapidly the fluid is deformed; that is, viscosity in a newtonian fluid is independent of the rate of shear, said Dr. Eley. With non-newtonian fluids, the viscosity depends on the rate of shear. A time dependent shear thinning fluid is thixotropic; the viscosity depends not only on the rate of shear but also the amount of time that the shear force is applied. The opposite of this is a shear thickening time dependent fluid which is called a rheotectic system. A pseudo-plastic system is shear thinning but not time dependent and a dilatant system is shear thickening but again not dependent on time, explained Dr. Eley.

In the paint industry, for many years, rheology was basically a Q.C. function measured by single point devices such as the stromer viscometer, the Gardner Bubble tubes, the orifice cups such as the Ford and Zhan, and the falling ball viscometer. In all these single point instruments the rate of shear is not controlled and they are adequate only for newtonian fluids. Research instruments where the shear rate is known and defined are available but most are quite costly, said Dr. Eley.

If you use a good instrument and plot shear rate against shear stress, you will find that when the shear rate is increased in a steady fashion, the shear stress will change in proportion, and when the shear rate is then decreased, the shear stress will also change but will be a different value than on the up-slope, explained Dr. Eley. This curve is normally referred to as a thixotropic loop.

Dr. Eley described some of the instruments used in his research. At the Joyce Research Center they have built a high shear rate capillary rheometer capable of measuring viscosities up to one million reciprocal seconds. He also used an automated dynamic rheometer which uses an oscillating type of deformation that is capable of measuring from

50 to 200,000 reciprocal seconds. This type of rheometer can be used to separate and identify both the viscous and elastic properties of a fluid. All fluids, even water, have both solid and liquid characteristics.

Dr. Eley discussed chemo-rheology which was defined as changes in rheology not due to physical changes but to chemical changes like crosslinking. Basically in the study of cure by rheology, you are looking at the change from fluid to solid. With a dynamic cure measurement, you get a direct measure of the modulus of the film as it develops. With detailed analysis of the rheological changes during cure, you can relate rheology to chemical activation parameters which relate to the functionality of the resin, the molecular weight distribution, and the catalyst level. The ultimate goal in this area of rheology, according to Dr. Eley, is to relate the formulation to the performance of the coating.

Dr. Eley discussed extensional viscosity, which may be used as a measure of roller spatter. Unlike a shear type of deformation where a lowering of viscosity is generally observed with an increase in the rate of shear, with elongational viscosity the opposite is usually observed,

as a rate of extension increases, the elongational viscosity increases.

Dr. Eley noted some work that has been done with a laser particle size analyzer which he felt was an excellent instrument but quite expensive. It allows the quick determination of particle size distribution. It is finding its greatest utility in water-borne and high solids coatings research, explained Dr. Eley.

Q. What is an example of a pseudo-plastic fluid?

A. Almost any aqueous pigment dispersion with no thickener will exhibit pseudo-plastic behavior.

Q. Are most exterior latex paints newtonian or non-newtonian?

A. Non-newtonian. They are mostly thixotropic shear thinning materials. Almost anything that contains a fairly high volume of pigment or polymer in solution or polymer emulsion, and water soluble thickener will have non-newtonian behavior. It's a matter of degree. Only very dilute latexes will be newtonian.

Q. What ever happened to hysteresis?

A. If you remember the thixotropic

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loops, they were hysteresis loops, where the shear stress on the way down is lower than on the way up. Using the thixotropic loop as a measurement of thixotropy is falling out of use because it depends on too many other things.

Q. Do you recall what the maximum shear rate is on a Wells-Brookfield?

A. Less than 1,000, probably closer to 700.

Q. What would you say is an economical instrument to measure high shear?

A. The capillary rheometer is built and operating and wouldn't be terribly expensive, probably less than an ICI cone and plate which will be good up to about 10,000 reciprocal seconds.

Q. What about instrumentation for low shear rates?

A. For less than \$2000 a Wells-Brookfield cone and plate will measure down to one reciprocal second. A dynamic instrument will cost \$60,000-\$70,000.

ROBERT A. BURTZLAFF, *Secretary*

Chicago

Mar. 1

Dr. Kayson Nai, of Rohm and Haas Co., discussed "OPAQUE POLYMER."

Opaque polymer was defined by Dr. Nai as a synthetic paint additive that can reduce the raw material cost of a formulated paint without sacrificing quality. Opaque polymer, supplied as an emulsion, has a hard polymeric shell surrounding an air-containing core, which imparts hiding by scattering light, explained Dr. Nai.

According to Dr. Nai, opaque polymer yields lower cost, equal hiding, equal quality paints compared to conventionally pigmented controls. This was demonstrated using an empirical formulating methodology.

"NEW DEVELOPMENTS IN THE FORMULATION OF GLOSS LATEX PAINTS" was presented by John Bax, of Pacific Scott Bader, Inc.

To meet new regulations and improve performance with latex paints, problems arise in trying to achieve improved gloss, flow and leveling, together with lower glycol levels, explained Mr. Bax. These problems can be solved, according to Mr. Bax, by the use of alkali soluble acrylic (ASA) polymers in combination with the latex. The ASA encapsulates the pigment and promotes stability against flocculation on drying, enhancing gloss, flow, opacity, and color development.

Results were presented by Mr. Bax on the recent work on ASA's and their application in both trade sales and industrial finishes. Also, work done with an electron micrograph, which illustrated the

effect on pigment utilization within the paint film, was demonstrated.

JOHN R. INGRAM, *Secretary*

Golden Gate

Feb. 8

Manufacturing Committee Chairman, Louie Sanguinetti announced that the June Manufacturing Meeting will be entitled, "Computer Time?". The program will consist of seven parts covering the subjects of: time sharing versus bureau versus ownership; office functions; manufacturing and process control and systems; types to begin with and how to expand upon them; laboratory, quality assurance, and quality control; color matching; and practical session and review.

A special presentation was made to Ted Favata for his outstanding contribution to the coatings field. Mr. Favata is currently Chairman for the 1983 Western Coatings Symposium.

Dave Waldron, of duPont, made a special presentation to Bob Minucciani and Ed Kevin for their outstanding efforts in dealing with the State Air Resources Commission for the Bay Area Coatings Group.

"CORROSION, COATINGS AND A COMPLYING SYSTEM" was presented by Tim Specht, of the Sherwin-Williams Co.

Described were three methods for protecting iron metal from corrosion. The first method is a physical barrier, such as coal tar/epoxy-tar coatings, said Mr. Specht. The second method is a sacrificial protective coating such as a zinc rich coating and the third type is an inhibitive coating, containing corrosion inhibitors.

Mr. Specht discussed the inhibited coating which protects the substrate by changing the electrical properties in the corrosion cell. According to Mr. Specht, the most successful pigments have been lead salts and chromate salts for inhibition of corrosion.

A study was described by Mr. Specht that involved the analysis of five primers which conformed to the current Air Pollution Regulations in California and compared them to two Federal Specification primers which did not conform to the air pollution regulations. Three sites were used for the exterior exposure series to evaluate the performance of these primers and an accelerated test series was done, explained Mr. Specht.

Conclusions from the study were discussed which included: the VOC conforming primers supplied by raw material suppliers did not perform as well as the nonconforming controls; a conforming primer was compared to the red

lead primer for surface treatment resulting in red lead primer being less sensitive to surface treatment than the conforming water-based primer.

Q. What happened to zinc molybdate in the study?

A. There was no supplier submission.

Q. Why were pretreatments of the steel not included in the study?

A. It was not practical. It is hard to pretreat a bridge.

E. Bruce Euchner, of Glidden, discussed "THE EFFECTIVENESS ISSUE OF R&D."

The "Innovation Process" was described by Mr. Euchner as a combination of routine and development, marketing, engineering, finance, distribution, and purchasing. According to Mr. Euchner, the key elements to innovation are the combination of marketing and routine and development.

The concept of productivity was discussed. Mr. Euchner described this concept as the combination of efficiency and effectiveness.

Mr. Euchner explained the effects of human relations management in light of a need for increased productivity. The factors, according to Mr. Euchner, which are most important included direction—having goals. Organizations which have very definite goals established seem to progress more efficiently, stressed Mr. Euchner.

In the area of staff, one important aspect to be considered is attitude, said Mr. Euchner. Employees' attitudes, established in the first six months of employment, will often stay with them throughout employment in an organization. In addition, motivation of the staff member will be affected by this attitude and will affect teamwork efforts, explained Mr. Euchner.

Supervision is the most important factor in R&D effectiveness, according to Mr. Euchner. Functional organization was discussed as it involves the management of human relations.

Mr. Euchner concluded by describing a technique using the computer and quantitative evaluation for monitoring R&D efficiency and effectiveness. One of the key factors to progress is post evaluation, stressed Mr. Euchner.

K.E. TRAUTWEIN, *Secretary*

Kansas City

Feb. 11

Jim Schlueter, of American Felt and Filter, presented a talk on "FILTRATION EQUIPMENT."

Since the 1900's, wool felt had been used to filter paints, said Mr. Schlueter.

Various advances that have been made were outlined and Mr. Schlueter discussed the problems that occur during filtration due to these advances. He stressed that special problems occur with bag filters when gelatinous particles are present or when the material has a high viscosity.

Q. At what viscosity should you switch from a bag filter to a cartridge filter?

A. One bag equals five to six cartridges. Based upon the flow rate, if your material is clean enough, stay with the bags. Go to cartridge only after bags have already been tried.

Q. What is the output with your factory-sized model that uses bags?

A. Output is up to 80 gal/min with water. Paints run 30-40 gal/min.

MELVAN BOYER, Secretary

Los Angeles

Feb. 10

Jim Elliott, Environmental Committee Co-Chairman, reported on the CARB Task Force and the San Diego AQMD's rule position.

Ron Stark, Vice-President of the International Animated Film Society (ASIFA), presented "ANIMATION MAGIC—THE PART PAINTS PLAY." Mr. Stark specializes in the restoration of animation artwork through ASIFA, a California nonprofit organization devoted to the enhancement of the art of animation. As conservator of animated art, Mr. Stark directs the Search and Rescue Team which repairs damaged art from animated films. He advises museums, galleries, and collectors on preservation.

Mr. Stark described that he was by profession a voice actor having done many voice characterizations, including Mickey Mouse, Pluto, etc. The Search and Rescue Team was formed about four years ago at an Animation Art Festival, an annual fund raising event. With no prior experience Ron was asked to restore a celluloid rendition of Mickey Mouse. All techniques have been developed therefrom, explained Mr. Stark.

A slide/tape show illustrated the activities of the Search and Rescue Team, starring "Rocky the Flying Squirrel" and "Bullwinkle Moose." Animated cartoons are made by photographing individual drawings at the rate of 24 drawings per second of screen action or 1440 pictures per minute or 72,000 for a 15 minute feature length cartoon, said Mr. Stark.

The ASIFA laboratory looks more like an artist studio than a conventional laboratory, explained Mr. Stark. It is here that the actual cel used in the film making process is restored. The work cel

is derived from celluloid, used until the 1950's and now replaced by the less flammable cellulose acetate. The actual drawings for the animation are transferred onto these cels. The unique characteristic of cels is that their image is copied onto the front and they are painted on the rear. According to Mr. Stark, the restoration process is initiated by development of a color key. The key is a new cel, overlaid in register and marked appropriately. The key guide then is used to start repair. Either hygroscopic paints are used as in the early days of animation or the new vinyl paints. Over the years, the Search and Rescue Team has been sponsored by some of the many well-known manu-

facturers and distributors of artists products and paint manufacturing materials, said Mr. Stark. Many well-known cartoon character cels were shown, before and after restoration.

Mr. Stark described some of the accomplishments of the Search and Rescue Team. The slide/tape presentation has been on NBC's Today Show. Some of the Animation Art Cels have become very valuable—recent Disney characters sell at \$100-\$200. A Superman cel was recently sold for \$3000. The Cleo the Fish restoration shown in the slide/tape presentation is worth more than \$10,000, said Mr. Stark. Steamboat Willie is priceless. Requests for restoration originate worldwide. The laboratory

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is endorsed by the National Film Archives in Washington, D.C., Denver Conservation Center, and others. Mr. Stark said he is collaborating with a historian (Charles Solomon) in writing a book on animation for Eastman Kodak scheduled to be published this fall. Mr. Stark provides technical help to film studios; such as Disney, Hanna-Barbera, Kirtsen-Frost, others. *People* magazine is interested in doing a story on the Search and Rescue Team. Mr. Stark thanked several members of the paint industry who have provided help for his needs for coating materials in this restoration process.

Mr. Stark introduced Bill Scott, President of ASIFA, and voices of Bullwinkle Moose, Dudley Do-Right, and Super Chicken. Mr. Scott accorded praise upon Mr. Stark for creating an entire restoration and conservancy form from his own experience and knowledge.

ASIFA started in 1959 in France, said Mr. Scott. There are now four chapters in the United States of which the Hollywood Chapter is the largest. Membership embraces the whole spectrum of animation: artists, actors, writers, producers, teachers, students, and interested people. Anybody can join. Animation Art is a contemporary and growing art form. Many people are now buying, collecting, gathering, and collating animation art and values are rising rapidly. "Annie" Awards are bestowed annually at the Animation Art Festival for major contributions to the art, said Mr. Scott.

The "Adopt a School" program was described by Mr. Scott. ASIFA is interested in the education of young people from kindergarten to college about animation. The program joins an animation studio with a school to educate and encourage interest in animation art, explained Mr. Scott.

Bullwinkle Moose, Dudley Do-Right, Mr. Peabody the Dog and Sherman, and Super Chicken concluded the discussion with a few words of wisdom and a great round of applause.

Q. What is a Cel?

A. A piece of clear acetate on which the characters are drawn, so they can move against a background. Cel is short for celluloid.

Q. Why don't we see cartoons or animated art in the movie theaters any more? Are people still making them?

A. The cost to produce the great number of drawings is very high. Theaters generally will not pay the price for the added feature. Saturday morning cartoons are "limited" animations in which there are 12 drawings or frames per second and movement may be limited.

Q. Do you take volunteer artists?

A. We take volunteer artists, clerks, etc. We look forward to anyone interested in helping our program.

EARL B. SMITH, *Secretary*

New England

Feb. 18

Society Treasurer, Fran Koebert, has resigned due to his employment with a Florida paint company.

Peter Robinson, President of the Paint Research Institute Board of Trustees briefly reviewed the past problems of PRI and reported on its current status.

According to Mr. Robinson, the major problem was communications. Two other difficulties were funding, which is very difficult and inadequate, and lack of planning. Mr. Robinson explained how the Federation responded to this situation by establishing an Ad Hoc Committee to study PRI and to get Society input.

Seventy percent of PRI activities are funded by a few large companies, said Mr. Robinson, and the other 30% comes from a large number of other people. This inevitably puts pressure on PRI to tailor their research to the few large companies, explained Mr. Robinson.

The question of relevance came up, and Mr. Robinson asked, "Relevant to who?". Of the 150 papers published by PRI, 12% were on polymer synthesis, 33% were on coatings studies, 18% were on polymers (not synthesis), 20% were on general studies, 2% were on paint manufacturing, and there were none on application, said Mr. Robinson. As for the management of PRI, Mr. Robinson stated that the program is a collection of projects. He maintained that projects should be solicited from the Board of Trustees, the Federation Board of Directors, the Federation Technical Advisory Committee, the NPCA Scientific Committee, the local Societies, and the Society Technical Committees.

PRI now has a five year plan that will be reviewed and updated each year, explained Mr. Robinson. There is a scientific/basic research component and an applied research/development component. Much has been said about the reader's inability to understand the published PRI papers. According to Mr. Robinson, the goal of a researcher is to be understood by his peers; therefore, the researcher is going to write the best paper he can. It is the responsibility of the paint chemist to remain current with the technology, and to keep up to date. Technology will not wait for us, he said.

Mr. Robinson mentioned the mildew consortium and its special funding and suggested that we should pursue this

approach in other fields. We should have an aqueous coatings consortium, a high solids coatings consortium, and a corrosion control by coatings consortium, said Mr. Robinson.

N. BRADFORD BRAKKE, *Secretary*

New York

Jan. 12

Dr. Edward Bozzi, of Ciba-Geigy Corp., discussed "MULTIFUNCTIONAL EPOXY RESINS."

The uses of epoxies in coatings were explained and illustrated with visual examples. Dr. Bozzi emphasized their use in beer and beverage can linings. Multifunctionals are characterized by more than two epoxy groups per molecule, explained Dr. Bozzi, such as epoxy cresol novalac where high performance uses are required.

Tri-functional epoxies were also discussed. According to Dr. Bozzi, they have fairly low viscosities (3,000 cps), are noncrystalline, have excellent chemical resistance and good thermal properties, and are good for adhesives and flooring.

Tetra-functional epoxies, said Mr. Bozzi, are usually solid, with a 90°C melting point and are used in powder coatings.

The reasons for the multifunctionals' outperformance were discussed. These included their tighter crosslink density, giving greater chemical resistance, and their more aromatic nature, giving excellent heat stability.

Dr. Bozzi explained their uses in drill pipe coatings, composite coatings for airplanes, scrubbers in duct work, over expensive alloys, and stacks for coal fire power plants.

Differences of performance between standard and multifunctionals in severe environmental conditions were noted by Dr. Bozzi.

HERBERT ELLIS, JR., *Secretary*

Pacific Northwest

Jan. 21

"HYDROPHOBIC SILICAS" was discussed by Terry Bowerman, of Degussa Corp.

Uses for silicas were explained by Mr. Bowerman and these included: enveloping and hydrophobizing; anti-gassing in zinc-rich primers; corrosion protection; and suspension agents.

Mr. Bowerman noted that fumed silicas have very wide ranges of surface areas. Hydrophobic silicas react with their OH groups enabling them to retain the moisture level in different humidity levels without suffering in efficiency. Treating a fumed silica makes it a good stabilizer in epoxies, said Mr. Bowerman.

O. SCHMIDT, *Secretary*

Philadelphia**Feb. 11**

The meeting was held jointly with the Philadelphia Printing Ink Production Club. Honored guests included Club President, Edward Mahoney and Federation Executive Vice-President, Frank Borrelle and Field Services Director, Thomas Kocis.

Donald Fritz, of Superior Varnish & Drier Co., discussed "COMPARISON—INKS AND COATINGS: PRODUCT DEVELOPMENT, TESTING, AND MARKETING."

The basic comparative properties of coatings and inks were discussed by Mr. Fritz. Presented were formulation parameters, application and performance testing, technical services, and suggested users. Mr. Fritz evaluated the relative complexity and/or difficulty of coatings and inks.

RALPH MYERS, *Secretary*

Philadelphia**Mar. 11**

A moment of silence was called in observance of the death of Wade Hall, of New Jersey Zinc, Inc.

Sam Belletiere, of Tenneco Chemicals, Inc., presented "DRIERS FOR WATERBORNE COATINGS."

According to Mr. Belletiere, drier technology for water-borne coatings is more complex than it is for solvent-based coatings in terms of compatibility, basic efficacy, and stability of dry in the system. A brief review of the technology of driers in solvent-based coatings was presented, pointing out the similarities and differences that apply to the two systems.

Mr. Belletiere discussed the effect of variables on drying properties, such as vehicle type, neutralizing amines or ammonia, cosolvents, and other interacting formula components. Also discussed by Mr. Belletiere were the methods of incorporation, potential discoloration problems, poor initial dry, and drying stability.

Q. Have you encountered any problems with loss of dry using high surface area pigments; e.g., carbon black?

A. Yes—this is a recurring problem and the adsorption of the drier on this kind of pigment will cause loss of dry as the material ages.

Q. What effect do driers in water coatings have on gloss?

A. Assuming proper compatibility and adequate dispersion are achieved, they do not effect gloss. Zinc pigments due to drier interference can effect gloss and other properties.

RALPH MYERS, *Secretary*

Constituent Society Meetings and Secretaries

BALTIMORE (Third Thursday—Eudowood Gardens, Towson). JOSEPH D. GUISTO; Lenmar, Inc., 150 S. Calverton Rd., Baltimore, MD 21223.

BIRMINGHAM (First Thursday—Calthorpe Suite, Edgbaston). D. H. CLEMENT, Holden Surface Ctg. Ltd., Bordesley Green Rd., Birmingham B9 4TQ, England.

CHICAGO (First Monday—meeting sites in various suburban locations). JOHN R. INGRAM, DeSoto, Inc., 1700 S. Mt. Prospect Rd., Des Plaines, IL 60018.

C-D-I-C (Second Monday—Sept., Jan., Apr., June in Columbus; Oct., Dec., Mar., May in Cincinnati; Nov., Feb., in Dayton). ROBERT A. BURTLZAFF, Potter Paint Co. of Ind., P.O. Box 265, Cambridge City, IN 47327.

CLEVELAND (Third Tuesday—meeting sites vary). DONALD C. DENISON, JR., Hilton Davis Chemical Co., 5254 Berkshire Dr., N. Olmsted, OH 44070.

DALLAS (Thursday following second Wednesday—Steak & Ale Restaurant). T. LEON EVERETT, Dan-Tex Paint & Ctg. Mfg., Inc., P.O. Box 18045, Dallas, TX 75218.

DETROIT (Fourth Tuesday—meeting sites vary). PETER BURNETT, Wyandotte Paint Products, Inc., 650 Stephenson Hwy., Troy, MI 48084.

GOLDEN GATE (Monday before third Wednesday—Alternate between Sabella's Restaurant on Fisherman's Wharf and the Sea Wolf at Jack London Square, San Francisco). KEN E. TRAUTWEIN, Sherwin-Williams Co., P.O. Box 23505, Oakland, CA 94623.

HOUSTON (Second Wednesday—Sonny Look's, South Main). GEORGE SCHWARTZ, Cook Paint & Varnish Co., P.O. Box 3088, Houston, TX 77001.

KANSAS CITY (Second Thursday—Cascone's Restaurant). MEL BOYER, Patco Coatings Products, 3947 Broadway, Kansas City, MO 64111.

LOS ANGELES (Second Wednesday—Steven's Steak House). EARL SMITH, Spencer Kellogg Div., Textron, Inc., P.O. Box 7205, Long Beach, CA 90807.

LOUISVILLE (Third Wednesday—Hasenour's Restaurant). E. D. THOMAS, Louisville Varnish Co., 1400 Maple St., Louisville, KY 40207.

MEXICO (Fourth Thursday—meeting sites vary). TERESA SUAREZ, Sherwin-Williams Co., Mexico, D.F., Mexico.

MONTREAL (First Wednesday—Bill Wong's Restaurant). ERIC TEMPLETON, NL Chemicals Can., Inc., 2140 Sun Life Bldg., Montreal, Que., Can., H3B 2X8.

NEW ENGLAND (Third Thursday—Fantasia Restaurant, Cambridge). N. BRADFORD BRAKKE, Lilly Chemical Products, P.O. Box 188, Templeton, MA 01458.

NEW YORK (Second Tuesday—Landmark II, East Rutherford, NJ). H. ELLIS, D. H. Litter Co., Inc., 116 E. 16th St., New York, NY 10003.

NORTHWESTERN (Tuesday after first Monday—Edgewater East Restaurant). HERBERT DAVIDSON, Spencer-Kellogg Div., Textron, Inc., 525-25th Ave. S.E., Minneapolis, MN 55414.

PACIFIC NORTHWEST (Portland Section—Tuesday following second Wednesday; Seattle Section—the day after Portland; British Columbia Section—the day after Seattle). WILLIAM SHACKELFORD, Gaco-Western, Inc., P.O. Box 88698, Seattle, WA 98188.

PHILADELPHIA (Second Thursday—Valle's Steak House). RALPH MYERS, Del Vac Ink & Color Co., 1301 Taylors Ln., Riverton, NJ 08077.

PIEDMONT (Third Wednesday—Howard Johnson's Coliseum, Greensboro, NC). JAMES E. HUSTED, Mobil Chemical Co., P.O. Box 2438, High Point, NC 27261.

PITTSBURGH (First Monday—Skibo Hall, Carnegie Mellon Univ.). MICHAEL GILLEN, Van Horn, Metz & Co., Inc., 400 Keystone Dr., Carnegie, PA 15106.

ROCKY MOUNTAIN (Monday following first Wednesday—Gusthaus Ridgeview, Lakewood, CO). DONALD SHILLINGBURG, Union Chemical Div. of Union Oil, 1535 W. 13th Ave., Denver, CO 80204.

ST. LOUIS (Third Tuesday—Salad Bowl Restaurant). ROBERT J. GIERY, Spatz Paint Industries, Inc., 1601 N. Broadway, St. Louis, MO 63102.

SOUTHERN (Gulf Coast Section—Various Dates; Central Florida Section—Third Thursday after first Monday; Atlanta Section—Third Thursday; Memphis Section—Second Tuesday; Miami Section—Tuesday prior to Central Florida Section). J.E. GEIGER, Sun Coatings, Inc., 12295 75th St., N., Largo, FL 33540.

TORONTO (Second Monday—Cambridge Motor Hotel). R. KUHNEN, Toixide Canada, Inc., 1 Eva Rd., Etobicoke, Ontario, Canada M9C 4Z5.

WESTERN NEW YORK (Third Tuesday—Lord Amherst Restaurant, Williamsville, NY). MICHAEL C. KAUFMAN, Bisonite Co., Inc., P.O. Box 84, Kenmore St., Buffalo, NY 14217.

Future Society Meetings

Cleveland

(May 18)—60th ANNIVERSARY OF FEDERATION MEMBERSHIP. PAST PRESIDENTS AND SPOUSES' NIGHT. "WHAT DO M&M'S AND MINKS HAVE IN COMMON"—William Mirick, Battelle Laboratories.

Detroit

(May 25)—JOINT MEETING with Detroit Paint & Coatings Association. (Sept. 28)—Presentation by Cargill Corp.

(Oct. 19)—EDUCATION COMMITTEE'S PRESENTATION/PAST PRESIDENTS' NIGHT

(Dec. 14)—"HIGH SOLIDS COATINGS"—Dick Hong, Spencer Kellogg Div., Textron, Inc.

Golden Gate

(May 17)—"NEW DEVELOPMENTS IN SANDMILL DISPERSIONS TECHNOLOGY"—Roland F. Swett, Moorehouse Industries, Inc.

(June 14)—"COMPLIANCE SOLVENTS FOR INDUSTRIAL COATINGS"—Violete Stevens, Dow Chemical Corp.

Los Angeles

(June 9)—"COMPLIANCE SOLVENTS FOR INDUSTRIAL COATINGS"—Violete Stevens, Dow Chemical Corp.

Piedmont

(May 20)—"COMPUTER SELECTION OF SOLVENT BLENDS"—Dr. Albert Rocklin, Shell Development Co.

(June 16)—"ECONOMIC RECOVERY OF SOLVENT VAPORS"—Larry J. Durr, DCI Corp.

Rocky Mountain

(June 7)—"COMPLIANCE SOLVENTS FOR INDUSTRIAL COATINGS"—Violete Stevens, Dow Chemical Co.

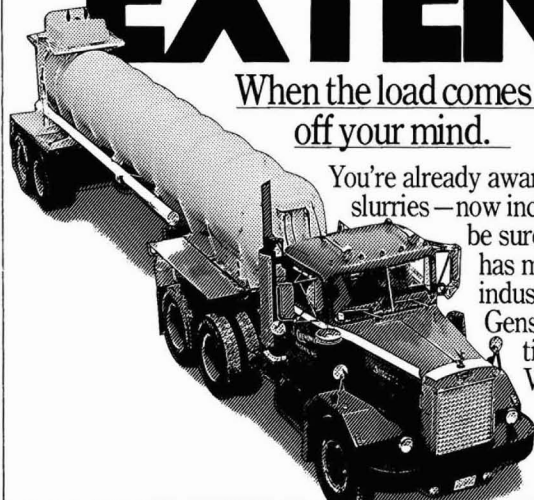
St. Louis

(May 18)—"THE WHYS AND WHEREFORES OF CARTRIDGE FILTRATION IN THE COATINGS INDUSTRY"—D. S. Onnen, AMF Cuno Div. "EFFECTIVE PAINT WASTE TREATMENT"—E. M. Antonucci, Drew Chemical Corp. "MODERN PAINT DISPERSIONS"—H. Purcell, Morehouse, Ind.

(June)—JOINT KANSAS CITY/ST. LOUIS SOCIETIES MEETING.

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 NIE, DENNIS A.—Perry & Derrick Co., Inc., Cincinnati, OH.
 VIGAR, MYRON K.—PPG Industries, Inc., Delaware, OH.

CLEVELAND

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 SCHUMAKER, L.E.—Poly-Carb, Inc., Solon, OH.
 SELDEN, GEORGE—Selden Chemical, Cleveland, OH.
 SKILES, DENNIS J.—Limbacher Paints & Color Works, Inc., Lakewood, OH.

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 HAND, PATRICK F.—Diamond Shamrock Corp., Beachwood, OH.
 KELLY, RICHARD J.—Technical Products, Inc., Cleveland, OH.
 ROBERTS, JAMES W.—Filter Specialists Inc., Aurora, OH.
 THOMAS, ELIAS—Dar-Tech, Inc., Cleveland, OH.

Retired

WILLIAMS, HUGH B. JR.—Clearwater, FL.

LOS ANGELES

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 BAUER, RALPH H.—Union Chemicals Div., La Mirada, CA.
 BORBOLLA, FRANCISCO J.—Productos Aurolin S.A., Ensenada, Baja, CA.
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 FRANCISCO, RENANTE A.—Major Paint & Varnish Co., Torrance, CA.
 GUPTA, LAXMI C.—Arnco, South Gate, CA.
 LONG, LU DAW—W.C. Richards of California, Anaheim, CA.

MANNINO, FRANK—Devoe Marine Coatings, Riverside, CA.
 MERRITT, GENE R.—Mero Corp., Baldwin Park, CA.
 MILICI, STEVE—Sinclair Paint Co., Los Angeles, CA.
 MOUALIM, RICHARD J.—J.&R. Industries, Inc., Los Angeles, CA.
 O'NEAL, JOHN R.—Standard Brands, Torrance, CA.
 POPAT, GHANSHYAM—Avery Label, Azusa, CA.
 RUSSELL, RAYMOND F.—Paint & Coatings Corp., City of Industry, CA.
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 WHITE, SAUNDRA R.—Major Paint & Varnish Co., Torrance.
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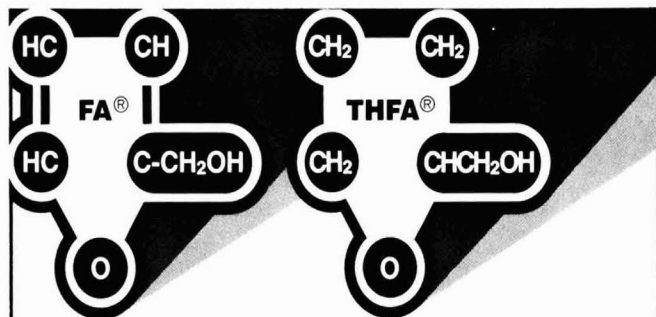
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Farbe und Lack (in German)

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- Höfner, K.—"Strategic Planning for Business (1)"; 643-646.
- Petersen, H., Klug, L., Hahn, H., and Huber, W.—"Formaldehyde in Amino Resins and Lacquers. (1) Critical Consideration of an Analytical Method for Determining Free Formaldehyde According to DIN 53187"; 647-652.
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- German Standard Draft DIN 53 216 Part 1: Testing of Paints and Varnishes; Determination of Non-Volatile Matter Content at Elevated Temperature; p. 674.
- German Standard Draft DIN 53 238 Part 32: Testing of Pigments; Test of Ease of Dispersion; Test Medium Alkyd—Melamine Resin System II Low Viscosity Stoving Type; p. 676.

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- Höfner, K.—"Strategic Planning for Business (2)"; 798.

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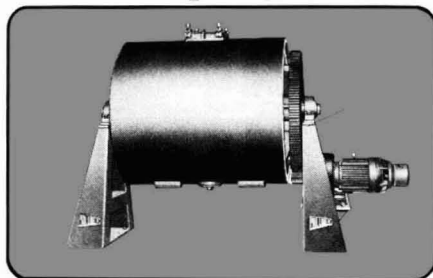
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FSCT Members To Speak at Overseas Meetings

The Federation is pleased to have two of its members representing it at the 1982 meetings of the Federation of Associations of Technicians in the Paint, Varnish, Lacquer, and Printing Ink Industries of Continental Europe (FATIPEC) and the Federation of Scandinavian Paint and Varnish Technologists (SLF).

Dr. Gordon P. Bierwagen, of Sherwin-Williams Co., Chicago, IL, will speak on "Computer Prediction of Latex Paint Properties," at the XVIth FATIPEC Congress, May 9-14, in Liege, Belgium. Dr. Wilfred A. Côté, of the State University of New York's College of Environmental Science and Forestry at Syracuse, NY, will talk on "Wood as a Substrate for Coatings," the 10th SLF Congress in Copenhagen, Denmark on October 11.

Dr. Bierwagen is the Director of the Physical and Analytical Laboratory at the Sherwin-Williams Co. Research Center in Chicago. He received his B.S. Degree in 1964 from Valparaiso University and his Ph.D. Degree in Physical Chemistry in 1968 from Iowa State University. After a year of postdoctoral work in the Chemical Engineering Department of the University of Minnesota and work in the Electrochemical Engineering Department of the Battelle-Columbus Labs., he joined Sherwin-Williams in 1970. At Sherwin-Williams he has worked in fundamental research on foam stability, pigment packing, new concepts of coating formulation, pigmented suspension polymers, film formation in latex coatings, aqueous coating development, and contract research for the U.S. Air Force. He has also given presentations at the 1976 Gordon Conference on Coatings, at the 1977 Lehigh University Short Course on Emulsion Polymerization and Latex Technology, and at the XVth FATIPEC Congress (1980). He will be giving presentations at the 1982 Lehigh Short Course and the 1982 International Conference in Organic Coatings Science in Athens, Greece.



Dr. Côté is Professor of Wood Technology at the State University of New York College of Environmental Science and Forestry, Syracuse, New York. He received a B.S. Degree in Forestry from the University of Maine, a Master's Degree from Duke University and the Ph.D. Degree from the State University of New York at Syracuse. His university training was interrupted by service in the U.S. Army during World War II.

He joined the faculty of the State University in 1950 and has remained at this institution in various capacities except for a number of official leaves of absence. He was a Fulbright Postdoctoral



Research Fellow at the University of Munich in 1959-60, a Walker-Ames Visiting Professor at the University of Washington, Seattle, in 1966, Visiting Professor at the Technical University of Denmark for the fall semester, 1972, and a Guest Scholar at Kyoto University during the summer of 1978.

Dr. Côté has authored or co-authored about 75 publications, six of which are books. He has lectured in a number of foreign countries including Japan, Australia, Turkey, Finland, Sweden, England, and France. His professional interests are in the field of electron microscopy, in wood ultrastructure and in the area of interactions of wood with coatings, preservatives and other materials. He has served as Director of Paint Research Institute projects dealing with the wood and coatings interactions for several years.

Federation Publishes Southern Society's 'Consumer Guide to Trade Paint Quality'

A *Consumer Guide to Trade Paint Quality*, produced to help promote an appreciation of paint quality features and an understanding of paint application, has been published by the Federation of Societies for Coatings Technology.

The guide, entitled "Know Paint Quality Before You Buy," focuses on latex interior flat paint and depicts the performance characteristics of low, average, and high-quality products.

Written and developed by the Southern Society for Coatings Technology, the pamphlet is designed for point-of-purchase use to help the consumer understand what to look for in paints. Full-color reproductions illustrate the effects of paint quality features on staining and washability-durability, as well as spreading rate, application, and wet & dry hiding.

Commenting on the guide, Federation President Howard Jerome said, "The Southern Society is to be commended for developing the brochure and responding to the need for consumer information. Publication by the Federation is in keeping with the May 1981 resolution of the Federation Board of Directors to support appropriate efforts to increase consumer awareness of various qualities of architectural paints."

Cooperating with the Federation in the distribution of the guide will be the National Decorating Products Association and its member paint store dealers.

The price of the guide is 10¢ each, minimum order of 100 copies. Order from the Federation of Societies for Coatings Technology, 1315 Walnut St., Philadelphia, PA 19107.

Seminars Scheduled for 'Coatings Tech Expo '82', May 19-20

The New England Society for Coatings Technology will sponsor the biennial "Coatings Tech Expo '82" at the Sheraton Inn & Conference Center, Boxborough, MA, May 19-20. Robert Marderosian, Chairman of the exposition, and John Fitzwater, Society Vice-President and Program Chairman, have announced the scheduling of industry-related seminars to be featured in addition to the trade show.

The seminar schedule, arranged by Tom Manning, Chairman of the Manufacturers/Managers Program, and George Finn, will commence on Wednesday, May 19, at noon and will be directed towards the management and manufacturing sector. The following program is scheduled:

Dispersion In Industry

"Dispersion of Organic Pigments"—Al Singleton, American Hoechst Corp.
"Optimizing Productivity of Small Media Mills"—Leo Dombrowski, Chicago Boiler Co.

"High Speed Dispersion"—Greg Delong, Shar, Inc.

Waste Management

"Technological Advancements in Solvent Vapor Recovery"—Bruce McKenna, United Air Specialists, Inc.

"Hazardous Waste Incineration"—George Finn, New Way Industries.

"E.P.A.: Current Regulations"—E.P.A. Representative.

Also included in Wednesday's program is a presentation given by Dr. Harold Resnick, of Work Systems Associates, entitled "Why Do We Need Computer Training in Industry Today?" and Patrick Mastrola, of Rapidstan, will present a discussion on "Material Handling and Warehousing."

Thursday's seminars will be more technically oriented and directed towards the bench chemist. The program, planned by Maureen Lein and N. Bradford Brakke, Technical Program Chairmen, is as follows:

Technical Uses of Computers In the Coatings Industry

"State of the Art Color Control for the Coatings Industry"—Presented by Applied Color Systems, Inc.

"Coatings Formulations Using the Personal Computer"—Gary Keltz, Technical Subcommittee on Computer Applications, NESCT.

"The Use of Computers for Evaluating the Environmental Impact of Coatings"—Gregory A. Conner, Davidson Rubber Div., Ex-Cell-O Corp.

Advances in Coatings Formulations

"Effect of the Geometries of Pigment Loading on the Formulation and Performance of Organic Zinc Rich Metal Primer"—Clive Hare, Consultant, Clive H. Hare, Inc.

"Role of Acetylenic Glycols in Water-Based Coatings"—Presented by Air Products & Chemicals, Inc.

"Concept of Pigment Wetting in Aqueous Coatings Systems"—Presented by Byk-Mallinckrodt.

Following the theme, "PAT: Produc-

tivity, Availability, and Technology in the 80's," the exposition will open on Wednesday at 12:00 noon with 13,000 square feet of exhibit space and on Thursday, at 10:00 a.m. to 4:00 p.m.

The program will be concluded with the Annual Dinner featuring Dick Flavin, "The Art Buchwald of Television," as keynote speaker, which has been arranged by Social Functions Chairman, Daniel Toombs.

For additional information, contact Dame Associates, Inc., 51 Church St., Boston, MA 02116.

Kent State to Sponsor Dispersion Course, May 17-21

The Rheology and Coatings Laboratory of the Chemistry Department of Kent State University, Kent, OH, will present "Dispersion of Pigments and Resins in Fluid Media," May 17-21.

This week-long short course will be presented by lecturers from industry and the university who are experts on the subject of dispersion. The program will cover surface chemistry fundamentals related to the dispersion process and a discussion of dispersion of pigments and resins in water-based and classic systems. Lectures will discuss the mechanical means and selection of the proper equipment for dispersion. A broad background of dispersion fundamentals and applications with the most recent updates in these areas will be featured and would benefit laboratory chemists, research and plant supervisors in coatings, polymer, and related industries.

The short course program will feature the following presentations:

Monday, May 17

"Fundamentals of Surface and Colloid Chemistry I"—Richard J. Ruch, Kent State University.

"Practical Selection of Dispersants and Dispersing Resins"—Edward J. Schaller, Rohm and Haas Co.

"Fundamentals of Surface and Colloid Chemistry II"—Richard J. Ruch.

"Pigment Dispersion Technology in Water-Based Systems"—Robert F. Conley, Mineral and Resource Technology.

Tuesday, May 18

"Dispersion of Pigments in Liquid Media—A Review of Principles"—Geoffrey D. Parfitt, Carnegie-Mellon University.

"Interactions at the Pigment/Vehicle Interface and Their Relevance to Pigment Dispersion"—Geoffrey D. Parfitt.

"Dispersion of Carbon Black and Other Pigments in Fluid Vehicle for Printing Inks"—John W. Vanderhoff,

National Printing Ink Research Institute, Lehigh University.

"Measurements of Degree of Dispersion of Water-Based Flexographic Inks by Capillary Chromatography and Color Strength"—John W. Vanderhoff.

Wednesday, May 19

"Factors Governing Tinter Performance"—George Goodwin, Daniel Products Co.

"Theory and Application of Mixers in Blending and Dispersion"—James Y. Oldshue, Mixing Technology, Mixing Equipment Co.

"Choice of Equipment for Dispersion"—Robert S. Bailer, Lilly Industrial Coatings.

"High Shear Mixing"—Richard Gash, Silverson Machine, Ltd., Gash Associates.

Thursday, May 20

"Dispersion of Classic Solvent Systems"—George R. Pilcher, Hanna Chemical Coatings Corp.

"Dispersion Technology"—James W. White, Hockmeyer Equipment Co.

"Small Media Milling and Dispersion Techniques"—Leo Dombrowski, Chicago Boiler Co.

"Attritor Grinding and Dispersing Equipment"—James F. Johnson, Union Process, Inc.

"Practical Aspects of Dispersion of Particulates in Polymers"—Stan Jakopin, Buss-Condux, Inc.

Friday, May 21

"Dispersing Fine-Particle Materials: I. Determining Equipment Requirements (With Choices Based on Materials), and II. Evaluating Processing Results (Including Basic Optical Microscopy)"—David G. Bosse, Maginet-Projects.

Further details can be obtained from the Program Chairman, Carl J. Knauss, Chemistry Dept., Kent State University, Kent, OH 44242, (216) 672-2327.

Summer Coatings Courses Scheduled at NDSU

Two summer coatings courses will be conducted by the Polymers and Coatings Department of North Dakota State University, Fargo, ND.

"Coatings Science" will be offered June 7-18, and is designed to provide an understanding of the principles involved in the preparation, formulation, application, and evaluation of paints and industrial coatings. Emphasis will be placed on developments in the field reflecting the need to meet air pollution, energy conservation, and toxic hazard regulations while maintaining or improving product performance at competitive cost levels. The course is introduced by consideration of methods of film formation by solvent evaporation, latex coales-

cence, fusion, and crosslinking. Special emphasis will be given to the importance of glass transition temperatures, molecular weight and crosslink density. Topics to be discussed include: resins; color and gloss of coatings; pigments and pigment dispersion; solvents; rheology; coatings performance; and coatings formulation.

Instructor for the course is Dr. Zeno W. Wicks, Jr., Chairman and Professor of Polymers and Coatings. Registration fee for the two-week session is \$950 including books and materials. Cost of dormitory room and board, and scheduled banquets is an additional \$450.

"High Solids Coatings" is the second session course, scheduled June 21-25. The course will be taught at a research level with emphasis on the importance of understanding the underlying physical and organic chemistry of the systems. Theoretical considerations will be related with practical problems while pointing out opportunities for new approaches to meeting the challenges of formulating superior high solids systems. Topics to be

covered include: viscosity; resins and crosslinking; radiation curing; application properties; and film properties.

Instructors for the session include Dr. Loren Hill, Research Associate, Monsanto Plastics & Resins; Dr. S. Peter Pappas, Professor of Chemistry and Polymers and Coatings; and Dr. Wicks, Jr. Fee for the one-week course is \$600 including books and materials. Cost of dormitory room and board and other scheduled activities is an additional \$225.

Applicants for "Coatings Science" must have at least two years of college level chemistry, including organic chemistry. Applicants wishing to take "High Solids Coatings" must have the background equivalent to the introductory session and preferably should have a B.S. or Ph.D in chemistry or a closely related field.

For additional information, contact Dr. Zeno Wicks, Jr., NDSU, Fargo, ND 58105, (701)237-7634, or Dr. Richard Chenoweth, (701)237-7106.

NDSU To Sponsor Polymer Symposium, May 25

North Dakota State University will sponsor "The Influence of Associative Thickeners and Rheology on Coatings Performance" symposium, May 25, at the Fountain Blue restaurant, Des Plaines, IL.

The emphasis of the symposium will be on water-soluble polymers, which compete with surfactants and dispersants at the interfaces of latex, pigments, and other component particles, and are dramatically changing the character of trade-sale and industrial coatings. These changes and their dependence on various water-soluble polymer chemical structures will be discussed in the following lectures:

"Factors Influencing Polymer and Latex Rheology and the Criteria for Association"—J.E. Glass, NDSU.

"The Nightmares of an Innovative Supplier"—J.E. Miller, Dow Chemical Co.

"Structural Aspects Promoting Association in Methacrylate Terpolymers"—W.C. Arney, Union Carbide Corp.

"Formulating Trade-Sale Latex Paints with High-Efficiency Rheology Modifiers"—E.J. Schaller, Rohm and Haas Co.

"Associative Cellulose Ethers"—L. Landoll, Hercules Incorporated.

"Advantages and Disadvantages of Associative Thickeners in Coatings Performance"—F.G. Schwab, Coatings Research Group, Inc.

"Structural Limitations of Thickeners in Industrial Roll Coating Performance"—J.E. Glass.

For additional information and registration forms, contact Professor J.E. Glass, Polymers and Coatings Dept., Dunbar Hall, NDSU, Fargo, ND 58105.

'Computer Programming for Coatings' Offered at UMR

A short course in "Basic Microcomputer Programming for Coatings" will be offered at the University of Missouri-Rolla, Rolla, MO, May 24-27.

Designed for laboratory, purchasing, and marketing personnel, the course will demonstrate how to use the computer to make jobs move faster, with efficiency and productivity. No prior programming experience is required.

Topics featured in the session include: types of computers; computer hardware; number systems used by computers; a review of high-level computer languages; programming techniques; and design of a number of programs including sorting, information retrieval, cost of inventory, and paint formula bulking and costing.

Participants will learn how to write their own custom-designed programs to be used on a microcomputer costing less than \$2,000. Students will be given "hands-on" programming experience, from basic design to final working programs. These programs can be tailored to fit specialized needs, and will be useful in such areas as formulation, information retrieval, purchasing, costing/pricing, sales analysis, and inventory control.

Faculty members include Stanley W. Harshfield, of United Paint Co., Memphis, TN; and UMR faculty members: Kenneth I. Magel, Assistant Professor of Computer Science, James Stoffer, Associate Professor of Chemistry, and John A. Gordon, Jr., Coatings

Continuing Education and Lecturer in chemistry.

Fee for the four-day course is \$550.

To register or for additional information contact Norma Fleming, Arts and Sciences Continuing Education, UMR, Rolla, MO 65401.

'Colloids and Surface Science' Offered at University of Minn.

"Colloids and Surface Science," will be held at the University of Minnesota, Minneapolis, MN, May 17-21.

Designed for persons working with grinding, adhesives, sealants, wetting agents and other lubricants, emulsions and films, pigments, powders, printing inks, and solids and clays, the course will feature lectures, laboratory demonstrations, and problem solving group sessions. Topics to be discussed are: methods of measuring surface tension; contact angles in wettability; characterization of materials by modern surface techniques; flocculation and rheology of colloids; electrophoresis; mono-dispersed colloids; colloid size, number, and charge measurements.

For further information, contact John S. Vollum, Program Director, Dept. of Conferences, 222 Nolte Center, 315 Pillsbury Dr., S.E., University of Minnesota, Minneapolis, MN 55455.

ASTM Terminology Symposium To Be Held June 23 in Toronto

Basic principles and methodologies in the preparation and use of standard terminology by both man and machines will be the focus of review and discussion at the American Society for Testing and Materials Symposium on "Terminology: The Cornerstone of Global Communications Through Standards." Sponsored by the ASTM Standing Committee on Terminology, the symposium will be held June 23 during the ASTM Meeting Week in Toronto, Canada.

Symposium Chairman, Wayne P. Ellis, of the H.B. Fuller Co., has announced that the symposium program is divided into two sessions: Standardization Principles and Standardization Practices. Papers to be presented will cover subjects such as the necessity of standardization in both scientific and technical fields; the variety and treatment of compound terms; what happens to terms which have failed standardization; the birth of a terminology standard; international harmonization of terms and definitions in the field of nonferrous metals; managing uncontrolled vocabulary; and future terminology developments.

The symposium program is as follows:

Standardization Principles

"Basic Principles and Methods for Terminological Standards"—Helmuth Felber, INFOTERM Austrian Standards Institute.

"Is Standardization Necessary in Both

the Scientific and Technical Fields?"—Dorothy Nakos, Aupetit, Université Laval, Quebec.

"Terminology in Technical Communications"—James R. Gaskill, Consulting Engineer.

"Neonymic Creativity: A Comparative Study of the Most Productive Morphological and Morphosyntactic Term-Formation Processes in English, German, French, and Russian in the Field of Chemistry"—Rosy Alber-Dewolf, GRSTERM Université Laval.

"The Varieties of Compound Terms and Their Treatment"—Richard A. Strehlow, Oak Ridge National Labs.

"The Banque de Terminologie du Québec, An Instrument Within the Limits of Québec's Program to Work in French"—Robert Globensky, Government of Québec.

"What Happens to Terms Which Have Failed Standardization? They Live On and Proliferate in Dictionaries"—Diane Duquet-Picard, Université Laval.

Standardization Practices

"Systems of Terminology"—Herbert T. Pratt, duPont.

"Birth of a Terminology Standard"—Charles D. Sullivan, Tektronix, Inc.

"Writing a Definitive Work for the Coatings Industry: The Paint/Coatings Dictionary"—Stanley LeSoto, Rohm and Haas Co.

"International Harmonization of

Terms and Definitions in the Field of Nonferrous Metals"—H.J. Fischer, DIN Deutsches Institute für Normung.

"Preparing Terminology Standards: the Importance of Situation Concepts and Usage"—Joanne Davidson and Mary Sitariski, Canadian Government Translation Bureau.

"Managing an Uncontrolled Vocabulary"—J.R. Smith and M.C. Kelly, Bio-Sciences Information Service.

Symposium Review

"The Future of Standards in Terminology Developments"—Frank Heymann, Westinghouse Electric Corp., and Past Chairman of ASTM Committee on Terminology.

Additional information can be obtained from Wayne P. Ellis, H.B. Fuller Co., P.O. Box 625, Springhouse, PA 19477.

Golden Gate Society To Hold Computers Seminar, June 14

The Golden Gate Society for Coatings Technology will sponsor an all-day seminar featuring computers on June 14 at A. Sabella's Restaurant on Fisherman's Wharf, San Francisco, CA.

The session, beginning at 9:00 a.m., will continue through 3:00 p.m. An equipment display will be featured before dinner at 6:00 p.m. A review of the subjects covered during the day program will be included in a short evening session.

Topics featured in the seminar include: time sharing versus service bureau versus owning computers; order entry and office functions; manufacturing and process control; laboratory, quality assurance, and quality control; and color matching.

Fee for the session, which includes lunch and dinner, is \$44.

For additional information, contact E. Bud Harmon, Borden Chemical Co., 41100 Boyce Rd., Freemont, CA 94538.

2nd World Congress on Bridge Coatings Scheduled for October 26-27, New York

The 2nd World Congress on Coatings Systems for Bridges and Steel Structures has been scheduled for October 26-27, Holiday Inn LaGuardia, New York, NY. The program is sponsored by the University of Missouri-Rolla, in cooperation with the Federal Highway Administration, Steel Structures Painting Council, Painting and Decorating Contractors of America, and the Institute for Bridge Integrity and Safety.

The purpose of the 1982 Congress will be to provide up-to-date guidelines for using paint and coatings to protect steel bridges and structures from corrosion. The two-day program will include sessions on the preparation of surfaces; the selection of materials; water-borne bridge paints; alternative corrosion-inhibiting pigments; protection of weathering steel; state and municipal painting practices; and unexpected paint performance and contractor responsibility.

Contractors, specification writers, structural engineers, and industrial and commercial researchers in the United

States and abroad are expected to attend the program.

Dr. Bernard Appleman, Project Manager for Coatings Research of the Federal Highway Administration, is Program Chairman.

For additional information, contact Norma R. Fleming, Congress Coordinator, Arts & Sciences Continuing Education, UMR, Rolla, MO 65401.

Lehigh University Offers Short Course in Polymer Latexes

The 13th annual short course, "Advances in Emulsion Polymerization and Latex Technology," will be sponsored by Lehigh University, Bethlehem, PA, June 7-11.

Designed for engineers, chemists, and other scientists and managers who are actively involved in emulsion work, the course is an in-depth study of the synthesis and properties of high polymer latexes. Subject matter includes a balance of theory and applications as well as a balance between chemical and physical

problems. Lectures, given by leading academic and industrial personnel, begin with introductory materials and reviews, and progress through recent research results.

Fee for the course and a set of notes is \$525 for the entire week or \$150 per day for any part.

Further information can be obtained from: Dr. Mohamed S. El-Aasser, Dept. of Chemical Engineering, Sinclair Lab #7, Lehigh University, Bethlehem, PA 18015.

People

Bruning Paint Co., Baltimore, MD, has announced the appointment of **William T. Cochran** to the position of General Manager of the firm's Pompano Beach, FL operation. Mr. Cochran is a Past-President of the Baltimore Society and was a recent recipient of the Society's Herman Shuger Award.

Ted Favata, of Triangle Paint Co., in San Francisco was presented a special award at the February meeting of the Golden Gate Society. Mr. Favata was cited for his many years of outstanding contributions to the coatings industry in the Bay Area. He is a Past-President of the Society and the current Chairman of the Educational Committee and 1983 Western Coatings Societies' Symposium and Show.

Terralab Engineers, Salt Lake City, has announced the appointment of **John W. Holmes** to head its newly formed Coatings and Corrosion Division. Mr. Holmes previously served as Manager of Bennett's Paint Technical Department. He is a member of the Rocky Mountain Society and has served as its President.

Abel Banov has been appointed Co-Publisher/Editorial of the *American Paint & Coatings Journal*. The appointment is the final change in the editorial staff following the retirement of **Fred Schulenberg** and the appointment of **Chuck Reiter** as Editor. Mr. Schulenberg was named Editor, Special Projects.

Mr. Banov, who has been Market Editor in New York for 21 years and Senior Editor for 12 years, brings to the new duties a background in coatings industry affairs and in industrial editing.

Mr. Banov has worked closely with leaders of the Federation of Societies for Coatings Technology and has served on several key committees of the National Paint and Coatings Association. Presently, he is Senior Vice-President of The Institute for Bridge Integrity and Safety and was General Chairman of the recent World Congress of Coatings Systems for Bridges, sponsored by IBIS and the University of Missouri-Rolla. He has addressed UMR seminars and has lectured on coatings at the University of Wisconsin.

David F. Iden has been named Manager of Chemical and Raw Material Purchasing for Ashland Oil, Inc., Ashland, KY.



W.T. Cochran



T. Favata



H.H. Reichhold



B.H. Todd

Reichhold Chemicals, Inc., White Plains, NY, has announced that **Henry H. Reichhold**, its founder, Chairman of the Board, and the only Chief Executive Officer in the company's 52-year history, has retired. Mr. Reichhold will remain as a director and consultant to the company. The Board of Directors has elected **C. Robert Powell** as Chief Executive Officer.

Dr. Stanley J. Buckman, who was a well-known figure in the chemical industry, was honored posthumously by the Memphis Chemical Club (MCC), a non-profit association of manufacturers, distributors, and industrial users of chemicals in the Memphis area. Dr. Buckman founded Buckman Laboratories in 1945, and served as Chairman of the Board until his death in 1978. An award in his name is to be presented annually to an individual who has contributed significantly to the chemical industry of Memphis.

Hercules Incorporated, Wilmington, DE, has announced two promotions in its Northeastern Region. **George Laut** is assigned to Northeastern Region headquarters as Senior Technical Sales Representative of Organic Resins. **Maurice J. Sadowsky** was promoted to Technical Sales Representative, Water Soluble Polymers and Coatings, based in Paramus, NJ.

Andrew A. Eglolf has been promoted to General Manager, Pigments Department, at the Hilton-Davis Chemical Group, Cincinnati, OH.

Thomas R. Laakso has been appointed Director of Sales and Marketing—Pigments for the Minerals, Pigments and Metals Division of Pfizer Inc., New York, NY.

Bruce H. Todd has joined the Specialty Chemicals Group at Johnson Wax, Racine, WI, as Commercial Development Manager—Polymers. Mr. Todd will be responsible for identifying, recommending, and developing new polymer markets. He is a member of the Detroit Society.

Bywater Coatings, Inc., Belle Chasse, LA, has announced the appointment of **Mrs. Nils A. Wirstrom** as its President, succeeding **Mr. Wirstrom** who has recently died. Appointed Vice-Presidents were **Robert E.** and **William C. Wirstrom**.

Chemcentral Corp., has appointed **Richard A. Smith** as Sales Representative for the Los Angeles area. **Philip A. Fortier** was named Technical Sales Representative for the Dallas, TX operation.

Charles Winterburn has joined Stamat, Inc., Dallas, TX, as Sales Manager. He assumes responsibility for the firm's accounts in Tennessee, Arkansas, Louisiana, and East Texas and for supervision and coordination of the graphic arts product lines.

The firm has also announced that through an organizational change **Frank Verduin** has been assigned primary responsibility for the company's marketing programs relating to Thwing-Albert instruments, Diano Color Computers, Cadmium Pigments, and Rhone-Poulenc Titanium Dioxides. Mr. Verduin is a Dallas Society member.

George F. Polzer, Jr., Executive Vice-President of Commercial Services for Witco Chemical Corp. and a member of the firm's Board of Directors, has been appointed to a three-year term on the Governor's Commission on Hazardous Waste Facility Siting for the state of New Jersey.

Dr. Raymond R. Myers, of Kent State University, Announces Retirement From Paint Research Institute

Dr. Raymond R. Myers, a University Professor at Kent State University, has announced his retirement as Research Director of the Paint Research Institute of the Federation of Societies for Coatings Technology, effective January 1, 1983.

Dr. Myers was appointed Research Director in January 1964, succeeding Dr. J. S. "Shorty" Long. At the time, Dr. Myers was Research Professor of Chemistry at Lehigh University.

The Paint Research Institute seminar at the 1982 Annual Meeting of the Federation (Sheraton Washington Hotel, November 3-5) will be dedicated to Dr. Myers and the many accomplishments made by PRI under his direction.

A graduate of Lehigh, Dr. Myers received his M.S. Degree from the University of Tennessee in 1942 and his Doctorate from Lehigh in 1952. He spent several years teaching at Tennessee and the University of Dayton before joining the Lehigh faculty in 1952 as a Research Associate. He rose to full Professorship.

Dr. Myers moved to Kent State University, Kent, OH, in 1965 as a Professor and Chairman of the Chemistry Dept. In

1977, the University Trustees named him a University Professor, the top rank at KSU. Only four other persons at KSU held that title, established to provide unusual opportunities for scholars who have demonstrated talents on a national scale.

Dr. Myers, a long-time member of the Federation of Societies for Coatings Technology, was the recipient of the Federation's George Baugh Heckel Award in 1973. Two years later, he presented the Mattiello Memorial Lecture, "A Prospectus for Basic Research," at the Federation's Annual Meeting.

In 1970, Dr. Myers received the American Chemical Society Award in the Chemistry of Plastics and Coatings, sponsored by the Borden Foundation. He was Chairman of the ACS Div. of Organic Coatings and Plastics Chemistry in 1965 and Chairman of the Gordon Research Conference on Organic Coatings in 1962. He currently serves on the ACS Council and on the Joint Board-Council Patent Committee.

Dr. Myers, who is listed in "Who's Who in the World," is the Editor of the Society of Rheology, and a member of

Sigma Xi and the Oil and Colour Chemists Association. He is a Fellow of the American Institute of Chemists and the New York Academy of Science whose A. Cressy Morrison Award was presented to him in 1958.

Bryant Scism has joined Dexter Chemical Corp. as a Technical Service Representative based in Charlotte, NC.

duPont de Nemours & Co., Inc. has announced the retirement of **Leonard F. Smith**, Account Manager in the Los Angeles area for the White and Colored Pigment Products Division. Mr. Smith, a 34-year employee with the firm, is a member of the Los Angeles Society. He will be succeeded by **John Pritchard** who has extensive experience in pigments manufacture with duPont.

Glidden Coatings & Resins, Division of SCM Corp., has announced several promotions at its Research Center in Strongsville, OH. **P. Duane Smith** was named Manager—Quality Assurance. **Phillip K. George** was promoted to Manager—Facilities Planning and **Gerald E. Brown** was named Manager—Transportation. Promoted to the position of Technical Manager—High Solids Coatings was **Dr. Archie W. Garner**. Mr. George is a member of the Chicago Society and Dr. Garner is a member of the Cleveland Society.

Glidden has also announced that at its Western Region headquarters, **William B. Anthony** was named Technical Manager. Mr. Anthony is a Cleveland Society member.

Flecto Co., Inc., Oakland, CA, has announced the appointment of **Martin Misfeldt** as Manager of Operations of Flecto Coatings, Ltd., Richmond, B.C.

Woolsey Marine Industries, Inc., Brooklyn, NY, has announced the promotion of **Raymond Gangi** to Vice-President, Technical Manufacturing. Mr. Gangi was most recently Technical Director. He is a member of the New York Society.

Buckman Laboratories, Inc., Memphis, TN, has appointed **Kenneth A. Haagensohn** as Manager—Distributor Marketing in the United States. Mr. Haagensohn is a member of the Southern Society.

Roy Brown Becomes Consultant to Federation

Royal A. Brown, well-known figure in the coatings industry for many years, has been retained as a consultant to the Federation of Societies for Coatings Technology. The announcement was made by Howard Jerome, Federation President.



Mr. Brown, whose title will be Technical Advisor, retired earlier this year from the National Paint and Coatings Association, where he served for 16 years, most recently as Vice-President-Technical.

In his announcement, Mr. Jerome said that Mr. Brown will be concerned with advancing the technical, educational, and manufacturing activities of the Federation in cooperation with those committees of the organization. In this capacity, he will be responsible for

developing national programs, including a Federation-sponsored seminar in the spring of 1983. He will also be called upon, from time to time, to represent the Federation in various industry liaison capacities.

Mr. Jerome added that the Federation is fortunate to obtain the services of Mr. Brown, currently a Trustee of the Paint Research Institute, noting that his extensive background and experience in both technical and administrative aspects of the industry uniquely qualify him for his Federation duties.

Mr. Brown's industry career includes service with Gilman Paint & Varnish Co., Southern Varnish Corp., Egyptian Lacquer Manufacturing Co., and the Chemical Div. of The Stanley Works, prior to joining NPCA as Technical Director in 1966. He was appointed Vice-President of the Association in 1978.

Mr. Brown will work out of his home in the Washington, D.C. area.

NCCA's Literature List

The expanse of the coil coating industry is reflected in a recently published list of literature available from the National Coil Coaters Association. The brochure, revised and consolidated into a new format, outlines a broad range of NCCA publications relevant to the coil coating industry. New literature, as well as that which was previously available, is included. The new list offers a brief description of all NCCA publications, the NCCA Product Capability Directory, and the NCCA Fact Sheet. Additionally, the list contains price information and an order form. Copies of the updated Literature List can be obtained without charge from the NCCA Office, 1900 Arch St., Philadelphia, PA 19103.

Spackling Compound

A new vinyl spackling compound, which spreads onto drywall, plaster, or wood in seconds, dries fast and can be sanded and painted over with any type of interior or exterior paint, is the subject of recent literature. Contact Southern Protective Products Co., 1135 Sylvan Rd., S.W., Atlanta, GA 30310, for more information.

Color Control Brochure

Applied Color Systems, Inc., has released a four-color six-page brochure describing its line of computer color control systems for the plant, plastics, textile, and ink and printing industries. The brochure discusses the impact of computer color control on the profitability of these industries and details the capabilities of ACS systems. For more information, contact ACS, P.O. Box 5800, Princeton, NJ.

Heat Processing Systems

A new, 20-page, illustrated catalog describing infrared, convection and conduction industrial heat processing systems and components has been published. The catalog features extensive literature describing the systems and includes 33 line drawings and photographs illustrating the operation of various types of heat processing systems. An application locator directs the reader to the equipment needed for his application and end product. Over 250 applications are discussed. For a free copy, contact Jim Alimena, Glenro, Inc., 39 McBride Ave., Paterson, NJ 07501.

Extender

Literature is available which highlights a new type of fine particle size, high strength microspherical extender called Zeospheres®. Featured are its eight different size grades and its uses in a variety of paint and plastic systems. For information, contact Zeelan Industries Inc., 320 Endicott Bldg., St. Paul, MN 55101.

High Solids Coatings

The new "1982 High Solids Coatings® Buyer's Guide" is now available. Serving the high solids coatings industry, the guide is published annually to include the most complete and reliable information of suppliers in the industry. The guide is available for \$21 in the U.S. and \$26 elsewhere from Technology Marketing Corp., 17 Park St., Norwalk, CT 06851.

For The **INSIDE** Story On **OUTSIDE** Aluminum Coatings

When Silberline brought into the marketplace our exciting new family of EternaBrite® leafing aluminum pigments a few short years ago, we said this represented the most significant advance in ready-mix paint technology in decades. We said EternaBrite aluminum paints would yield greater leafing values when formulated, higher reflective values when applied and increased protective values for years longer.

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Thickness Gauge

A recent data sheet describes a new digital hand-held microprocessor-based gauge, designed to test the thickness of any nonmagnetic coating on a ferrous substrate. The pocket-size solid-state gauge features an error-free liquid crystal digital display and converts from inches to metric. Information on the Model 255F thickness gauge is available from Elcometer, Inc., P.O. Box 1203, Birmingham, MI 48012.

Powder Coatings

Technology Marketing Corp. has published the new "1982 Powder Coatings® Buyer's Guide." The buyer's guide is the first of its kind, serving the powder coatings industry. Published annually, the guide includes the most complete and reliable listing of suppliers to the industry. Information is provided which will serve to meet the needs of those interested in converting to, or expanding their present technology in this revitalized coatings industry. Cost of the guide is \$20 in the U.S. and \$24 elsewhere, and can be obtained from the Technology Marketing Corp., 17 Park St., Norwalk, CT 06851.

Painting Systems

The 1982 catalog of the Sherwin-Williams Co. painting systems is now available. This complete products catalog contains 60 pages of information for use by architects and engineers involved in new construction and industrial maintenance projects. Specifications for surface preparation and application methods are provided along with specific product data for normal and heavy duty exposures. Specification selection guides are divided by major coating types: chlorinated rubber, epoxy, vinyl, zinc rich, aluminum, acrylic latex, polyurethane, and alkyd enamels. The catalog also provides selection charts for interior and exterior surfaces of wood, metal, masonry, plywood, hardboard, drywall, plastic, and glass. Writing specifications for painting systems outline details that directly affect the quality of the paint job, from surface preparation through inspection and approval procedures. Product descriptions include recommended uses, performance information, analysis, and preparation and priming instructions. For additional information, contact Jack Linden, Manager of Architectural Services, Stores Div., P.O. Box 6027, Cleveland, OH 44101.

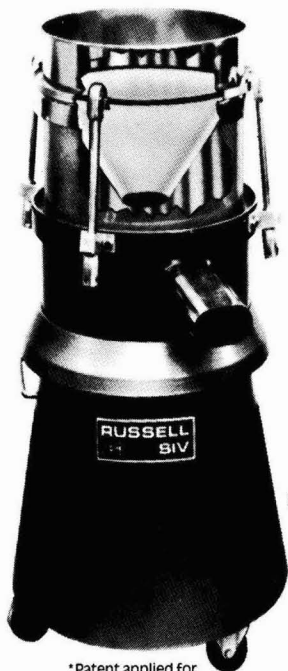
Trucks and Forklifts

A new full color brochure has been published featuring a line of industrial trucks and specially designed forklifts. Illustrations of the various models and descriptions of their design, use, and accessories are included. For information, contact The Gregory Group, Inc., 8701 Tonnelle Ave., North Bergen, NJ 07047.

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*Patent applied for.

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Tel: (914) 668-1100 Telex: 137398

Book Review

POLYMER CHEMISTRY An Introduction

Written by
Raymond B. Seymour
and
Charles E. Carraher, Jr.

Published by
Marcel Dekker, Inc.
New York, NY
1981
564 pages, \$29.75

Reviewed by
Dr. Thomas J. Miranda
Whirlpool Corp.
Benton Harbor, MI

This text is a welcome addition to the field and offers a good introduction to the study of polymer chemistry for students and those teaching polymer chemistry at the undergraduate level.

Beginning with a history of the development of polymer chemistry and a glossary of terms, the reader is led through Polymer Structure, Rheology, Molecular Weight, Testing and Characterization of Polymers. This is followed by Naturally Occurring Polymers and four chapters on Polymer Reactions including Stepwise, Ionic, Free-Radical and Copolymerization Processes.

A short chapter on Inorganic Polymers is included.

The remaining chapters are devoted to Fillers and Reinforcement, Plasticizers,

Stabilizers, Flame Retardants and Other Additives, Reactions of Polymer and Synthesis of Intermediates. The text concludes with a chapter on Polymer Technology.

Several noteworthy features are included in this text, such as a summary, glossary, bibliography, and exercises; and, at the end of each chapter, an appendix which lists symbols and their meaning and an extensive list of trademarks, products and manufacturers.

Solutions are provided to exercises in the text.

This text should be of value to the novice, the teacher and those engaged in the field of polymer chemistry, and should provide a good base for further study in the field.

Letters to the Editor

Methods Questioned in New England Study

TO THE EDITOR:

We question the methods used to evaluate products, including our Strodex MO-100, as anti-flash-rusting agents in coatings described in a report of the New England Society, published in the January 1982 issue of JCT.

First, after the introduction of the additive into the coating, each formulation was not buffered to a given pH. As the table shows, these additives ranged from low to high pH. It is known that greater protection is obtained on steel at a pH of 9 or higher.

Secondly, the test coating at a pH of 9 (ammonia) did not have sufficient alkali to neutralize Strodex MO-100 which has an acid number of 330-380 mg KOH/gm (pH of 9.5).

Strodex MO-100 is an organic phosphate ester in acid form, and when unneutralized hydrolyzes to a free acid in water and is only partially soluble.

We recommend in aqueous systems Strodex MOK-70, a potassium neutralized Strodex MO-100, for protection against flash rusting. Strodex MO-100

can be used in such coatings if neutralized with an amine or another alkali.

J.J. MCGUINNESS
Manager, Industrial Chemicals
Dexter Chemical Corp.

New England Society replies:

Mr. McGuinness may have misinterpreted the data. In the second paragraph of his letter he says, "each formulation was not buffered to a given pH. As the table shows, these additives ranged from low to high pH." What the table (Table 2) shows is the pH of the chemical solution, not the paint formulation. As stated in the article: "Measurement of the pH of the test paints after adding the solutions indicated the effect on final pH to be negligible." We presented the pH data of each paint formulation after chemical solution addition in the oral presentation at the Annual Meeting. We deleted it in the published paper in the interest of brevity. The paint pH after addition of the 2-Ethylhexylpolyphosphoric ester acid anhydride was 8.9-9.0.

We are aware of the effect of pH on corrosion as we mention in the introduction to the paper. Its effect is complicated by the change in pH during the drying process. But that is another problem.

As any competent formulator knows many additives are formulation and concentration specific and must realize that we did not try to optimize the formulation around any one chemical. Nor do we mean to suggest that the New England study was exhaustive or complete. We wanted to test a variety of chemicals, alone, in a standard formulation under standard conditions to eliminate as many variables as possible in an already complex environment. Much more work remains to be done to understand this phenomenon.

If Mr. McGuinness's product works when formulated properly, that is great. We are all concerned with eliminating corrosion in any of its forms.

N. BRADFORD BRAKKE,
Co-chairman
New England Society
Technical Committee

Coming Events

FEDERATION MEETINGS

(Nov. 3-5)—60th Annual Meeting and 47th Paint Industries' Show. Sheraton Washington Hotel, Washington, D.C. (FSCT, 1315 Walnut St., Suite 832, Philadelphia, PA 19107).

1983

(Oct. 12-14)—61st Annual Meeting and 48th Paint Industries' Show. Queen Elizabeth Hotel, Montreal, Quebec, Canada. (FSCT, 1315 Walnut St., Suite 832, Philadelphia, PA 19107).

SPECIAL SOCIETY MEETINGS

(May 19-20)—New England Society Coatings Tech Expo '82. Sheraton Inn, Boxborough, MA. (Robert Marderosian, Chairman, c/o Dame Assoc., 51 Church St., Boston, MA 02116).

(June 11-12)—Joint meeting of Kansas City and St. Louis Societies on "Instrumentation for Quality Coatings in the Eighties." Hilton Plaza Hotel, Kansas City, MO.

(Oct. 5)—Cleveland Society for Coatings Technology Manufacturing Committee Symposium on "The Use of Computers in the Manufacture of Coatings." Cleveland Engineering and Scientific Societies Bldg., Cleveland, OH. (Chairman Charles K. Beck, Premier Industrial Corp., 4415 Evelid Ave., Cleveland, OH 44103).

1983

(Feb. 23-25)—16th Biennial Western Coatings Societies' Symposium and Show. Hyatt Regency, San Francisco, CA. (Ted Favata, Chairman, Triangle Coatings Co., 2222 Third St., Berkeley, CA 94710).

(Mar. 23-25)—Southern Society Annual Meeting. Peabody Hotel, Memphis, TN. (William E. Early, Piedmont Paint Mfg. Co., P.O. Box 6223, Stn. B, Greenville, SC 29606).

OTHER ORGANIZATIONS

(May 17-21)—"Dispersion of Pigments and Resins in Fluid Media" Short Course. Kent State University, Kent, OH. (Carl J. Knauss, Chemistry Dept., Kent State University, Kent, OH 44242).

(May 18)—"Industrial Paints and Painting Methods" Workshop. Philadelphia Civic Center, Philadelphia, PA. (Susan Buhr, Technical Activities Dept., Society of Manufacturing Engineers, One SME Dr., P.O. Box 930, Dearborn, MI 48128).

(May 18-20)—"Estimating Workshop for Painting Contractors." Villa Hotel, San Mateo, CA. (Norma R. Fleming, UMR, Rolla, MO 65401).

(May 19)—"Powder Coatings: How It Will Work for You" Workshop. Philadelphia, PA. (Susan Buhr, Technical Activities Dept., Society of Manufacturing Engineers, One SME Dr., P.O. Box 930, Dearborn, MI 48128).

(May 24-27)—"Basic Microcomputer Programming for Coatings Manufacturers" Short Course. University of Missouri-Rolla, Rolla, MO. (Norma R. Fleming, UMR, Rolla, MO 65401).

(May 25)—"The Influence of Associative Thickeners and Rheology on Coatings Performance" Symposium. Fountain Blue Restaurant, Des Plaines, IL. (Professor J.E. Glass, North Dakota State University, Polymers & Coatings, Dunbar Hall, Fargo, ND 58105).

(May 25-27)—"Colorimetry and the Eye" Short Course. Rensselaer Polytechnic Institute, Troy, NY. (Office of Continuing Studies, Rensselaer Polytechnic Institute, Troy, NY 12181).

(June 2-3)—"Color Technology for Management" Short Course. Rensselaer Polytechnic Institute, Troy, NY. (Office of Continuing Studies, Rensselaer Polytechnic Institute, Troy, NY 12181).

(June 7-11)—"Adhesion Principles and Practice for Coatings and Polymer Scientists" Short Course. Kent State University, Kent, OH. (Carl J. Knauss, Chemistry Dept., Kent State University, Kent, OH 44242).

(June 7-11)—"Advances in Emulsion Polymerization and Latex Technology" Short Course. Lehigh University, Bethlehem, PA. (Dr. Mohamed S. El-Aasser, Dept. of Chemical Engineering, Sinclair Lab #7, Lehigh University, Bethlehem, PA 18015).

(June 7-11)—"Principles of Color Technology" Short Course. Rensselaer Polytechnic Institute, Troy, NY. (Office of Continuing Studies, Rensselaer Polytechnic Institute, Troy, NY 12181).

(June 7-11)—"Surface Modification, Cleaning, and Adhesion" Short Course. Soderkopings Brunn, Sweden. (Course Registration Office, Anita Hall, Gustav Adolfsgratan 9, S-582 20 Linköping, Sweden).

(June 7-18)—"Coatings Science" Short Course. North Dakota State University, Fargo, ND. (Dr. Zeno Wicks, Jr., NDSU, Polymers & Coatings, Fargo, ND 58105).

(June 13-16)—Dry Color Manufacturers' Association Annual Meeting. The Greenbrier, White Sulphur Springs, WV. (P.J. Lehr, DCMA, Suite 100, 1117 N. 19th St., Arlington, VA 22209).

(June 14-18)—"Principles of Color Technology" Short Course. Rensselaer Polytechnic Institute, Troy, NY. (Office of

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Continuing Studies, Rensselaer Polytechnic Institute, Troy, NY 12181).

(June 20-23)—American Society for Testing and Materials Committee D-1 Meeting on Paint and Related Coatings and Materials. Sheraton Conference, Toronto, Canada. (Jane M. Turner, ASTM, 1916 Race St., Philadelphia, PA 19103).

(June 20-25)—75th Air Pollution Control Association's Annual Meeting and Exhibition. The Rivergate Convention Center, New Orleans, LA. (APCA, P.O. Box 2861, Pittsburgh, PA 15230).

(June 21-25)—"Advances in Color Technology" Short Course. Rensselaer Polytechnic Institute, Troy, NY. (Office of Continuing Studies, Rensselaer Polytechnic Institute, Troy, NY 12181).

(June 21-25)—"Applied Rheology for Industrial Chemists" Short Course. Kent State University, Kent, OH. (Carl J. Knauss, Chemistry Dept., Kent State University, Kent, OH 44242).

(June 21-25)—"High Solids Coatings" Short Course. North Dakota State University, Fargo, ND. (Dr. Zeno Wicks, Jr., NDSU, Polymers & Coatings, Fargo, ND 58105).

(June 23)—"Powder Coatings: How It Will Work for You" Workshop. Birmingham, AL. (Susan Buhr, Technical Activities Dept., Society of Manufacturing Engineers, One SME Dr., P.O. Box 930, Dearborn, MI 48128).

(June 28-30)—"Organic Coatings Technology" Short Course. Center for Professional Advancement's Academic Center, East Brunswick, NJ. (Center for Professional Advancement, Dept. NR., P.O. Box H, East Brunswick, NJ 08816).

(June 28-July 8)—"Polymer Colloids" Short Course sponsored by NATO Advanced Study Institute. University of Bristol, United Kingdom. (Dr. Gary W. Poehlein, School of Chemical Engineering, Georgia Institute of Technology, Atlanta, GA 30332).

(June 29-July 7)—20th Session of the International Commission on Illumination. National Philharmony Bldg., Warsaw, Poland. (U.S. National Committee, CIE, c/o National Bureau of Standards, Washington, D.C. 20034).

(July 12-16)—8th International Conference on Organic Coatings, Science and Technology. Athens, Greece. (Angelos V. Patsis, Coykeydall Science Bldg., State University of New York, New Platz, NY 12561).

(July 12-16)—International Union of Pure and Applied Chemists' 28th Macromolecular Symposium. University of Massachusetts, Amherst, MA. (James C.W. Chien, Dept. of Polymer Science & Engineering, University of Massachusetts, Amherst, MA 01003).

(Aug. 2-20)—Battelle's International Program in Productive R&D Management. Columbus, OH. (Dr. William D. Hitt, Battelle's Columbus Laboratories, 505 King Ave., Columbus, OH 43201).

(Aug. 9-13)—"Introductory Short Course on Composition of Coatings." University of Missouri-Rolla, Rolla, MO. (Norma Fleming, Senior Coordinator, Arts & Sciences Continuing Education, UMR, Rolla, MO 65401).

(Aug. 16-20)—Fifth Annual Short Course on "Advances in Emulsion Polymerization and Latex Technology." Schatzalp Berghotel, Davos, Switzerland. (Dr. Gary W. Poehlein, School of Chemical Engineering, Georgia Institute of Technology, Atlanta, GA 30332).

(Aug. 16-20)—"Physical Testing of Paints and Coatings" Short Course. University of Missouri-Rolla, Rolla, MO. (Norma Fleming, UMR, Rolla, MO 65401).

(Aug. 30-Sept. 3)—"Films and Coatings for Technology" Short Course. Davos Congress Center, Davos, Switzerland. (Course Registration Office, Anita Hall, Gustav Adolfsgatan 9, S-582 20 Linköping, Sweden).

(Sept. 12-17)—American Chemical Society's 184th National Meeting. Kansas City, MO. (A.T. Winstead, ACS, 1155 Sixteenth St., N.W. Washington, D.C. 20036).

(Sept. 13-17)—"Introduction to Paint Formulation" Short Course. University of Missouri-Rolla, Rolla, MO. (Norma Fleming, Senior Coordinator, Arts & Sciences Continuing Education, UMR, Rolla, MO 65401).

(Sept. 18-21)—Canadian Paint and Coatings Association. 70th Annual Convention. Four Seasons Hotel, Toronto, Ont.

(R. Murry, CPCA, 515 St. Catherine St. W., Montreal, Que., Canada H3B 1B4).

(Sept. 20-24)—"Advanced Paint Formulation—Industrial" Short Course. University of Missouri-Rolla, Rolla, MO. (Norma Fleming, Senior Coordinator, Arts & Sciences Continuing Education, UMR, Rolla, MO 65401).

(Sept. 21-23)—"Radiation Curing VI" Conference and Exhibition sponsored by the Association for Finishing Processes of the Society of Manufacturing Engineers. Ramada O'Hare Inn, Des Plaines, IL. (Susan Buhr, Technical Activities Dept., SME, One SME Dr., P.O. Box 930, Dearborn, MI 48128).

(Sept. 29-Oct. 1)—"Surfair '82"—Conference on surfaces' treatments in aeronautical and aerospace industries sponsored by *Surfaces* magazine. Cannes (French Riviera), France. (Thierry Delmotte, *Surfaces*, 46, Rue Ampere, 75017 Paris).

(Oct. 5-7)—9th International Naval Stores Conference. Mayflower Hotel, Washington, D.C. (Pulp Chemicals Assoc., 60 East 42nd St., New York, NY 10165).

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'Humbug' from Hillman

L'Envoi

Next month will see me loading the old covered wagon and hitting the trail for our new mountain top home in Vermont. Since our house is the only 1843 farm house I know with aluminum siding, I go with a slightly tainted conscience. However, I promised myself to paint the barn every year or so to give my friends in the industry that I leave behind, some hope for the future.

Let me say, right now, I do not leave the New York scene to sever ties with an industry which has shared 45 years plus of my life. No, I will look down from the crest of the mountain and muse about the joy with which many of you are pursuing, the struggle and exercise of controlling flow, hastening dry, keeping up with OSHA and holding back EPA. I am pleased that, I anticipate, with more leisure, building on my technical knowledge so that I can read the articles in the JCT beyond the abstracts. It is pleasant, too, that at a more modest pace, I expect to continue my present responsibilities and corporate commitments with about 25% of my time spent in the "Big Apple."

It has been interesting to observe the reactions of acquaintances and friends when they learn that Libby and I will shift operations to Vermont, a state that possesses more than enough beauty and interesting activities for me. For some convinced urbanites, it is as though we, with traitorous intent, are giving up our citizenship. Others, apparently fearful at reaching the age for secular rebirth, want desperately to hear my detailed plans as to what my day to day agenda will be.

What will I do?—I expect to smile a lot! It was Lester Arnstein, who with relish described to me the joys of a second life style. He said, "You know what's great about my life now? It can be summed up in four words—I don't have to."

It is important, however, I know, that I—will want to—want to do many things and enjoy and appreciate. I don't expect to find life so simple and I do look forward to the chores of country living and to the commitments and interesting involvements I have planned. It is wonderful to be able to think with lessened pressure and to work from choice. What a happy privilege!

So to those who see our preference for the delightful smell of clean air, spiced slightly with the scent of pine, and the excitement of looking out on nature's glorious vista; to those who see our "retirement" (?) as a foreshadow of their eventual doom, I say, take heart—it ain't all that bad—not if you don't want it to be.

To those of you who have found their way to the back of this book for the past 20 months and have patiently read this nonsense—you have my thanks and my appreciation for the lack of complaints. For those members of the Federation who haven't even opened the cover of this journal—well, they will be blissfully ignorant of my scorn and righteous resentment. For those who read all the technical articles and look with disdain at "H from H"—congratulations on your discernment and—"bad cess to ye."

What will be Humbug's future? It depends! Depends on what?—

How crops will be.

How much of my time will be spent playing with the deer and the antelope.

How convinced I am that "H from H" is needed—for the mail has been very light of late.

And—how much time I can take off from loving everything!

A Bientot—Peutetre!



Milt Glaser has again offered to share several of his collection of quotes with us.

Mark Twain once replied to a really difficult question with, "I am gratified to answer that question promptly—I don't know."

In the same vein, it is said that after a lengthy lecture on a related subject, the speaker was asked, "Sir, would you tell us some more about this question?" "The fact is," replied the speaker, "I've already told you more than I know."

Mark Twain also said, "Once a cat is burned on a hot stove, it is smart enough never to sit on a hot stove again. But it will never sit on a cold stove either."

Sid Lauren sends us:

Imhoff's Law

The organization of a bureaucracy is very much like a septic tank. The really big chunks always rise to the top.

Stedman's Killer Phrases

We tried something like that years ago.

That's ridiculous.

That's too radical.

Let's form a committee to consider it.

That's contrary to policy.

Has anyone ever tried it?

It won't work.

That's too obvious to be considered.

That's too superficial.

That's interesting, but we don't have the time or the manpower.

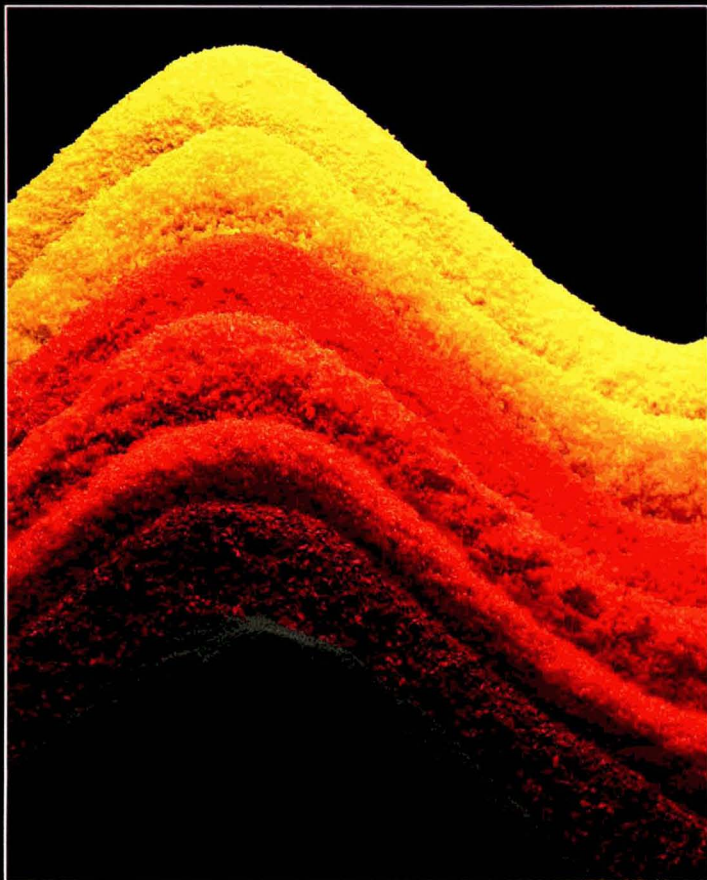
Tell me right now—what's the potential profit in it?

That's not the kind of idea we expect from you.

Kalan's Corollary to Stedman

If that were possible it would already be in practice.

—Herb Hillman



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For samples and formulating information on RHOPLEX WL-71 or any of our broad line of low-VOC vehicles, contact your Rohm and Haas technical representative, or write our Marketing Services Dept., Independence Mall West, Philadelphia, PA 19105.

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