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Ultraviolet light curing: some benefits and recent advances
M. A. Parrish

Analysis of the constant-rate period of ink drying
H. Hardisty

Determination of solubility parameters of polymers by a group contribution technique
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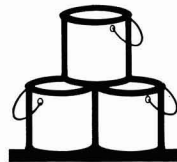
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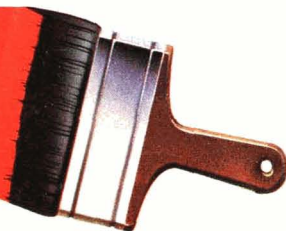
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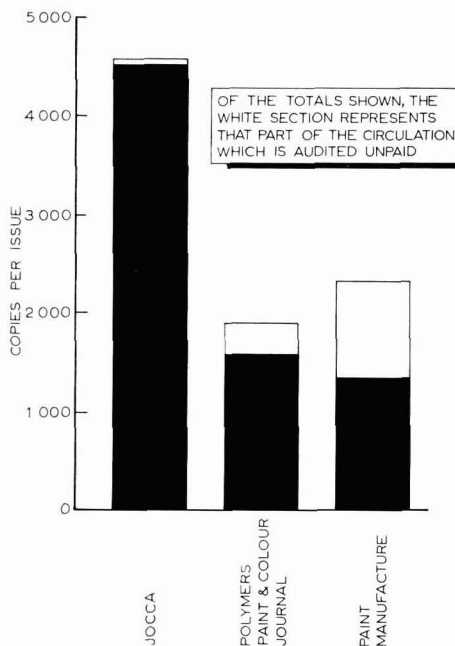
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Tel: 01-908 1086
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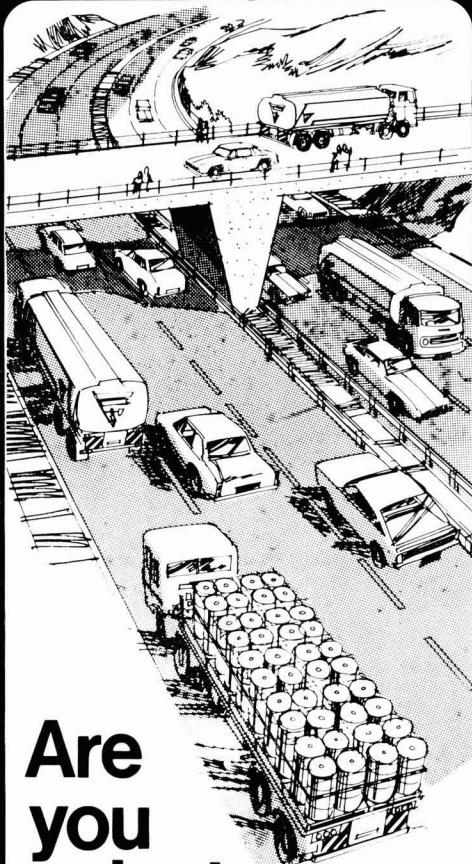
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Atmospheric corrosion testing of metallised, metallised and painted, and painted steel*

By S. Haagenrud

Norwegian Institute for Air Research, P.O. Box 130, 2001 Lillestrøm, Norway

Summary

Long term corrosion testing of different types of metallised, metallised and painted, and painted steel at test stations in Norway is described. The objective is to obtain experimental data as a basis for the choice of optimum protection systems under various

conditions of atmospheric exposure. Measurements and analyses of the environmental parameters determining the local corrosivity are being carried out in order to make the results applicable under those conditions where the environmental factors can be specified.

Keywords

Types and classes of structures or surfaces to be coated

steel

Equipment primarily associated with:

analysis, measurement or testing

exposure facility

Processes and methods primarily associated with:

analysis, testing or measurement

corrosion testing

exposure testing

Properties, characteristics and conditions primarily associated with:

dried or cured films

weather resistance

Une proposition à l'égard des essais pour doser la corrosion atmosphérique d'acier métallisé, métallisé et peint, et peint seulement

Résumé

On décrit les essais à long terme pour doser la corrosion de divers types d'acier, soit métallisé, soit métallisé et peint, ou peint seulement, qui se produit à des stations d'essai en Norvège. Le but est l'obtention des données expérimentales pour établir la base de la choix des systèmes de protection optimale sous de diverses condi-

tions atmosphériques d'exposition. On fait des observation et des analyses des paramètres climatiques qui déterminent le taux de corrosion régnant dans la localité, afin de rendre les résultats valables dans le cas où l'on saurait préciser les facteurs climatiques.

Vorschlag für atmosphärische Korrosionsprüfung von metallisiertem, metallisiert und angestrichene und angestrichenem Stahl

Zusammenfassung

Eine Beschreibung langfristiger Korrosionsprüfung von verschiedenen metallisierten, metallisiert und angestrichenen und angestrichenen Stahlsorten in norwegischen Versuchsstationen. Bezweckt wird, experimentelle Werte zu erhalten als Basis für die Wahl bester Schutzsysteme unter verschiedenen Bewitterungs-

bedingungen. Messungen und Analysen der klimatischen Parameter, welche die lokale Korrosionsvorgänge bestimmen, werden durchgeführt um die Ergebnisse unter Umständen, unter denen die klimabedingten Faktoren spezifiziert werden können, verwenden zu können.

Introduction

Refs. 1-4

The objective of the programme is to obtain experimental data which can serve as a basis for the choice of optimum protection systems under various atmospheric exposure conditions, taking into consideration the technical, economical and environmental aspects. The testing is being carried out by long term exposure at six atmospheric corrosion test stations in Norway.

The atmospheric corrosivity is usually classified in terms of *rural, industrial, urban and marine* atmospheres. This classification is far too inexact. This is illustrated by test results from NILU's atmospheric corrosion test stations showing that the corrosion rate of steel can differ by a factor of five in different industrial atmospheres^{1,2}.

The term "rural" is also ambiguous with respect to atmospheric corrosivity. Due to greater and more acid precipitation³ zinc coatings corrode twice as fast at rural sites in the southernmost part of Norway, compared to inland sites in eastern Norway.

The vague classification of atmospheres is due mainly to the lack of definition and measurements of the parameters determining the local corrosivity. Allowance for these factors will be made by the detailed measurements of meteorological and air pollution parameters at the NILU test stations. The data will then be subjected to multiple regression analyses and the relationship between corrosion and environment evaluated. The use of the relationships found, and a knowledge of environmental data at other localities, will enable the test results to be more generally applicable. The test stations established are also intended to serve as standard test sites for users and producers of metals and protection coatings.

An aspect of environmental concern in corrosion protection is the possible damage to the environment by the paint maintenance work on steel structures *in situ*. This maintenance work often includes sand blasting and causes the dispersion of sand together with old and new paint waste on to cultivated land, rivers etc. As paints are more or less toxic, maintenance procedures can thus represent a serious pollution problem⁴. A change to more durable and less toxic corrosion protection systems, for example, less toxic paint systems on metal coatings, would, therefore, lead to a much better solution of

*Paper presented at the Association's Biennial Conference held at the Grand Hotel, Eastbourne, Sussex from 16-19 June 1977

the environmental problems connected with maintenance work. Most of the sand blasting could be carried out at the workshop in the first instance, whilst maintenance work in field would be limited to the renewal of the top coating.

Experimental

Refs. 3, 5

As the exposure programme started in December 1976 no results are available yet for report in this paper. The field stations and the exposure programme will, however, be described.

Atmospheric corrosion test stations

The test programme is being carried out at six stations situated in different types of atmosphere. Description and location of the stations are given in Table 1 and Figure 1, whilst Figure 2 shows station no. 1.

*Table 1
Atmospheric corrosion test stations*

Station no.	Name	Type of atmosphere
I	Borregaard (Sarpsborg)	Acid industrial atmosphere, strongly SO ₂ -polluted
II	Folehavnen 10m from sea (Sandefjord)	Marine atmosphere with sea spray
III	Folehavnen 250m from sea (Sandefjord)	Marine atmosphere.
IV	Brevik	Alkaline industrial atmosphere, heavy dust-polluted
V	Birkenes (30km north of Kristiansand)	Rural atmosphere with much acid rainfall (long range transport of air pollutants (3)
VI	Marineholmen (Bergen)	Urban, industrial and marine atmosphere.

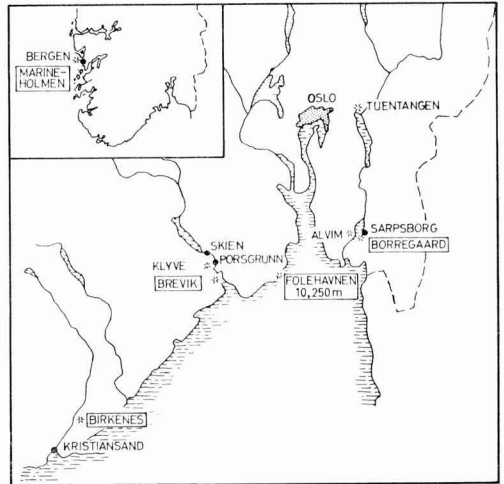


Fig. 1. Location of atmospheric corrosion test stations in Southern and Western Norway (inset)

As a reference for the aggressiveness of the atmosphere, the corrosion rates of identical samples of unalloyed carbon steel and pure zinc are determined on a monthly, quarterly and yearly basis at each station. The corrosion is determined by weight loss.

All stations have identical equipment for sampling of rainfall and air. Precipitation is collected both in a polyethylene gauge with a 20 cm diameter opening, and in an open polyethylene jar. Both samplers are placed 2 metres above the ground in a stand which has a ring above the rim of

*Table 2
Corrosion and environmental data at corrosion test station no 1 (Borregaard)*

Year and month	CORROSION DATA						CHEMICAL DATA						
	Zn		C-steel		P-steel		In precipitation (mg/m ²)					Air µg/m ³	
	G/m ²	MY	G/m ²	MY	G/m ²	MY	pH	NH ₄	Ca	SO ₄	Cl	MY	S
74 Oct	1.80	0.25	78.0	9.9	49.0	6.3	3.50	24	22	848	52	151	31
74 Nov	6.00	0.84	232.0	29.6	117.0	14.8	4.10	24	13	1003	216	151	102
74 Dec	6.50	0.91	281.0	35.7	110.0	14.0	3.30	10	30	1720	460	191	84
75 Jan	8.80	0.98	146.0	18.5	87.0	11.1	3.60	104	67	2990	560	160	115
75 Feb	5.00	0.70	102.0	12.9	63.0	8.1	3.30	37	46	1738	159	275	82
75 Mar	6.30	0.88	109.0	6.9	69.0	8.8	3.55	103	73	825	168	265	76
75 Apr	3.80	0.53	90.0	11.5	75.0	9.5	3.80	48	98	826	36	120	60
75 May	4.60	0.65	79.0	10.1	60.0	7.6	4.00	21	20	168	9	23	37
75 June	5.90	0.82	84.0	10.6	79.0	10.0	4.40	46	53	568	16	57	83

METEOROLOGICAL DATA

Year and month	Termohygraph					Pluviograph (precipitation)			
	% rel. hum	h > 85%	h > 90%	h > 95%	d < 0°C	d.w/prec	h.w/prec	mm prec	
	74 Oct	78	264	168	88	2	25	81	58
74 Nov	84	392	320	80	12	20	100	122	
74 Dec	85	488	357	80	21	17	80	74	
75 Jan	83	441	301	146	18	17	92	121	
75 Feb	88	501	446	315	24	3	41	23	
75 Mar	74	338	282	160	20	7	49	31	
75 Apr	62	170	115	51	14	7	46	26	
75 May	62	132	100	35	1	9	42	33	
75 Jun	45	11	2	1	0	2	9	5	

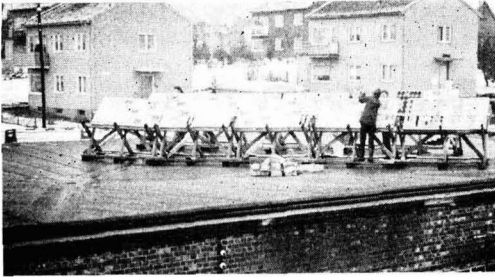


Fig. 2. Atmospheric corrosion test station No 1 (Borregaard)

the sampler to prevent contamination from bird droppings. The rain samples are analysed for pH, ammonium, calcium, sulfate, chloride and nitrate.

Air sampling is carried out with a NILU automatic air sampler in which the air is drawn (about 3 m³ per day) through a Whatman 40 filter for the collection of sulfate. After filtering, the air is bubbled through a solution of 0.3 per cent hydrogen peroxide for absorption of atmospheric SO₂. The amount of sulfate formed in the solution is determined by the barium perchlorate method. The minimum detectable concentration³ of SO₂ is 0.5-1 µg/m³.

Temperature, humidity and duration and intensity of rainfall are continuously recorded.

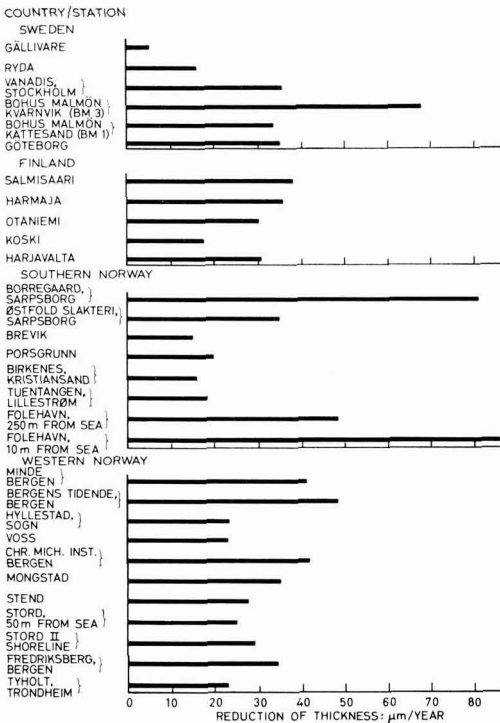


Fig. 3. Corrosion rate of unalloyed steel at 30 atmospheric corrosion test stations in Scandinavia

Examples of the data on a monthly basis are shown in Table 2.

By a Scandinavian co-operative research project on atmospheric corrosion, these six test stations are integrated into the net of thirty Scandinavian stations⁵. The corrosion rates for unalloyed steel on these stations are shown in Figure 3 for the period July 1975 to July 1976.

Effect of environmental parameters on corrosion

Based on data of the type shown in Table 2, the effect of parameters on corrosion has been analysed by plotting the corrosion rate and each single parameter in the same diagram, and by statistical evaluation of the results. This analysis has not yet been fully completed, so that the results must be regarded as preliminary to some extent.

The correlation coefficients between the monthly corrosion of steel on three corrosion stations for a two-year period show that the corrosion velocity is well correlated with sulfur dioxide in air ($R = 0.82$), sulfate ($R = 0.64$) and strong acid ($R = 0.51$) in the rainfall.

In the multiple linear regression analysis the ten best equations including two, three or four climatic parameters are calculated. The best equation for the three parameters is:

$$Y = 1.5 X_1 + 2.3 X_2 + 0.05 X_3 - 15.2$$

$$(R = 0.87) \dots\dots\dots (1)$$

where

- Y = monthly corrosion of carbon steel (g/m²)
- X_1 = concentration of SO₂ (µg/m³)
- X_2 = days with precipitation
- X_3 = concentration of strong acid in precipitation (µ eqv. H⁺/l)

The correlation coefficient indicates that 76 per cent of the corrosion can be explained by this equation. The calculated monthly corrosion from this equation is plotted in Figure 4 against the measured corrosion.

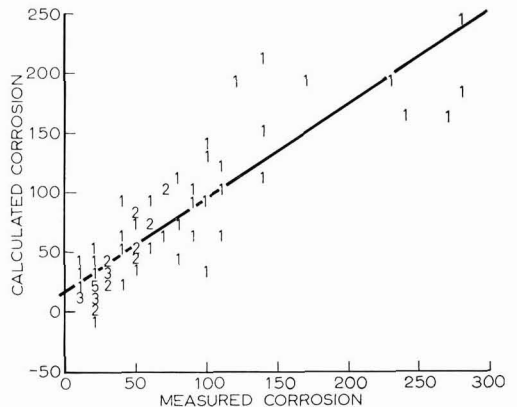


Fig. 4. Relationship between calculated and measured monthly corrosion of unalloyed steel over a two-year period at three corrosion test stations

In this way, the test results from one station can be extrapolated to other localities where the environmental parameters are known or can be evaluated.

Test programme

Ref. 6

Protection systems

The protection systems being tested are divided into six series (Table 3), including a total of 57 systems. All systems are exposed at all the six test stations.

Table 3
Test programme

SERIES

- | | |
|---|---|
| A | Hot-dip galvanised, flame-sprayed zinc, arc-sprayed, flame-sprayed and aluminised aluminium (system A1-A9). |
| B | Hot-dip galvanised, flame-sprayed zinc and arc-sprayed aluminium, top-coated respectively with alkyd, epoxy, chlorinated rubber (1 and 3 coats), vinyl (1 and 3 coats) and polyurethane (system B10-B30). |
| C | Zinc-rich primers: inorganic water reducible (Na-Li), inorganic solvent reducible (ethyl-silicate) (system C31-C32). |
| D | Top-coating of the zinc-rich primers in series C with the same top-coating systems as in series B alkyd, epoxy, etc (system D33-D46). |
| E | Organic zinc-rich epoxy shop-primer top-coated with the same systems as in series B (system E47-E53). |
| F | Tie-coat (basic zinc-chromate vinyl butyral washcoat) plus respectively alkyd chlorinated rubber, epoxy, vinyl (system F54-F57). |

The aim with series A is to compare various metal coatings of zinc and aluminium on steel. Different thicknesses of the coatings are also being tested.

Under the severely aggressive conditions the metal coatings may be top-coated with various paint systems. In series B, various types of duplex systems are being investigated.

Zinc-rich paints have been widely applied during recent years⁹. In series C two zinc-rich primers without top-coating are investigated, and in series D the same zinc-rich primers top-coated with the systems in series B are investigated. The purpose is partly to compare zinc-rich paints (plus top-coating) with metal coatings (series A), and partly to investigate top-coating for zinc-rich paints.

Also included in the test programme are some paint systems on bare steel (series E and F), although these systems will have less resistance than the duplex systems.

Test panels

The test panels being metallised/painted are untreated unalloyed carbon steel with dimensions 150 × 100 × 1.5 mm.

Types of paints

The paints tested are proprietary paints, chosen by the Working Group of the project, and the identity of these paints will not be published. However, the paints are analysed in the laboratory and the analytical results will be given.

Painting of test panels

The panels have been painted according to the manufacturers' specifications with respect to coating thicknesses, drying conditions *etc*. The temperature during painting was 20°C and the relative humidity did not exceed 70 per cent.

Scratches in the coating

The life time of a coating is very often limited by the occurrence of scratches and other damage. Because of this scratches down to bare steel have been made in all the panels. The scratches which are parallel to the short edge of the panel have been cut on both sides of the panels. The corrosion on the damaged and the undamaged parts of the panels will be evaluated separately.

Panels for reference

For each system ten extra panels are prepared and stored in the laboratory.

These panels will be used as references when evaluating the exposed panels, and also they can be used for short-time testing in the laboratory.

Programme of evaluation

Panels will be evaluated in the field and in the laboratory after 1.5, 2.5 and 4.5 years of exposure. In addition, panels will be left for further exposure for any desired period, say 8, 16 years *etc*. The first results will be available in summer 1978.

Parallel to this exposure programme, panels of unalloyed steel and pure zinc are exposed for successive quarters of the year on all stations to determine the corrosiveness of the climate.

Acknowledgment

This testing is a co-operative research programme between the participants listed in Table 4. The project is co-ordinated by the Norwegian Institute for Air Research, who gratefully

Table 4
Project participants

Norzink A/S
Metalliseringsverket/Olsen & Borge A/S
A/S Jotunggruppen
A/S Valvoline Oil
A/S Nodest Industrier
Waardals Kjemiske Fabrik
Alcro Carboline
Stabil-Alna
A/S Monopol Maling- og Lakkindustri
A/S Elkem Spigerverket
Sønnichsen Rørvalseverket A/S
The Norwegian Water Resources and Electricity Board
The Norwegian Road Department/Bridge Division
The Norwegian Telecommunication Administration
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The Engineering Research Foundation at the Technical University of Norway/Corrosion Centre
The Ship Research Institute of Norway
Det norske Veritas/Engineering Service Division
International Lead Zinc Research Organization

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[Received 15 March 1977]

Discussion at Eastbourne Conference

MR A. F. SHERWOOD said he had noticed in one of Dr Haagenrud's slides that he was using a rather unusual damage pattern on his panels. He was using a horizontal rather than the normal diagonal scratch, and also pointed out that it appeared to be tapered. He asked if this taper was deliberate and what was the thinking behind using the horizontal scratch rather than the normal pattern.

DR HAAGENRUD said that the apparent tapering shown on the slide was not intentional and that it was, in fact, much more regular and it was a poor slide. Regarding the type of scratch used on the test panels, Dr Haagenrud said that the horizontal scratch had been decided upon after consultation with the paint manufacturers and that there was a scratch both on the front and on the reverse sides so that an indication of the effect of being washed by the rainfall or being sheltered from it would also be gained. He pointed out that air pollutants would accumulate on the scratches on the reverse side and create a different corrosion climate.

MR E. H. WATSON said that he was pleased to see that Dr Haagenrud had taken cognisance of the difference in the environment on the underside of the test panels as opposed to the washed surface. However, he was not convinced that the particular design of the racks would give all the answers on this point. He asked if any further information on the actual paints used would be available rather than simply the analytical data. He questioned whether all the paint systems were of equal thickness and if the pigmentation was standardised—he wondered whether any included micaceous iron oxides which was commonly used in the UK. He suggested that if more data was given on the paints used then the results of the tests would become much more useful.

DR HAAGENRUD replied that the thickness of the paints had been based upon the recommendations of the producers of the paints and the thickness and the variance in the thicknesses had been measured and that this information had been correlated in Norway and a report was being written at that time. They had decided not to publish the names of the paints used, but only the analytical data; however, he assured Mr Watson that they were paint systems which are in everyday use and that complete analyses would be available.

DR L. A. VALENTINE pointed out that Dr Harrison, one of the leaders in the field of corrosion, was very keen on the theory that the presence of ammonia is a crucial factor in corrosion and he noticed this was one of the measurements Dr Haagenrud had made in the various tests. He asked if any

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correlations had been established on the influence of ammonia, either directly or as an interaction with any of the other impurities present, such as SO₂ or the pH. Secondly, he asked Dr Haagenrud how much of the corrosion in Norway he attributed to atmospheric effluents coming across the North Sea.

DR HAAGENRUD said that the correlation between the ammonia and rate of corrosion in the tests was of the order of 0.2 and as most of the ammonia was transported in the air in the form of a sulfate, it is strongly correlated with the amount of sulfate in the air. As regards the transport of pollutants across the sea to Norway, he said it was clear after about 4 or 5 years' research that this was a very considerable amount. It appeared that only 20-25 per cent of the total pollutants in the air actually originated in Norway, but clearly this varied from site to site. Dr Haagenrud pointed out that this problem was worst in the south of Norway and they had reason to believe that corrosion on their hydro-electric power plants, caused by pollutants dissolved in the water, was on the increase.

MR T. R. BULLETT, referring to Dr Haagenrud's remark that it took a long time, sometimes years, to establish an equilibrium corrosion rate for steel, suggested that perhaps it was more important to determine the initial corrosion rate. He gave an example of the low alloy steels which have a distinctly lower equilibrium corrosion rate, without there being any evidence that they were easier to protect or had particularly low initial corrosion rates.

DR HAAGENRUD said he agreed with Mr Bullett on this point. He pointed out that very often the corrosion rates in the first three months were a very good indication of the aggressiveness of the environment and that it is this aggressiveness that must be taken into consideration when a material or a paint protection system is chosen. The equilibrium corrosion rates were, of course, also very useful in estimating the minimum life times. He pointed out that in practice structures did not stand in the open without protection, but were covered with some protective system and so the equilibrium corrosion rate was important.

MR D. J. R. MASSY asked if Dr Haagenrud could give the units used in the term X3 in his corrosion rate equation, the concentration of strong acid in the precipitation.

DR HAAGENRUD said that he was not sure what the units were, but that obviously it was very important and he would have the units forwarded for inclusion in the paper when it appeared in the *Journal* (now included in paper).

Ultraviolet light curing: some benefits and recent advances*

by M. A. Parrish

Ward Blenkinsop & Co. Ltd. Fulton House, Empire Way, Wembley, Middlesex HA9 0LX

Summary

A brief review of the status of World energy supplies is given. Attention is drawn to the effect of exponential increase in energy usage-rate on reserves, and the necessity for conservation is indicated. In the field of surface-coatings and printing inks, quantitative data are presented to show that the technique of ultraviolet light curing can result in significant energy savings.

Keywords

Processes and methods primarily associated with drying or curing coatings

ultraviolet curing
infrared drying
photopolymerisation
pollution control
photoinitiation

manufacturing or synthesis

photoinitiation

Although the technique is becoming widely accepted in various areas of application, the curing of thick pigmented films still gives some problems. Some ideas are given concerning the solution of these problems, involving the use of a new photoinitiator-photo-activator combination.

Miscellaneous terms

cost
operation cost

Durcissement par rayons ultra violets: Quelques avantages et améliorations récentes

Résumé

On donne un bref aperçu de la situation actuelle des sources mondiales d'énergie. On fait remarquer l'effet sur les réserves qu'exerce la croissance exponentielle de la cadence de consommation d'énergie et l'on indique la nécessité de les conserver. Dans le domaine de revêtements de surface et d'encre d'imprimerie, on présente des données quantitatives qui démontrent que la technique de durcissement par rayons ultra violets peut offrir des économies

importantes en énergie. Bien que la technique devienne largement utilisée dans divers domaines, le durcissement des épaisses couches pigmentées met en évidence encore quelques problèmes. On propose certains idées en ce qui concerne la solution de ces problèmes, grâce à l'emploi d'une nouvelle combinaison de photo-amorceur et de photo-activateur.

Härtung mit Ultraviolettem Licht: Einige Vorteile und neue Fortschritte

Zusammenfassung

Eine kurze Übersicht des Standes der zur Verfügung stehenden Weltenergie wird gegeben. Auf die Auswirkung exponentionaler Steigerung des Energieverbrauchs auf Reserven wird aufmerksam gemacht, und auf die Notwendigkeit damit sparsam umzugehen wird hingewiesen. Für das Lackund Druckfarbengebiet werden quantitative Werte vorgelegt, um zu zeigen, dass Härtung mittels der Ultraviolet-Lichthärtungstechnik bedeutende Energieerspar-

nisse ergeben kann. Obwohl diese Technik für verschiedene Anwendungsgebiete mit offenen Armen aufgenommen wird, ist das Härten dicker pigmentierter Filme noch problematisch. Einige die Lösung dieser Probleme betreffende Ideen werden vorgelegt, welche den Einsatz einer neuen Photoinitiator-Photoaktivator-Kombination einschliessen.

Energy and Fuel Reserves

Refs. 1-6

At a Conference concerned with the conservation of energy and materials it is appropriate to emphasise the dependence of an industrial society on energy availability.

Figure 1 shows¹ the relationship between energy consumption and gross national product (GNP). There is clearly a relationship between the two although this is not precise, as variations can occur due to extent of energy-intensive industries and to the efficiency of energy-usage. At present, however, it may be said that energy availability is strongly linked with material living standards.

The short-term crises in the early 1970s, concerning coal and oil, underline the fact that energy supplies are becoming increasingly susceptible to man-made politico-economic pressures, but it is of greater importance to understand the status of energy availability in absolute terms:

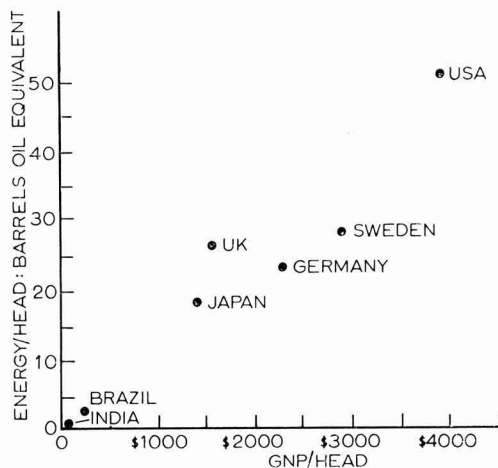


Fig. 1 Relationship between energy consumption and GNP

*Paper presented at the Association's Biennial Conference held at the Grand Hotel, Eastbourne, Sussex from 16-19 June 1977

If a term Q is defined as 10^{18} BTU (or 2.93×10^{14} kWh), then it has been estimated² that from the beginning of the Christian era until the mid-19th century, mankind used about eight Q of energy. In the 19th century four Q were consumed, and assuming growth-rate in energy-usage typical of the 1960s then the requirement in the 21st century would be 100-400 Q . Against this, one can compare the World reserves of fossil fuels (23 Q) and nuclear fuels (130 Q). A more recent study³ indicates a value of 20.9-21.9 Q as the value of the World's supply of proved and recoverable reserves. Estimated total remaining recoverable fossil fuel reserves are 107.5-122.5 Q . To put these figures in perspective, consider that in 1963 hydroelectric plants in the United States² produced 0.0006 Q , *ie.* a rate of 0.06 Q per century, and that the total solar input to the Earth is approximately 5200 Q per year⁴.

A forceful reminder of the finite nature of fossil fuel reserves has been given by ESSO⁵—if oil consumption grew at five per cent per year continuously from this time onwards, the total amount consumed within the next 500 years would be equivalent to the total cubic capacity of the Earth.

A study of the interaction between such vital factors as reserves, population, pollution *etc.* has been conducted by Meadows *et al* for the Club of Rome's project on the predicament of mankind⁶. Their assessment of the situation concerning fossil fuels is shown in Table 1.

With a sustained annual growth-rate in usage in the order of 3.5 per cent, therefore, it is possible that virtual depletion of natural gas and petroleum reserves could occur by the end of this century or in the first half of the next century.

Any improvement in process technology which also involves energy saving is thus particularly welcome: the ultraviolet

light (UV)-curing of inks and coatings is an example of such a process.

Indirect energy conservation with UV-curing

The production of raw materials and materials of construction involves the expenditure of energy, therefore, economy in the use of materials represents, indirectly, the saving of energy. Unlike conventional inks and surface coating formulations, UV-curable systems contain no volatile solvent to be lost on drying. Instead, viscosity modification is achieved by the use of reactive diluents such as the multifunctional acrylates, which are subsequently involved in the polymerisation process.

In many cases, the equipment used for UV-curing is more compact than the corresponding thermal unit. For example, a UV oven for metal can-coating can occupy a third of the space occupied by an oven powered by natural gas⁷. This could imply a smaller usage of constructional materials.

Direct energy conservation with UV-curing

Refs. 8-14

The use of UV-curing in certain areas of application will result in direct energy saving. This is demonstrated by the following quantitative data⁸:

(a) Printing inks

Direct operational comparisons are possible in cases where UV-curing has replaced thermal curing of heat-set inks. Two such comparisons (which refer to web-offset presses) are shown in Table 2:

Table 1
Fossil fuel resources

Resource	Known global reserves (a)	Static index (b)	Projected average growth rate (% per yr) (c)	Exponential index (yrs) (d)	Exponential index (yrs) "times 5" (e)
Coal	5×10^{12} tons	2300	4.1(f)	111	150
Natural gas	1.14×10^{15} cu. feet	38	4.7	22	49
Petroleum	455×10^9 barrels	31	3.9	20	50

(a) Source: US Bureau of Mines "Mineral Facts and Problems—1970" (Washington D.C., Government Printing Office 1970).

(b) The number of years known global reserves will last at current global consumption (from ref. (a)).

(c) From ref. (a).

(d) The number of years known global reserves will last with consumption growing exponentially at the annual rate of growth in column 4.

(e) The number of years that 5 times known global reserves will last with consumption growing exponentially at the average annual growth rate (column 4).

(f) US Bureau of Mines contingency forecasts based on the assumption that coal will be used to synthesise gas and liquid fuels.

Table 2
Comparison of energy consumption

Printers	Rate of energy consumption		Approx. cost at current UK prices*	
	Thermal curing (Gas-fired ovens)	UV curing	Thermal	UV
Dunfermline Press	1×10^6 BTU/h	30 kW	£1.66/h	60p/h
Telegraph Press, Harrisburgh, USA	8×10^6 BTU/h	150 kW	£13.28/h	£3.00/h

*gas 16.6p per therm electricity 2p per kWh

(b) Wood Finishing

Table 3 shows the energy requirements for four different curing methods, and refers to wood-fillers cured to the extent of being "just sandable". The formulations used in each case were among the fastest curing available for that particular method⁹.

Table 3
Energy requirements

Curing method	Energy required per unit area of material. kJ/m ²
Infrared	1,600
Radiofrequency	330
Ultraviolet	64
Electron beam	30

Although the electron beam process is the most efficient in terms of energy consumption, it is considered to be competitive only in finishing operations which coat more than 20 000 000 feet²/year because of the high capital cost¹⁰.

In an earlier comparison of UV-curing of a polyester formulation versus infrared curing of a urea-modified alkyd¹¹, power requirements were given as 100 kW and 250 kW respectively for a dry coating thickness of 50 micron and a line-speed of 60 feet per minute. The width of particle board being treated was unstated but assuming that this was 4 feet, energy consumption per unit area of material can be shown to be 269 kJm⁻² by UV and 673 kJm⁻² by IR. The apparent discrepancy between the data given in references (10) and (11) could result from differences in formulation type, coating thickness, or criteria for determining when satisfactory cure has been achieved.

(c) Metal Finishing

An approximate estimate of comparative energy consumption of UV versus thermal curing may be derived as follows: in the case of UV curing, consider the energy consumed per unit area of substrate, when the latter passes under a 200 W per inch UV tube at 100 feet per minute. This can be shown to be 15.5 kJm⁻². This can be compared with the energy required to raise the temperature of 0.02 cm steel sheet (density approximately 7.9 g cm⁻³, specific heat 0.1 cal g⁻¹°C⁻¹) from 25°C to 200°C, the latter being taken as a typical temperature required for thermal curing. The energy required in this case can be shown to be 116 kJm⁻². This represents an estimate of the minimum energy required for a typical thermal curing cycle, since the value does not include the efficiency of conversion of input energy to heating of the sheet, or the heat required to maintain the temperature for the duration of the curing cycle.

Comparison of the thermal and UV values indicates that at least seven or eight 200 W per inch UV tubes would be required, for a line speed of 100 feet per minute, before the energy consumption approached that required for thermal curing. Experience in the metal decorating field indicates that one or two UV tubes suffice for a line speed of approximately 200 feet per minute and film thickness approximately 12 microns. In this case, therefore, the energy requirement for UV-curing (Energy_{uv}) appears to be considerably lower than that for the corresponding thermal curing process (Energy_{thermal}).

In order to compare energy consumption in other areas of metal finishing consideration must be given to: (i) substrate

thickness; and (ii) film thickness and pigmentation level. Energy_{thermal} will increase in proportion to substrate thickness assuming that the whole of the substrate has to be heated to the curing temperature, whereas Energy_{uv} will be independent of substrate thickness. Conversely, Energy_{thermal} will be practically independent of film thickness and pigment level, whereas Energy_{uv} will increase with increase in these two parameters.

Some idea of Energy_{uv} for relatively thick, pigmented films may be obtained from the data given¹² in Ger. Offen. 2 514 249, in which UV-curing using two different sources consecutively (metal halide doped lamp emitting mainly 350-460nm, followed by high pressure mercury-vapour lamp emitting mainly 230-400nm) is described. A composition containing 17 per cent by weight titanium dioxide 35-40 micron thick on tinplate, gave a good cure after 10 seconds exposure to the halide lamp (2227 Wm⁻²) followed by 50 seconds exposure to the mercury-vapour lamp (1350 Wm⁻²). Thus total energy required = 90kJ m⁻².

This value is of the same order as that obtained using the data of North¹³ for curing a 25 micron paint film on a coil coating line 1.2 metres wide. For a line speed of 20 metres per minute, the power requirement for UV-curing is given as 50 kW (or 125 kJm⁻²). The corresponding power requirement for thermal curing in gas-fired ovens is given as 2900 kW (or 7250 kJm⁻²). In another publication, North *et al*¹⁴ quote Energy_{uv} equal to 400 kJm⁻² compared with an average Energy_{thermal} of 877 kJm⁻² for a range of thermal curing formulations. These figures include overall thermal efficiencies of 70 per cent gas-fired ovens and 28 per cent for electricity.

The problem of thick pigmented coatings

Refs. 15-18

As stated above, Energy_{uv} will increase with increase in film thickness and level of pigmentation, mainly because the pigment will tend to absorb or reflect incident UV light. In both cases the availability of UV radiation to the photo-initiator system will be diminished.

One of the most important pigments used in relatively thick films (up to, say, 50 microns) is titanium dioxide, used, for example, in decorative coatings on metal cans and board. The UK production of conventionally-cured white coatings for metal decorating is currently in the order of 1000 tons per annum. The strong desire in the coatings industries to change to UV-curable formulations underlines the importance of finding a suitable photoinitiator system for use with titanium dioxide.

Titanium dioxide exhibits high reflectivity throughout the visible range of the spectrum (which accounts for its excellent hiding characteristics). At about 400 nm, reflectivity diminishes and absorption increases until it reaches a maximum at around 350-360nm. The region 350-400nm represents a transition between reflection and absorption of light by titanium dioxide, and is therefore optimal with regard to light availability to a photoinitiator.

Figures 2 and 3 show the spectra for titanium dioxide and 2-chlorothioxanthone. It can be seen that 2-chlorothioxanthone (CTX) exhibits an absorption peak at 385nm and is therefore a particularly suitable photoinitiator for white-pigmented coatings¹⁵.

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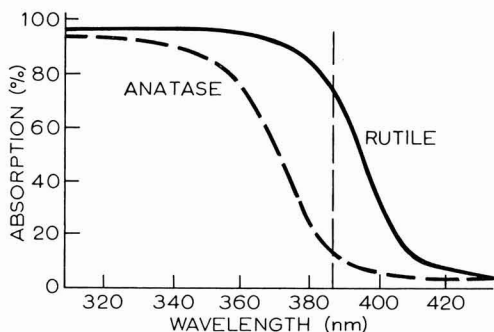


Fig. 2. Absorption spectra for rutile and anatase titanium dioxide

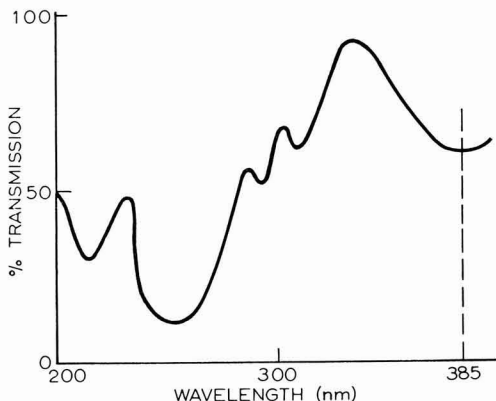
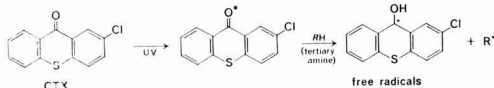


Fig. 3. Transmission spectrum for 2-chlorothioxanthone

Absorption of light by CTX results in the promotion of the ketone group to a chemically reactive excited state. In the presence of a hydrogen donor such as a tertiary amine, the excited-state ketone group abstracts hydrogen, and this results in the formation of free radicals. These free radicals can then initiate polymerisation of the resin binder system:



Excellent results may be obtained when ethyl 4-dimethylaminobenzoate (EPD) is used as the tertiary amine photoactivator in conjunction with CTX:

Films of 25 microns thickness consisting of an acrylated urethane resin¹⁶ containing 40 per cent by weight of titanium dioxide¹⁷ together with CTX and a photoactivator were irradiated for 0.075 seconds in a single lamp "Minicure" oven¹⁸. The properties of the cured films were tested by finger touch and by pencil hardness (2B (softest) to 6H (hardest)), with results as shown in Table 4.

The results¹⁹ show that by weight, EPD is six times more efficient as a photoactivator for CTX than the next best, N,N-dimethylaminoethanol, and that the colour of the photocured film is less yellow.

Physiological Aspects of CTX and EPD

A considerable additional advantage to be gained by using CTX and EPD is their lack of adverse physiological effects.

CTX. The acute oral toxicity is low, the LD₅₀ for mice being greater than 1 gram per kilogram body weight. The dermal LD₅₀ for rats is greater than 0.5 gram per kilogram body weight. CTX has been subjected to mutagenicity testing by the Ames method and within the context of this method does not have carcinogenic potential.

EPD. The acute oral toxicity is also very low, the minimum lethal dose for mice being greater than 4 grams per kilogram body weight. EPD has been used for many years as a topical sunscreen agent for cosmetic use, with no evidence of adverse effects.

Conclusion

The conservation of energy reserves is becoming vitally important in an industrial society. UV-curing provides surface coating technologists with a powerful new tool to enable them to contribute towards energy economy.

A safe and effective answer to the problem of UV-curing thick pigmented coating formulations containing titanium dioxide may be found in the combination of 2-chlorothioxanthone and ethyl 4-dimethylaminobenzoate.

[Received 5 April 1977]

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Table 4
Properties of cured films

% w/w of CTX	Photoactivator/% w/w	Feel	Hardness	Appearance
0.2	EPD 2.0	Dry	> 6H	White gloss finish
1.2	N,N-Dimethylaminoethanol/2.0	Dry	> 6H	Pale yellow gloss finish
1.2	N,N-Dimethylaniline 2.0	Dry	> 1H < 2H	Pale yellow gloss finish
1.2	Ethyl benzoate 2.0	Dry	> 2B < HB	White gloss finish

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Discussion at Eastbourne Conference

MR F. ARMITAGE said that Mr Parrish had claimed that the use of CTX and a photoactivator gave six times the normal efficiency (*ie* one-sixth of the curing time) with a particular resin and monomer combination. He asked if this new combination of photosensitiser and accelerator gave the same increase of efficiency with any resin monomer system or only with this particular combination.

Referring to Table 4, MR PARRISH said the increase in efficiency obtained by the new combination was based on the amount of photoactivator required. In other words, one-sixth of the quantity of CTX could be used. Mr Parrish said he had only looked at two or three other resin monomer systems, but the same order of advantage had been achieved with each, although it was not exactly six times as efficient.

Mr Armitage asked if he thought it was a fairly universal application.

Mr Parrish replied that he did.

DR G. D. DIXON pointed out that by using photosensitisers, such as CTX, the wavelength needed for curing was moving

away from the 360nm, at which the traditional mercury lamp was strongest, towards the red end of the spectrum. He wondered whether special lamps were available that were strongest in the 400 nm region as he was concerned with the efficiency and speed of cure.

MR PARRISH said that in experiments he had used a standard mercury vapour lamp, and although this lamp was strongest at the shorter wavelength, the range of wavelengths emitted was sufficient to cure effectively at 400nm. He stated that lamps were available giving other wavelengths, but that this system worked perfectly well with the standard medium pressure mercury vapour lamp.

Dr Dixon asked whether the same speeds of reaction would be obtained despite the lower energy being used.

Mr Parrish stated that it is not possible exactly to equate the concentration of wavelengths from the lamp with the efficiency of cure, because other factors such as the reactivity of the radicals produced, the effect of resin, pigment and other additives on these radicals could also affect the rate of cure. He repeated the point that the standard mercury lamp had been used for this work with adequate results.

Analysis of the constant-rate period of ink drying*

By H. Hardisty

School of Engineering University of Bath, Claverton Down, Bath BA2 7AY

Summary

High velocity impinging air jets are commonly used to accelerate evaporative ink drying on rotary presses for the packaging and converting industry. To provide data for dryer designers a programme of research has been implemented to study the heat and mass transfer processes which underlie the drying of thin ink films. The heat transfer situation under impinging jets is outlined and some experimental results are presented. A non-

contact infra-red technique for continuously monitoring the ink drying process is described and drying curves for an ink based on a single solvent (4-Methyl-2-Pentanol, MIBC) are presented. The constant rate sections of the IR curves are analysed and experimentally determined drying times are compared with those calculated using established heat and mass transfer theory.

Keywords

Types and classes of coatings and allied products
printing ink

Processes and methods primarily associated with drying or curing of coatings

solvent evaporation
forced drying
air drying

Properties, characteristics and conditions primarily associated with coatings during application

drying rate

L'analyse de la période de séchage à vitesse constante des encres d'imprimerie

Résumé

Aux industries de conditionnement et de transformation on se sert très fréquemment des jets incidents d'air à grande vitesse disposés sur les presses rotatives, pour accélérer le séchage par évaporation des encres d'imprimerie. En vue d'assurer au personnel chargé de l'évolution des siccatis, on a effectué un programme d'études sur les processus de l'échange thermique et du transfert de masse qui sont au fond du phénomène du séchage des feuillets minces d'encres d'imprimerie. Dans cet exposé on trace les grandes lignes du processus de l'échange thermique qui se produit devant les jets incidents et l'on présente certains résultats expérimentaux. On

décrit une technique à l'infra rouge, qui n'entraîne aucun contact avec le feuil d'encre, pour surveiller d'une manière continue le processus du séchage d'encre, et l'on présente les courbes de séchage à l'égard d'une encre basée sur un seul solvant (4-méthyle-2-pentanol, MIBC). On fait une analyse des parties des courbes à l'infra rouge où il s'agit de séchage à vitesse constante et l'on compare les périodes de séchage déterminées par expérimentation auprès de celles qui ont été calculées selon la théorie établie pour l'échange thermique et le transfert de masse.

Analyse der Konstanten—Geschwindigkeitsperiode der Druckfarbentrocknung

Zusammenfassung

Üblicherweise werden zur Beschleunigung der durch Verflüchtigung auf Rotarypressen für die Verpackungs- und Weiterverarbeitungsindustrien trocknenden Druckfarben Luftstrahle, die mit grosser Geschwindigkeit auftreten, angewandt. Um Zahlen für das Entwerfen von Trocknern zu beschaffen, wurde ein Forschungsprogramm durchgeführt, um Wärme- und Massentransferprozesse, welche der Trocknung von Druckfarbenfilmen zugrunde liegen, zu untersuchen. In der Abhandlung wird die Wärmeübertragungssituation unter auftreffenden Strahlen kurz aufgezeigt, sowie

werden einige experimentelle Resultate vorgelegt. Es wird eine Nicht-Kontakt Infrarottechnik beschrieben für ununterbrochene Überwachung des Druckfarbentrocknungsprozesses, und es werden auch Trocknungskurven vorgelegt für eine, auf einem einzigen Lösungsmittel (4-Methyl-2-Pentanol, MIBC) basierende Druckfarbe. Die konstanten Geschwindigkeits-Sektionen der IR Kurven werden analysiert, und experimentell bestimmte Trockenzeiten werden mit Hilfe der gebräuchlichen Wärme- und Massentransfertheorie berechneten verglichen.

Introduction

Ref. 1

On most modern high speed rotary presses in the printing and packaging industry, the ink coating is dried by the physical process of evaporation. Drying is accelerated by using nozzles, with their axes normal to the direction of the moving coated web, to direct jets of hot air on to the solvent laden coating. Impinging jets of this type are used, rather than jets blowing parallel to the surface, because of the high rates of heat and mass transfer which occur in the primary stagnation region where the jet axis intersects the moving surface.

The nozzles which emit the jets may be of any shape, but most commonly are either long (one-dimensional) slots or circular (axi-symmetric) holes. In practice, a bank of nozzles may be supplied with high pressure air from a common

plenum chamber. After interaction with the ink, the air and its burden of solvent vapour must be removed from the vicinity of the web by a suitable extraction system. In practice plenum chamber, nozzles and extraction ducts are often combined into a unit dryer box.

The high cost of rotary presses for the converting industry provides incentive to run them at the highest practical throughput (web speed). Inter-colour drying on a multi-colour press may present the dryer designer with a particularly difficult problem because of space limitations between colour units. Alternatively, the specification of a low value for "retained solvents" may entail that final drying requires critical appraisal. Even to-day, final dryness at the press is estimated subjectively by touch or smell or by manifestations of incomplete drying such as blocking or pick-off. For purposes of quality control, gas chromatography may be used to monitor the retained solvent; although accurate, this

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method is retrospective and reveals nothing of the drying process as a whole.

The dryer designer's task is a difficult one in that he must match a multi-variable solution to a multi-variable problem. The designer must specify size, shape, pitch and distance from web of the nozzles: temperature and velocity of the air; air supply and extraction system: source of energy *etc.* To do this the designer must have detailed information on substrate, ink and solvents, ink thickness and coverage and web speed. The cost of heating the drying air must be scrutinised. Fan power rises roughly in proportion to the cube of air velocity and high jet velocities may lead to unacceptably high noise levels at the fans.

The research into drying at Bath, by Black and Hardisty¹, can be sub-divided into two complementary lines of investigation. The first is concerned with the effect of different nozzle arrangements and air conditions on the surface heat transfer coefficient. In the second, an infra-red technique is used to obtain a continuous record of ink solvent content throughout the drying process.

Notation

A_s	Surface Area	m^2
B	Slot (nozzle) width	mm
C	Concentration	Kg/m^3
D	Diffusion coefficient	m^2/s
h_{fg}	Enthalpy of evaporation	J/Kg
h	Surface heat transfer coefficient	$W/m^2 \text{ } ^\circ K$
h_p	Surface mass transfer coefficient	m/s
k	Specific thermal conductivity of air	$W/m \text{ } ^\circ K$
L	Characteristic length (in Re)	m
L	Ink film thickness	micrometre
Le	Lewis number $\frac{k}{\rho DC_p}$	
M	Molecular weight	
\dot{m}_D	Mass transfer rate	Kg/s
Nu	Nusselt number $\frac{hB}{k}$	
p	Pressure	$N\text{-}m^2$
Pr	Prandtl number $\frac{\nu C_p}{k}$	
\dot{Q}	Rate of energy transfer	w
$RMOL$	Universal gas constant	$kJ/kg \text{ mole } ^\circ K$
Re	Reynolds number $\frac{VB\rho}{\mu}$	
Sc	Schmidt number $\frac{\nu}{D}$	
Sh	Sherwood number $\frac{VB\rho}{D}$	
T	Temperature	$^\circ C$
t	Time	s
V	Air velocity	m/s
V	Infragaugue output signal	volt
x	Lateral distance from stagnation point	m
x_n	Distance between adjacent nozzles	
Z	Vertical distance from nozzle outlet to plate	m
Properties of air or vapour		
μ	Viscosity	$Kg/m \text{ s}$
ρ	Density	Kg/m^3
C_p	Specific heat at constant pressure	$J/Kg \text{ } ^\circ C$
Suffices		
A	Air	
S	Ink Surface	
E	Nozzle exit	
o	Stagnation point	

Evaporative drying—background

Ref. 2

The drying process is most easily characterised and described in terms of three empirical graphs, Figure 1. From experiments on the forced convective drying of thick slabs of substances, such as wet clay, Sherwood² found that initially the slabs dried at a constant rate and subsequently at a diminishing rate. In the initial period, the rate of drying is entirely controlled by the fluid dynamic state of the drying air. The drying rate in the final period, which may take up a significant proportion of the total drying time, is limited by the rate at which liquid can pass through the solid to the free surface.

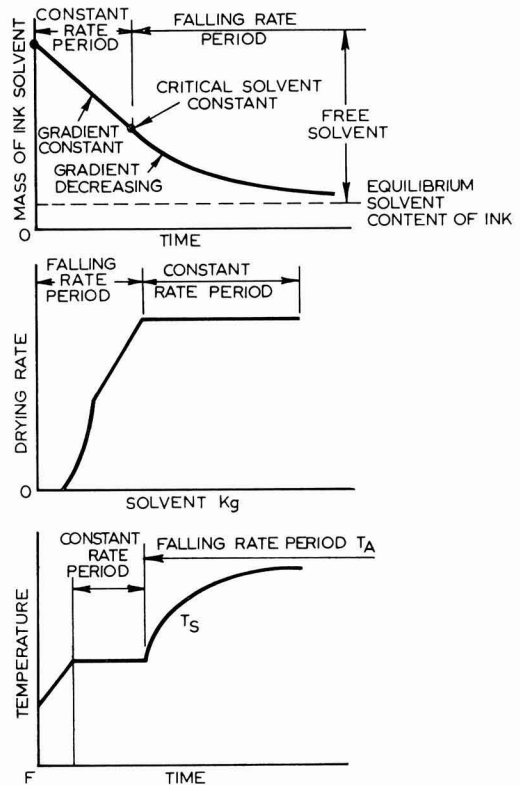


Figure 1. Characteristic drying graphs

The combined heat and mass transfer processes which occur during the constant rate period may be described as follows. By virtue of the temperature difference which exists between the hotter drying air and the colder ink surface, heat is transferred to the surface to supply energy (latent heat, h_{fg}) to evaporate the solvent. In an analogous manner, the concentration difference which exists between the saturated vapour condition at the free surface and the lower vapour concentration in the drying air, is the driving force for mass (solvent) transfer away from the free surface. Thus heat is transferred in one direction, whilst simultaneously, mass is transferred in the opposite direction.

Provided that liquid can pass through the solid sufficiently quickly to maintain an equilibrium condition at the free

surface, then liquid will evaporate from this surface at a constant rate. Evaporation proceeds as if from a free liquid with its surface at the wet-bulb temperature. In this situation, the rate of evaporation of a particular solvent is largely dependent upon the values of the surface heat and mass transfer coefficient.

Heat transfer—general

When a fluid is in turbulent motion past a solid surface, the fluid adjacent to the wall is retarded by viscous and turbulent drag and at the wall the fluid velocity is zero (the no-slip condition). This layer of retarded fluid is termed the boundary layer. Even though flow in the outer region of the boundary layer is turbulent, in the region immediately next to the wall the flow is essentially viscous. Because heat must be transferred across this viscous layer entirely by molecular conduction, it often constitutes the principal resistance to heat transfer. Indeed, it is conceptually useful to picture the fluid adjacent to the surface as a stagnant film whose "effective" thickness is such as to offer the same resistance to heat transfer as does the real boundary layer.

Steady state heat transfer across a turbulent boundary layer to a solid surface may be expressed by the rate equation:

$$\dot{Q} = h A_s (T_A - T_s) \dots\dots\dots(1)$$

For a given value of the temperature difference ($T_A - T_s$), h is dependent upon both the effective thickness and the thermal properties of the stagnant film.

$$h = f(V, L, \rho, \mu, C_p, k, \text{shape of surface})$$

It is usually necessary to resort to experiment to determine actual values of h . Forced convective heat transfer data may be expressed in terms of non-dimensional groups as follows:

$$Nu = C Re^a Pr^b \dots\dots\dots(2)$$

where C , a and b are numerical constants associated with a surface of a particular geometrical shape.

Heat transfer under an impinging air jet

Refs. 3, 4

The flow field under an impinging air jet is shown in Figure 2. At the nozzle outlet the turbulence level of the jet is relatively low. However, due to the intensive mixing in the shear layers on either side of the potential core the turbulence level on the jet centre-line increases and reaches a maximum at roughly 8 slot widths from the nozzle exit, Gardon⁴. The position of this turbulence maximum is an important factor in the nozzle to plate spacing, Z/B , for maximum heat transfer. The high static pressure in the primary stagnation region deflects the jet; the subsequent flow along the solid boundary is termed a wall jet. The point where two adjacent jets meet, the secondary stagnation point, is a region of increased turbulence which in turn causes some enhancement of the heat transfer coefficient.

The experimental heat transfer rig shown diagrammatically in Figure 3, essentially consists of a jet of air at ambient temperature directed down on to a horizontal aluminium plate. The temperature of the plate is maintained at 100°C throughout by means of a steam jacket fitted to its under surface. Heat transfer coefficients are measured by means of a small "Gardon"³ type fluxmeter, positioned so that its

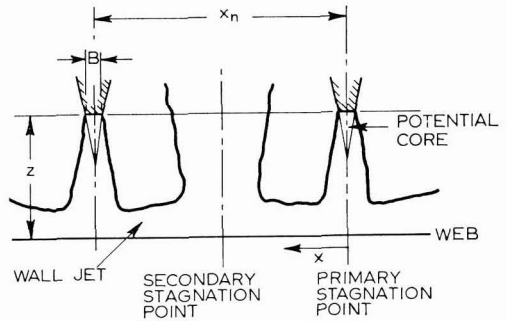
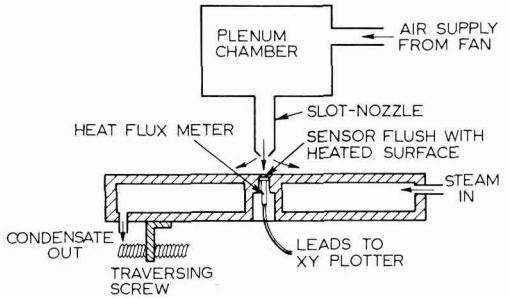


Figure 2. Flow field under an impinging air jet

sensor (3mm diameter) is flush with the heat surface. The variation of heat transfer coefficient is recorded by connecting the electrical output of the probe to the vertical axis of an XY plotter. The probe and plate are traversed under the jet with the recorder horizontal axis set to time base.



'GARDON' TYPE HEAT FLUX METER

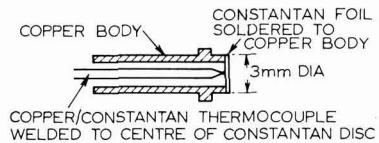


Figure 3. Heat transfer research rig

Figure 4 shows the x -wise variation of heat transfer coefficient under a slot jet for various values of the jet exit Reynolds number, $Re_E \left(\frac{V_E B \rho}{\mu} \right)$. The high values of h directly beneath the jet are apparent. The following correlation was obtained from these results by logarithmic plotting

$$Nu_o = 0.178 Re_E^{0.58} Pr^{1/3} \dots\dots\dots(3)$$

Nu_o = Nusselt number at the primary stagnation point.

Figure 5 shows the effect of nozzle to plate distance, Z/B , on heat transfer coefficient. The maximum value of the stagnation coefficient is seen to occur when Z/B is roughly 6, but this will depend upon nozzle shape and initial turbulence level.

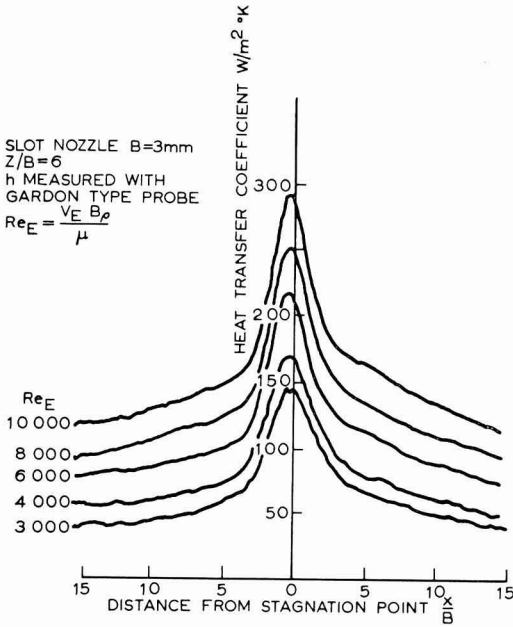


Figure 4. Effect of Re_E on heat transfer coefficient

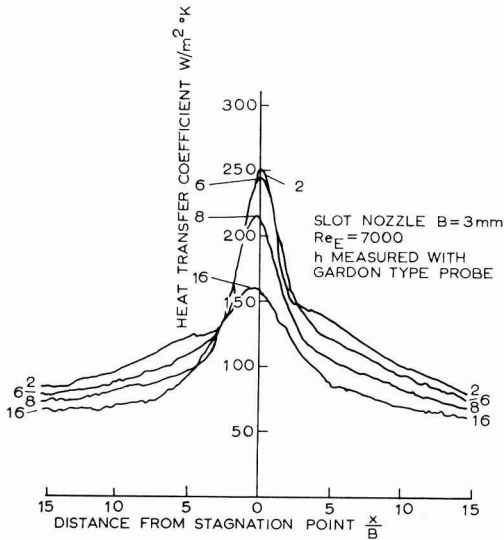


Figure 5. Effect of Z/B on heat transfer coefficient

Mass Transfer

Refs. 5-8

The same fluid dynamic processes which cause heat to be transferred across a temperature difference also cause mass to be transferred across a concentration difference. Heat and mass transfer are analogous, Sherwood and Pigford⁵.

Invoking this analogy, a mass transfer rate equation can be written, which corresponds to equation 1, as follows

$$\dot{m}_D = h_p A_s (\rho_s - \rho_A) \dots\dots\dots(4)$$

h_p = the surface mass transfer coefficient

ρ = solvent vapour density

Also, by analogy with equation 2, the dimensionless mass transfer relation may be written

$$Sh = C Re^a Sc^b \dots\dots\dots(5)$$

Where the constants C , a and b of (5) are identical with those of (3) provided both equations apply to surfaces of similar shape. Thus by analogy with (3), the mass transfer relation for impinging jet is

$$Sh_D = 0.178 Re_E^{0.58} Sc^{1/3} \dots\dots\dots(6)$$

Constant-rate drying

At equilibrium the surface takes on the wet bulb temperature and the following energy balance equation is satisfied:

$$h A_s (T_A - T_s) = h_p A_s (\rho_s - \rho_A) h_{fg} \dots\dots\dots(7)$$

where ρ_s is the saturated vapour density corresponding to T_s . Assume that $\rho_A = 0$ then:

$$T_A - T_s = \frac{h_p}{h} \rho_s h_{fg} \dots\dots\dots(8)$$

To obtain the ratio h_p/h divide (5) by (7):

$$\frac{h_p}{h} = \frac{1}{\rho C_p} \left(\frac{Pr}{Sc} \right)^{2/3} = \frac{Le^{-2/3}}{\rho C_p} \dots\dots\dots(9)$$

substitute (9) in (8) giving:

$$T_A - T_s = \frac{1}{\rho C_p} Le^{-2/3} \rho_s h_{fg} \dots\dots\dots(10)$$

Relative evaporation (drying) rates

Using (4) and assuming $\rho_A = 0$:

$$\dot{m}_D = h_p A_s \rho_s \dots\dots\dots(11)$$

From (6), assuming fixed values of air flow rate and surface geometry:

$$Sh \propto Sc^{1/3} \dots\dots\dots(12)$$

Assume that at small vapour concentrations the properties of the air/vapour mixture approximate those of pure air, then:

$$h_p \propto D^{2/3} \dots\dots\dots(13)$$

and

$$\rho_s = \frac{p_s M}{R M_o L T_s} \dots\dots\dots(14)$$

where P_s is the saturated vapour pressure corresponding to T_s .

Finally, for a surface at a given temperature

$$\text{Evaporation rate per unit area} \propto D^{2/3} p_s M \dots\dots\dots(15)$$

Equation (15) is consistent with the evaporative index of Gardner⁶ which was based on the stagnant film hypothesis.

Table 1
Relative Evaporation Rate ($M D^{2/3} p$) for some alcohols

alcohol	M	D ($m^2/s \cdot 10^5$)	bar c 20°C	$M D^{2/3} p$	Shell evaporometer (n-butyl acetate = 1)	h_{fg} (J/gm)
methyl	32.03	1.638	0.1266	5.63	4.1	1101
ethyl	46.05	1.249	0.0586	3.13	2.4	854
isopropyl	60.6	1.043	0.0440	2.74	2.2	665
n-propyl	60.6	1.043	0.0193	1.20	1.2	686
sec butyl	74.08	0.909	0.0150	1.11	1.1	561
iso butyl	74.08	0.909	0.0117	0.813	0.85	578
n butyl	74.08	0.909	0.0057	0.396	0.46	590
MIBC	102.11	0.72	0.0028	0.230	0.30	427

In Table 1 the relative evaporation rate of (15) has been evaluated for some of the alcohols. The diffusion coefficient D was calculated using the formula of Fuller, Schettler and Giddings⁷. For comparative purposes, results from the Shell Liquid Film Evaporometer⁸ are listed in Table 1 and the agreement with equation (15) is seen to be quite reasonable. Although the latent heat of evaporation h_{fg} does not enter directly into equation (15), it has been included in Table 1 because of the role it plays in controlling both the energy required and the surface temperature.

MIBC was specifically selected for use in this research because its slow evaporation rate allowed sufficient time for drying data to be recorded.

Drying curves using infra-red meter

Refs. 1, 9

In an earlier paper Black and Hardisty¹ described their use of the *SM2 Infragaug*⁹ to record the ink drying process. This earlier experimental work was handicapped by an inability to apply thin ink films in a controlled and repeatable manner using a simple laboratory coating device. This rather crude coating technique has now been discontinued in favour of a small rotary gravure press, Figure 6. For research purposes, the gravure cylinder was etched with four separate bands, each about 4cm wide, to print strips of increasing ink thickness on to the plastic (polypropylene) substrate. Tests show that with the gravure press, coating thickness can be closely controlled and repeatability is good. The thickness of the dry ink, estimated by weighing, coupled with the percentage solvent in the ink allowed the thickness of ink deposit from each gravure band to be estimated as follows

band	1	2	3	4
initial thickness (micron)	6.6	9.4	11.3	13.8

The ink used in the research had the following formulation

Solvent	Methyl iso butyl carbinol	51%
Resin	Versamid 930	34%
Pigment	Isol pthalto blue	15%

The IR instrument was described previously¹ but for completeness its mode of operation will be briefly outlined here. Figure 7 shows relevant absorption spectra of (a) polypropylene film (b) film and "wet" ink (c) film and dry ink. At a wavelength of 2.95 micrometre, the solvent in the ink absorbs IR strongly while the remaining constituents of the ink and the plastic substrate absorb this wavelength only weakly.

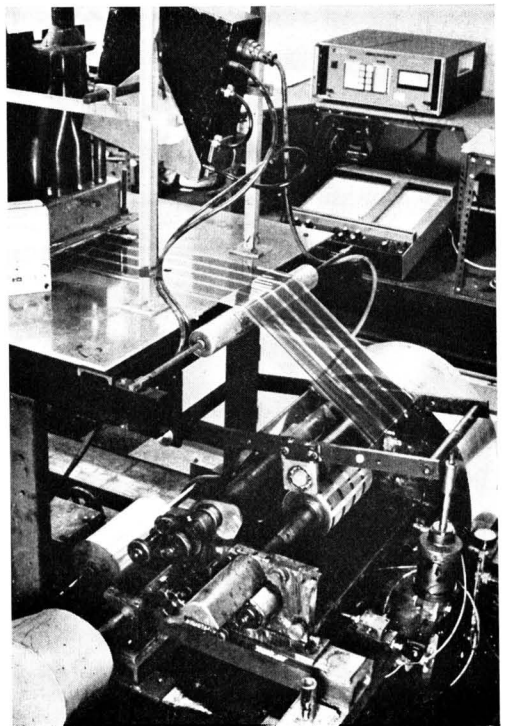


Figure 6. Drying research rig

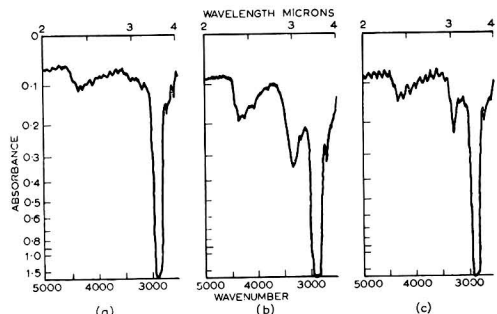


Figure 7. Absorption spectra

Figure 8, is a diagrammatical layout of the optical sensing head of the Infragaug. The optical head directs a beam of IR radiation about 2cm in diameter and at a precise wavelength of 2.95 micron on to a stationary inked specimen placed on a reflecting aluminium plate. Solvent present in the beam absorbs IR radiation, so reducing the radiation returning the sensing head. The electrical output of the IR detector is electronically processed so that, over the linear portion of its range, the output voltage of the Infragaug is directly proportional to the quantity of solvent in the beam. Drying curves were recorded using the following technique. The Infragaug output was connected to the Y-axis of an X-Y recorder. A short length of web was printed and then brought to rest at the IR scanning point adjacent to a slot nozzle, Figure 6. Starting the time base in the recorder produced a continuous record of the drying process in a stationary specimen.

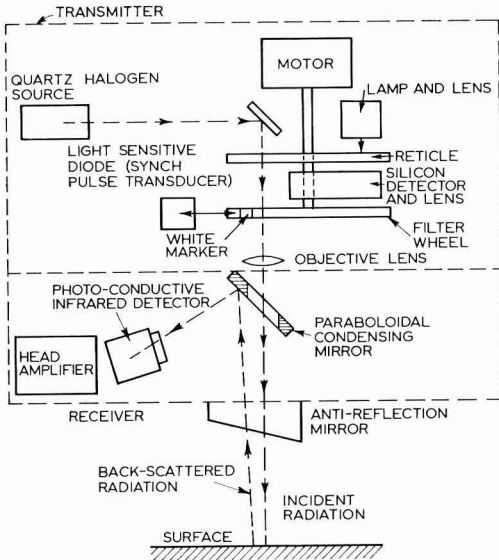


Figure 8. Infrared meter layout of sensing head

Tests showed the ink deposit from gravure band 4 to be sufficiently thick to saturate the sensitivity of the Infragaug. Because of this no drying curves were recorded for this band.

Effect of solvent content and ink thickness on drying time

The drying curves shown on Figures 9a-9d are the results of a series of tests, whose object was to determine the effect of ink thickness and percentage solvent in the ink on drying rate. At least three drying curves were recorded at each test condition and repeatability is seen to be good. The initial rising part of each curve is a consequence of the Infragaug response time. At voltages greater than 7 approximately, the output of the IR instrument is non-linear and at voltages greater than 12 the sensitivity of the instrument is saturated.

In Table 2 the gradients (volt/sec) of the linear portions of the drying curves shown in Figures 9a-9b are given:

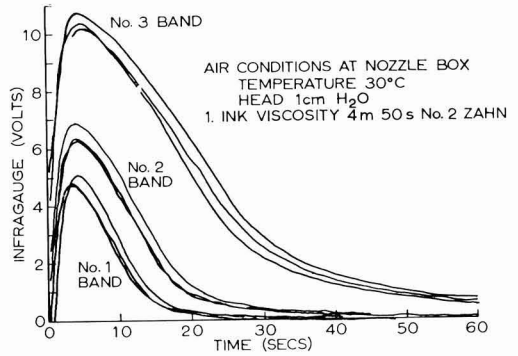


Fig. 9a

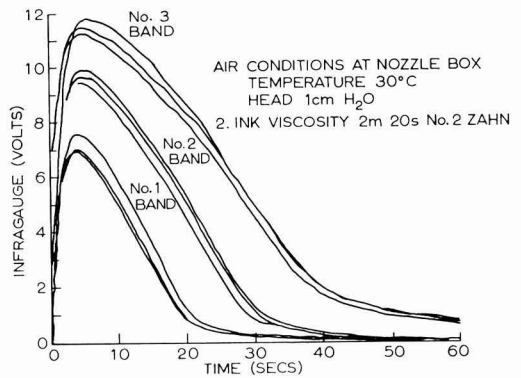


Fig. 9b

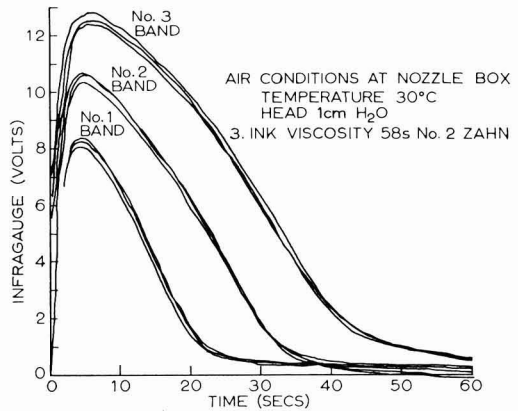
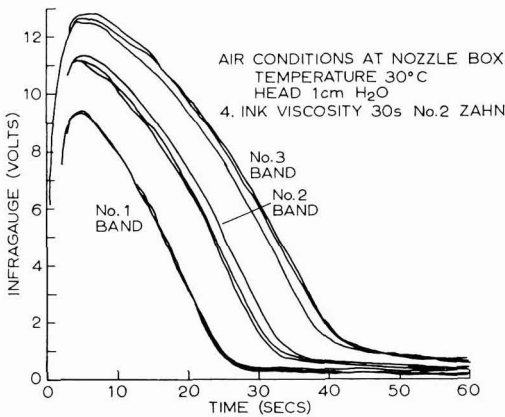


Fig. 9c



Figures 9 (a-d). Effect of solvent (MIBC) content on ink drying time

Table 2
Gradients of drying curves

Band	9a	9b	9c	9d
Band 1, ink thickness, 6.6 μ	0.5	0.49	0.52	0.54
Band 2, ink thickness, 9.4 μ	0.48	0.45	0.45	0.55
Band 3, ink thickness, 11.3 μ	0.43	0.41	0.41	0.52

Average gradient 0.48 V/s

Although there is some evidence of systematic variation (discussed below) the gradients are roughly constant, which is consistent with wet and dry bulb theory.

By extrapolation of the linear portion of the drying curve back in time to cut the voltage axis, the virtual voltage at zero time, V_0 , may be estimated. A check, both on the consistency of the test results and the linearity of the Infragaugage, may be obtained by comparing values of V_0 with the corresponding estimates of solvent deposit, Figure 10.

Table 2 shows that thicker ink layers have somewhat lesser gradients. This trend may be a real one in that thicker layers may dry more slowly than thinner layers. Alternatively, the effect could arise from an inconsistency in the Infragaugage, but such an inconsistency is not apparent in Figure 10.

Characteristics of constant-rate drying

Ref. 10

An alternative parameter to characterise drying is the hypothetical time (T_{con}) for the initial solvent content to fall to zero, the drying rate being maintained at the constant-rate value throughout. T_{con} may be estimated graphically by extrapolating the linear portion of the drying curve to the point where it cuts the time axis.

Based on the heat and mass transfer theory set out earlier and making the assumption that during constant-rate drying the surface takes up the wet-bulb temperature, a computer program was written to predict T_{con} for various values of jet velocity and jet temperature. Heat transfer data was based on the correlation of Gardon and Akfirat¹⁰. Results from this programme are summarised in Figure 11.

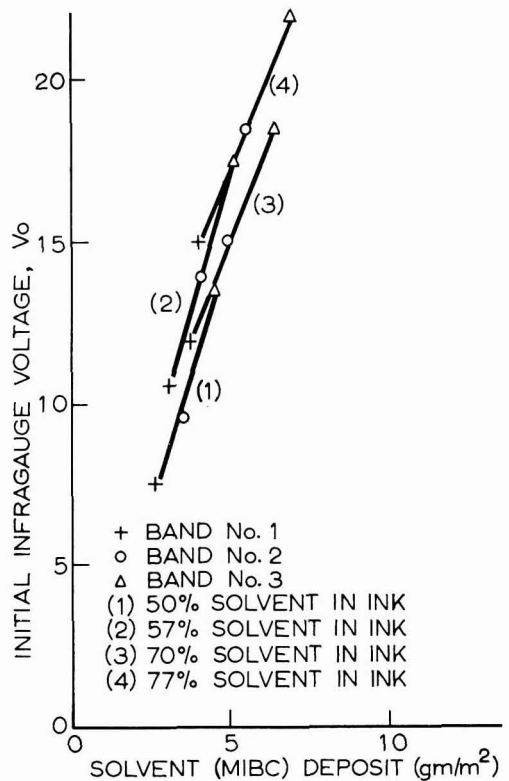


Figure 10. Comparison of infragaugage voltage and initial solvent deposit

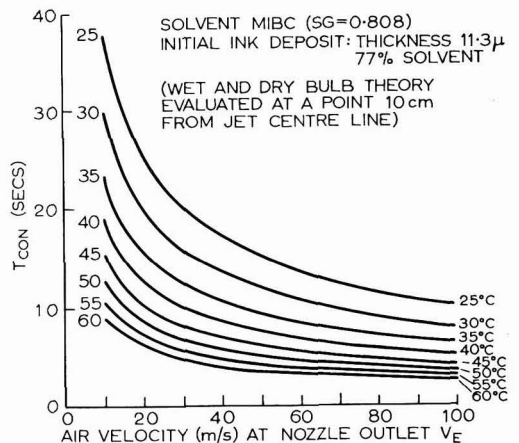


Figure 11. Characteristics of constant-rate drying

Figure 12 illustrates the effect on the IR drying curves of systematically varying air jet velocity whilst maintaining air temperature constant. To test repeatability three drying curves were recorded at each test condition. In Table 3, values of T_{con} from experiment are compared with those

predicted on the basis of constant-rate theory; the agreement is reasonable.

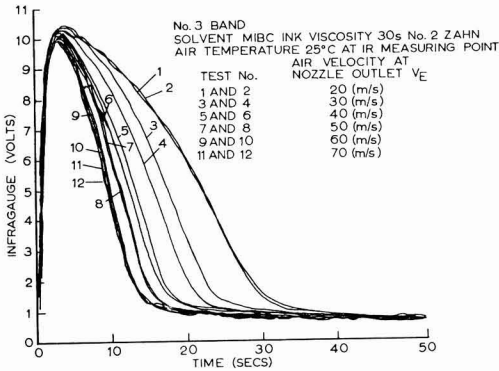


Figure 12. Effect of air velocity on drying time

Table 3
Comparison of T_{con} values

Air velocity m/s	20	30	40	50	60	70
T_{con} , sec	Expt 31.7	23.4	18.0	15.8	13.9	13.2
	Theory 25.5	20.0	17.1	15.0	13.4	12.3

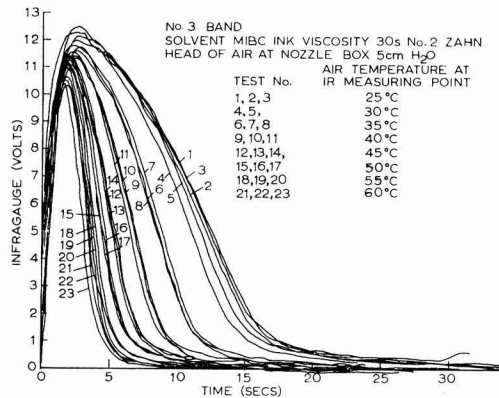


Figure 13. Effect of air temperature on drying time

Table 4
Comparison of T_{con} values

Air temperature °C	25	30	35	40	45	50	55	60
T_{con} , sec	Expt 16.5	15.2	11.5	8.8	7.0	6.0	5.0	4.3
	Theory 20.1	15.8	12.5	9.9	8.1	6.7	5.6	4.7

Figure 13 illustrates the effect on the IR drying curves of systematically varying air temperature whilst maintaining air velocity constant. To test repeatability, two drying curves were recorded at each condition. Comparative values of T_{con} from experiment and theory are tabulated below; again the agreement is reasonable.

Conclusions

- (1) A technique has been developed for the continuous recording of drying curves from thin ink films, which appears to yield consistent and repeatable results.
- (2) Analysis of the curves shows that initially the ink dries at a constant-rate. This is in agreement with earlier theories for thick slabs.
- (3) During the constant-rate period the drying rate is controlled by the external air conditions and is found to be largely independent of both coating thickness and percentage solvent in the ink.
- (4) The effect of changes in air velocity and temperature on experimental constant-rate drying times have been compared with predictions based on the theory of the wet-bulb hygrometer. Agreement is reasonably good.
- (5) Future research will investigate solvents with higher evaporation rates and continue the analysis of the falling rate period.

Acknowledgments

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Discussion at Eastbourne Conference

MR D. J. TUCKER asked Mr Hardisty to comment on the choice of solvent used in his work. It was evident that the choice of an alcohol made detection of solvent remaining in the film very easy but he asked if they had any difficulties with

its evaporation when using it in conjunction with a polar resin.

MR HARDISTY said that their choice of an alcohol solvent with a relatively slow evaporation rate had been made largely to facilitate their research into drying. The solvent selected

had suitable IR absorption characteristics and its slow speed of evaporation allowed sufficient time for the drying process to be analysed. However, when selecting the ink system they had sought advice from industry and he considered that the conclusions they had reached would be applicable to the more conventional faster solvents.

They had started their research with little detailed knowledge of the theory of evaporative ink drying. The simple, single solvent ink system had been chosen to provide basic data on the drying of thin ink films and to see the manner in which this data could be fitted to theories developed by chemical engineers for the drying of thick slabs. It should be noted that these latter theories assume a single, pure solvent and only the enthalpy of evaporation (latent heat) had been considered. Having obtained basic drying data they were now in a position both to extend the theory and to examine other, more practical, solvents. To extend the constant-rate theory developed in the paper, applicable to the initial period of drying, the properties of solutions would require inclusion. This was also required for the proper consideration of the later periods of drying and of the retained solvent problem. They would be grateful for any advice on these chemical aspects of the problem.

Mr Tucker said that he was no expert in ink drying, but he thought most people present would probably be more concerned about the problems of retained solvent.

Mr Hardisty agreed that this was possibly so.

Mr Tucker said that he could see advantages of using alcohol as a solvent from the point of view of detection as a starting point in the investigation, but he suggested that using hydrocarbon solvents with a less polar medium would be very difficult to deal with, especially using infrared drying, and he thought there might be difficulties in detecting a change in concentration of hydrocarbon solvent in a resinous medium.

Mr Hardisty said he accepted this point, but pointed out that when they had started there was no experimentally validated theory about the mechanism of ink drying, that is whether it was a constant rate or a falling rate process, and in this respect they had made some progress. Obviously, there were going to be difficulties when they changed to faster solvents and this was the stage they had now reached.

DR F. M. SMITH asked whether the reflectance of infra-red was influenced by the nature of the pigments in the ink. He asked how much infra-red was reflected from the surface and from within the film, and whether Mr Hardisty was printing on a black or on a white substrate.

MR HARDISTY said that this was something that had been carefully considered at the beginning of the work. They had chosen a dark coloured ink in order to reduce any reflection that might occur, but in theory, because the head was angled, what reflection there was would not be directed towards the head. When the beam strikes the ink film the only infra-red radiation directed back to the head is that scattered by interaction with the film. Clearly, if there was any direct reflectance, the system would not work.

Mr Hardisty summarised by saying that by using a combination of an inclined head and a dark coloured ink they had not encountered any problems in this respect.

MR P. FINK-JENSEN asked what would be the influence of the heat conductivity of the substrate on the drying rate of the ink film and whether different results were obtained when the ink film was on metal foil or polyethylene foil.

MR HARDISTY said that all their experiments had been carried out on a plastic foil and he thought that the heat conductivity effects were practically negligible. Mr Hardisty said that so far they had done no work on metal foils.

Determination of solubility parameters of polymers by a group contribution technique

By H. Ahmad and M. Yaseen

Regional Research Laboratory, Hyderabad-500009, India

Summary

Solubility parameters of an acrylamide polymer series calculated by the group contribution technique using four different reported contributions are $\delta_{coh} > \delta_S > \delta_H, K > \delta_H$.

Solubility parameters of polymers decrease with their increasing molar volumes. It is observed that $\delta_{normal} > \delta_{secondary} > \delta_{tertiary}$,

Keywords

Properties, characteristics and conditions primarily associated with materials in general solubility parameter

because more substitution around the carbon atom lowers the value of the F constant of the compound. Substitution of methyl and phenyl groups at two different positions results in an increase in δ values, because of steric effects. Results also show greater solubility parameter values for polymers than their parent monomers.

Miscellaneous terms internal cohesive energy

La détermination des paramètres de solubilité des polymères au moyen d'une technique basée sur la contribution spécifique des groupements chimiques

Résumé

Les paramètres de solubilité d'une série de polymères acrylamides, calculés par une technique basée sur la contribution spécifique des groupements chimiques et utilisant les valeurs déjà rapportées de quatre diverses contributions se rangent dans l'ordre suivant $\delta_{coh} > \delta_S > \delta_H, K > \delta_H$.

Les paramètres de solubilité des polymères se diminuent à mesure que le volume molaire s'augmente. On a observé que $\delta_{normal} >$

$\delta_{secondaire} > \delta_{tertiare}$ puisque la valeur du constant F du composé se diminue où le degré de substitution autour de l'atome de carbone devient plus important. L'introduction à deux différents sites des groupements phényle ou méthyle entraîne une augmentation des valeurs δ , en raison des effets stériques. Les résultats démontrent d'ailleurs que les valeurs des paramètres de solubilité des polymères sont supérieures à celles des monomères intéressés.

Bestimmung der Löslichkeitsparameter von Polymeren mittels einer von einer Gruppe Gemeinsam durchgeführten methode

Zusammenfassung

Löslichkeitsparameter einer Akrylamidpolymerserie mittels einer aus vier verschiedenen und beschriebenen Beiträgen berechneten Gruppentechnik sind Abfall des Löslichkeitsparameters von Polymeren mit steigendem molaren Volumen. Es wird beobachtet, dass $\delta_{normal} > \delta_{secundar} > \delta_{tertiar}$ ist, weil mehr Substitution rund um das Kohlenstoffatom herum den Wert der F Konstante

der Verbindung herabsetzt. Substitution der Methyl- und Phenylgruppen an zwei verschiedenen Stellen hat wegen der sterischen Wirkung höhere δ -Werte zur Folge. Die Ergebnisse zeigen auch höhere Löslichkeitsparameter für Polymere als für die elterlichen Monomere.

Refs. 1-8, 10-19

The knowledge of solubility parameters of film forming polymers and of solvents has been found to be useful for assessing their compatibility characteristics, either in solution or during evaporation of solvents in the course of drying of polymeric coatings. The studies on the theoretical concept of solubility parameter and the theories that relate it to other interaction parameters of a compound were the field of interest of earlier workers¹⁻⁴. However, Burrell⁵ demonstrated the application of solubility parameters of polymeric materials and solvents to simple and complex organic coating systems.

meter to that of the solvent in which the polymer is soluble in all proportions.⁵

The process of dissolution of the polymer in a solvent depends mainly on the heat of mixing, which is negligible when the cohesive energy densities of the polymer and solvent are almost equal. The free energy of mixing ΔF_m of polymer-solvent system can be expressed:

$$\Delta F_m = \Delta H_m - T \Delta S_m \dots \dots \dots (1)$$

$$\text{and } \Delta H_m = V_m \left\{ \left(\frac{E_1}{V_1} \right)^{\frac{1}{2}} - \left(\frac{E_2}{V_2} \right)^{\frac{1}{2}} \right\}^2 \cdot \varphi_1 \varphi_2 \dots \dots \dots (2)$$

$$= V_m \delta_1 - \delta_2 \}^2 \cdot \varphi_1 \varphi_2 \dots \dots \dots (3)$$

Where,

- ΔH_m = the heat of mixing
- ΔS_m = the entropy of mixing and is always positive
- V_m = total volume of the two components
- V_s' = their molar volumes
- E_s' = their cohesive energies
- φ_s' = their volume fractions
- δ_s' = their solubility parameters

The theoretical determination of solubility parameters of polymers by using fundamental equations^{1,6-8} has not been possible, because the data on various physical constants of polymers, *ie.* boiling point, heat of vaporisation, van der Waal's constant, compressibility factor, surface tension, *etc.*, are not available in the literature. However, the solubility parameter of a polymer can be determined by dissolving it in a series of solvents and then equating its solubility para-

In a system where the long chains of the polymer uncoil in the course of dissolution, it results in high ΔS_m value, which in turn favours the ΔF_m value to be negative. If the heat of mixing ΔH_m is not greater than $T\Delta S_m$, dissolution of polymer in the solvent is possible. In the other case where heat of mixing is very low ($\delta_1 \approx \delta_2$), the miscibility of two components is assured, but the extent of dissolution is governed by the entropy factor, ΔS_m .

Efforts were made to determine the solubility parameter of a polymer by measuring the degree of its swelling in various solvents², but difficulties were experienced in measuring the relative swelling of the polymer accurately because of the poor sensitivity of the measuring device. The other methods for determining solubility parameters of polymers also have certain limitations when carrying out the practical measurements.^{3,9} Therefore, the theoretical method based on the principle of additivity of contributions due to the groups present in the molecule was used for calculating solubility parameters of the polymers.^{4,7,10-19}

Acrylamides, methacrylamides, their polymers and copolymers and other derivatives are mostly used in film forming materials. Hence, it was felt worthwhile to determine solubility parameters of a series of acrylamide polymers by using values of group contributions suggested by various workers.^{4,7,16,19} For the sake of comparison of the results, solubility parameters of some monomers have also been calculated from their heat of vaporisation data.

Materials

Ref. 20

The structural formulae of monomers were collected from the book "Functional Monomers",²⁰ The formulae of the monomers were rewritten in the form of repeating units of their corresponding polymers for the purpose of calculating the solubility parameters of polymers. The data on boiling points of monomers were also taken from the same source for calculating their solubility parameters by heat of vaporisation method.

Procedure

The total molar attraction constant F or the cohesive energy, E , of the polymer was obtained by summing up the reported values of F_i or E_i due to the individual groups present in the molecules. Examples for calculation of F , E and δ have been illustrated earlier.²¹

$$F = \sum_{i=1}^n F_i \dots \dots \dots (4)$$

$$E = \sum_{i=1}^n E_i \dots \dots \dots (5)$$

$$\delta = \frac{F}{V} = \left(\frac{E}{V} \right)^{\frac{1}{2}} \dots \dots \dots (6)$$

As the data on their molecular weights and densities were not available, the molar volumes of polymers have been calculated by adding up the contributions due to atoms and bonds to the molar volume.²² Two examples of the method for calculating molar volume of a compound are illustrated here:

Example 1:

Poly N-(iso-propoxy methyl) acrylamide



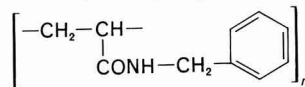
The atoms and bonds contributions to molar volume at 25°C are²²:

<i>Atoms and bonds</i>	<i>V</i> _{25°C}
7(C)	7 × 1.85
13(H)	13 × 6.59
2(O)	2 × 4.40
1(N)	1 × 4.82
1(=)	1 × 8.94
Polymer repeating unit	2.97
	130.78

and the molar volume of poly N-(iso-propoxy methyl) acrylamide is 130.78 cc.

Example 2:

Poly N-Benzyl acrylamide



<i>Atoms and bonds</i>	<i>V</i>
10(C)	10 × 1.85
11(H)	11 × 6.59
1(O)	1 × 7.70
1(N)	1 × 4.82
4(=)	4 × 8.94
1 (6-membered ring)	1 × 2.35
Polymer repeating unit	2.97
	143.69

The molar volume of this polymer is 143.69 cc.

Molar volumes of monomers, selected for the determination of their solubility parameters, were also calculated by this method.

Results

Refs. 1, 4, 21

Symbols δ_S , δ_H , δ_{HK} and δ_{coh} represent solubility parameter values calculated by using group contributions suggested by Small, Hoy and Hoftyzer-Krevelen and by cohesive energy method respectively (Tables 1-4). The values of solubility parameters of some monomers were calculated by a heat of vaporisation method¹ for comparing them to the values of solubility parameters of their polymers (Table 4, column 5).

The group "CONH-" is common in all polyacrylamides, but the value of its F constant has not been reported by Small. Hence, the value of the F constant due to the "CONH-" group was calculated so that the contributions due to other groups reported by Small could be used for determining δ of polyacrylamides. It has been observed that δ values calculated by Small's contributions and cohesive energy contributions are fairly comparable to each other.²¹ Therefore, the following relationship:

$$F_{\text{CONH}^-} = (EV)^{\frac{1}{2}} - \sum_{i=1}^{n-1} F_i (\text{Small}) \dots \dots \dots (7)$$

has been used for calculating the value of contribution due to F_{CONH^-} . Here, $\sum_{i=1}^{n-1} F_i$ (Small) is the total of contributions (reported by Small) due to all groups present in the molecule except for the CONH⁻ groups.

The total molar attraction constants for a large number of polymers were calculated by Small's contributions and cohesive energy method. The values of F_{CONH^-} for individual polymers were calculated by substituting the values of $\sum_{i=1}^{n-1} F_i$ (Small) and $(EV)^{\frac{1}{2}}$ in equation 7. The mean average value of contribution due to the CONH-group has been calculated. The calculated mean average value of contribution due to F_{CONH^-} group is 776 and this has been used for calculating solubility parameters of polyacrylamides by Small's method.⁴

Discussion

Ref. 4

The scrutiny of the solubility parameters of polymers shows that values calculated by adding up the group contributions

suggested by Hoy are the lowest of the values calculated by various other methods (Tables 1-3). The values obtained from the cohesive energy method are found to be relatively a little higher in magnitude than the other values. But in the case of compounds where groups such as fluorine, chlorine etc., are substituted into their structural chains the values calculated by Small's method are slightly higher than the δ_{coh} values. Mostly the values calculated by the Hoftyzer-Krevelen method are lower in magnitude than δ_s .

The values of solubility parameters of alkyl substituted polyacrylamides have been listed in increasing order of the substituted groups. A similar order has been followed when tabulating solubility parameters of branched substituted polyacrylamides, and also the linear and substituted polymethacrylamides. In doing so the molar volumes of the polymers automatically become arranged in increasing order in each classification (Table 1). An identical feature has been observed when solubility parameters of aryl substituted polyacrylamides, polymethacrylamides and other polymers have been arranged in the increasing order of the substituted groups (Tables 2 and 3).

Table 1
Solubility parameters of alkyl substituted polyacrylamides (cal/cc)^{1/2}

Name of polymer	Molar volume	Solubility parameter			
	<i>V</i>	δ_s	δ_H	δ_H, κ	δ_{coh}
	1	2	3	4	5
<i>Linear polyacrylamides:</i>					
1. Poly <i>n</i> -methyl acrylamide	77.96	16.67	11.26	13.48	16.50
2. Poly <i>n</i> -ethyl acrylamide	102.99	13.80	9.78	11.48	14.25
3. Poly <i>n</i> - <i>iso</i> -propyl acrylamide	108.02	12.89	9.37	11.15	13.70
4. Poly <i>n</i> - <i>n</i> -butyl acrylamide	123.05	12.59	9.69	10.90	13.03
5. Poly <i>n</i> - <i>iso</i> -butyl acrylamide	123.05	12.40	9.29	10.90	13.15
6. Poly <i>n</i> - <i>t</i> -butyl acrylamide	123.05	12.07	8.99	10.90	13.03
7. Poly <i>n</i> - <i>s</i> -amyl acrylamide	138.08	12.01	9.23	10.71	12.70
8. Poly <i>n</i> - <i>s</i> - <i>iso</i> -amyl acrylamide	138.08	11.84	9.02	10.71	12.82
9. Poly <i>n</i> - <i>t</i> -amyl acrylamide	138.08	11.72	8.96	9.71	12.59
10. Poly <i>n</i> - <i>n</i> -cyclohexyl acrylamide	142.28	—	9.59	10.94	—
11. Poly <i>n</i> - <i>n</i> -heptyl acrylamide	169.14	11.59	9.32	10.42	11.92
12. Poly <i>n</i> - <i>n</i> -octyl acrylamide	184.17	11.36	9.27	10.32	11.65
13. Poly <i>n</i> - <i>n</i> -dodecyl acrylamide	224.29	10.74	9.14	9.73	10.89
14. Poly <i>n</i> - <i>n</i> -octadecyl acrylamide	315.47	10.23	9.03	9.56	10.22
<i>Branched polyacrylamides:</i>					
15. Poly <i>n</i> -(1,1-dimethyl butyl) acrylamide	154.11	11.44	8.94	10.55	12.25
16. Poly <i>n</i> -(1,1-diethyl propyl) acrylamide	169.14	11.21	8.92	10.42	11.92
17. Poly <i>n</i> -(1,1-dimethyl amyl) acrylamide	169.14	11.21	8.92	10.42	11.92
18. Poly <i>n</i> -(1,1-diethyl butyl) acrylamide	184.17	11.01	8.91	11.06	11.65
19. Poly <i>n</i> -(1,1-dimethyl heptyl) acrylamide	199.20	10.85	8.89	10.22	11.43
20. Poly <i>n</i> -(1,1-diethyl amyl) acrylamide	199.20	10.85	8.89	10.22	11.43
21. Poly <i>n</i> -(1,1-dibutyl amyl) acrylamide	239.32	10.39	8.86	9.96	10.75
22. Poly <i>n</i> -(1,1,2-trimethyl propyl) acrylamide	154.11	11.22	8.75	10.55	12.33
23. Poly <i>n</i> -(1,1,2-trimethyl butyl) acrylamide	169.14	11.06	8.75	10.42	11.92
24. Poly <i>n</i> -(1,1,3-trimethyl butyl) acrylamide	169.14	11.06	8.75	10.42	11.92
25. Poly <i>n</i> -(1,1,4-trimethyl amyl) acrylamide	184.17	10.88	8.75	10.31	11.65
26. Poly <i>n</i> -(1,1,3,3-tetra-methyl butyl) acrylamide	184.17	10.88	8.75	10.31	11.65

Table 1 cont'd

27.	Poly <i>n</i> -(1-methyl-1-ethyl propyl) acrylamide	154.11	11.44	8.94	10.55	12.22
28.	Poly <i>n</i> -(1-methyl-1-ethyl butyl) acrylamide	169.14	11.21	8.92	10.42	11.92
29.	Poly <i>n</i> -(1-methyl-1-ethyl amyl) acrylamide	184.17	11.01	8.91	10.31	11.65
30.	Poly <i>n</i> -(1-methyl-1-propyl butyl) acrylamide	184.17	11.01	8.91	10.31	11.65
31.	Poly <i>n</i> -(1-methyl-1-propyl amyl) acrylamide	199.20	10.85	8.89	10.22	11.43
32.	Poly <i>n</i> -(1-ethyl-1-butyl amyl) acrylamide	209.26	10.58	8.88	10.08	11.05
33.	Poly <i>n</i> -(1-propyl-1-butyl amyl) acrylamide	224.29	10.48	8.87	10.02	10.89
34.	Poly <i>n</i> -(1-methyl-1-ethyl-2-methyl propyl) acrylamide	169.14	11.06	8.75	10.42	11.92
35.	Poly <i>n</i> -(1,4-dimethyl-1-ethyl amyl) acrylamide	184.17	10.88	8.75	10.31	11.65
36.	Poly <i>n</i> -(1,3-dimethyl-1-ethyl butyl) acrylamide	184.17	10.88	8.75	10.31	11.65
37.	Poly <i>n</i> -[1-(2-methyl propyl)-1-(3-methyl butyl)] acrylamide	214.23	10.67	8.79	10.14	11.12
38.	Poly <i>n</i> -(1-methyl-1-butyl-3-methyl butyl) acrylamide	224.29	10.59	8.75	10.14	11.31
<i>(Substituted alkyl) poly acrylamides:</i>						
39.	Poly <i>n</i> -(hydroxymethyl) acrylamide	85.66	—	11.88	15.28	—
40.	Poly <i>n</i> -(2-hydroxyethyl) acrylamide	100.69	—	11.41	14.38	—
41.	Poly <i>n</i> -(methoxymethyl) acrylamide	100.69	13.44	10.47	12.64	14.23
42.	Poly <i>n</i> -(ethoxymethyl) acrylamide	115.72	12.84	10.25	12.18	13.59
43.	Poly <i>n</i> -(<i>n</i> -propoxymethyl) acrylamide	131.99	12.39	10.08	11.83	13.09
44.	Poly <i>n</i> -(<i>iso</i> -propoxymethyl) acrylamide	131.99	12.21	9.21	10.11	13.21
45.	Poly <i>n</i> -(<i>n</i> -butoxymethyl) acrylamide	145.78	11.55	9.95	11.55	12.05
46.	Poly <i>n</i> -(2-cyanoethyl) acrylamide	111.02	14.52	11.51	14.04	14.82
47.	Poly <i>n</i> -[1(1-methyl-1-hydroxymethyl)-ethyl] acrylamide	117.87	—	10.05	13.17	—
48.	Poly <i>n</i> -(1-methyl-2-oxopropyl) acrylamide	126.51	14.30	11.20	13.89	—
<i>Linear polymethacrylamides:</i>						
49.	Poly <i>n</i> -methyl methacrylamide	92.99	13.37	9.71	12.34	14.10
50.	Poly <i>n</i> -ethyl methacrylamide	108.02	12.75	9.58	11.90	13.44
51.	Poly <i>n-iso</i> -propyl methacrylamide	123.05	12.08	9.24	11.56	13.03
52.	Poly <i>n</i> -butyl methacrylamide	138.08	11.71	9.13	11.56	12.63
53.	Poly <i>n-t</i> -amyl methacrylamide	153.11	11.18	8.90	11.08	12.12
54.	Poly <i>n</i> -cyclohexyl methacrylamide	157.31	—	10.00	10.71	—
55.	Poly <i>n-n</i> -octyl methacrylamide	199.20	10.97	9.20	10.63	11.34
<i>Branched polymethacrylamides:</i>						
56.	Poly <i>n</i> -(1,1,3,3-tetramethyl butyl)-methacrylamide	199.20	10.80	8.54	10.63	11.34
<i>(Substituted alkyl) methacrylamides:</i>						
57.	Poly <i>n</i> -(hydroxymethyl) methacrylamide	100.69	—	11.04	14.38	—
58.	Poly <i>n</i> -(methoxy) methacrylamide	115.72	12.50	9.93	12.18	13.47
59.	Poly <i>n</i> -(ethoxymethyl) methacrylamide	130.75	12.08	9.79	11.83	12.97
60.	Poly <i>n</i> -(allyloxy methyl) methacrylamide	141.54	11.78	9.76	11.50	—
61.	Poly <i>n</i> -2-(3-oxobutyl) methacrylamide	141.87	12.44	9.89	12.62	—
62.	Poly <i>n</i> -(propoxymethyl) methacrylamide	145.78	11.75	9.69	11.55	12.56
63.	Poly <i>n</i> -(butoxymethyl) methacrylamide	160.81	11.48	9.66	11.32	12.22
64.	Poly <i>n</i> -(hexoxymethyl) methacrylamide	191.87	11.07	9.48	10.98	—

Table 2
Solubility parameters of aryl substituted polyacrylamides (cal/cc)¹

Name of polymer	Molar volume	Solubility parameters			
		V	δ_S	δ_H	$\delta_{H, K}$
<i>Linear aryl polyacrylamides:</i>					
1. Poly <i>n</i> -phenyl acrylamide	126.50	13.29	10.44	12.33	13.92
2. Poly <i>n-p</i> -tolyl acrylamide	141.62	12.72	10.62	11.89	12.99
3. Poly <i>n</i> -benzyl acrylamide	141.62	12.62	9.40	11.78	12.81
4. Poly <i>n-p</i> -methyl benzyl acrylamide	156.65	12.32	10.43	11.53	12.56
<i>(Substituted aryl) acrylamides:</i>					
5. Poly <i>n</i> -(benzyl-oxomethyl acrylamide	164.09	14.29	12.24	13.85	13.57
6. Poly <i>n</i> -(acryl-2-phenyl-d-1-alanine	183.46	—	10.03	11.14	—
7. Poly <i>n</i> -(1-benzyl-2-oxopropyl) acrylamide	190.79	12.17	10.34	11.72	—
<i>Aryl methacrylamides:</i>					
8. Poly <i>n</i> -methacrylanilide	144.59	12.21	9.95	11.65	12.61
9. Poly <i>n-p</i> -tolyl methacrylamide	159.62	11.91	10.06	11.40	12.38
10. Poly <i>n</i> -benzyl methacrylamide	159.62	11.89	9.84	11.40	12.26
<i>(Substituted aryl) methacrylamides:</i>					
11. Poly <i>n-p</i> -chloro phenyl methacrylamide	158.92	15.69	13.59	14.79	14.24
12. Poly <i>n-p</i> -methoxy phenyl methacrylamide	167.32	11.79	10.30	11.63	12.47
13. Poly <i>n-p</i> -ethoxy phenyl methacrylamide	182.35	11.57	10.19	11.45	12.18

Table 3
Solubility parameters of general poly-(acrylamides and cinnamides), (cal/cc)¹

Name of polymer	Molar volume	Solubility parameters				
		V	δ_S	δ_H	$\delta_{H, K}$	δ_{coh}
		1	2	3	4	5
<i>Alkoxy poly acrylamides:</i>						
1. Poly <i>n</i> -ethyl-2-ethoxy acrylamide	110.98	14.28	11.54	13.93	14.07	
2. Poly <i>n</i> -ethyl-3-ethoxy acrylamide	131.78	12.13	9.78	11.74	13.15	
3. Poly <i>n</i> -2-chloroethyl-3-ethoxy acrylamide	145.08	12.30	10.19	11.78	13.02	
4. Poly <i>n-n</i> -propyl-2-ethoxy acrylamide	146.78	11.67	9.62	11.47	12.51	
5. Poly <i>n-n</i> -butyl-2-ethoxy acrylamide	160.81	11.48	9.60	11.32	12.22	
<i>Poly cinnamides:</i>						
6. Poly <i>n</i> -butyl cinnamide	175.42	12.06	10.12	11.94	12.36	
7. Poly <i>n</i> -(1,1-dimethyl propyl cinnamide	190.45	11.80	10.00	11.71	12.08	
8. Poly <i>n</i> -(1,1-dimethyl butyl cinnamide	206.48	11.53	9.86	11.47	11.81	
9. Poly <i>n</i> -(1,1,2-trimethyl propyl) cinnamide	206.48	11.41	9.73	11.47	11.89	
10. Poly <i>n</i> -(1,1-dimethyl pentyl) cinnamide	221.51	11.35	9.79	11.31	11.44	
<i>Crotonamides:</i>						
11. Poly <i>n</i> -ethyl-2-ethoxy crotonamide	156.78	13.22	10.83	13.18	13.53	
<i>Vinyl difunctional acrylamide:</i>						
12. Poly <i>n</i> -(2-vinyl oxyethyl) acrylamide	126.51	12.44	10.17	11.78	—	

Table 3 cont'd

<i>(Substituted alkyl) poly acrylamides:</i>						
13.	Poly <i>n</i> -acetyl or ethanoyl acrylamide	96.45	14.78	11.11	13.95	—
14.	Poly <i>n</i> -(2,2,2-trifluoroethyl) acrylamide	102.92	13.95	9.42	11.49	13.44
15.	Poly <i>n</i> -acryl- <i>d</i> -1-alanine	119.18	—	10.77	10.00	—
<i>(Substituted alkyl) poly methacrylamides:</i>						
16.	Poly <i>n</i> -methacrylamido acetonitrile	111.02	14.17	11.17	14.04	14.70
17.	Poly <i>n</i> -acetyl methacrylamide	111.48	13.59	11.03	13.30	13.95
18.	Poly <i>n</i> -(2-cyanoethyl) methacrylamide	126.05	13.54	10.88	13.45	14.08
19.	Poly <i>n</i> -acetyl acrylamide	126.51	13.07	10.76	12.82	13.40

Table 4

Solubility parameters of polymers and their respective monomers (cal/cc)¹

Name of polymer		Solubility parameters				
		δ_S	δ_H	$\delta_{H,K}$	δ_{coh}	$\delta_{monomer}$
		1	2	3	4	5
1.	Poly <i>n</i> -dodecyl acrylamide	10.74	9.14	10.74	10.89	6.75
2.	Poly <i>n</i> - <i>n</i> -octyl methacrylamide	10.97	9.20	10.63	11.34	6.86
3.	Poly <i>n</i> -hexoxymethyl methacrylamide	11.07	9.48	10.98	—	6.91
4.	Poly <i>n</i> - <i>t</i> -amyl methacrylamide	11.18	8.90	11.08	12.12	6.90
5.	Poly <i>n</i> - <i>n</i> -octyl acrylamide	11.36	9.27	10.32	11.65	6.81
6.	Poly <i>n</i> - <i>n</i> -butyl-2-ethoxy acrylamide	11.48	9.60	11.32	12.22	7.44
7.	Poly <i>n</i> -butoxy methyl methacrylamide	11.48	9.66	11.32	12.22	7.18
8.	Poly <i>n</i> - <i>n</i> -heptyl acrylamide	11.59	9.32	10.42	11.92	7.11
9.	Poly <i>n</i> -butyl methacrylamide	11.71	9.13	11.56	12.63	7.69
10.	Poly <i>n</i> -propoxymethyl methacrylamide	11.75	9.69	11.55	12.56	7.48
11.	Poly <i>n</i> -ethoxymethyl methacrylamide	12.08	9.79	11.83	12.97	7.68
12.	Poly <i>n</i> -methoxymethyl methacrylamide	12.50	9.93	12.18	13.47	7.85
13.	Poly <i>n</i> - <i>n</i> -butyl acrylamide	12.59	9.69	10.90	13.03	7.68
14.	Poly <i>n</i> -benzyl acrylamide	12.65	9.40	11.78	12.81	8.08
15.	Poly <i>n</i> -ethyl methacrylamide	12.75	9.58	11.90	13.44	8.05
16.	Poly <i>n</i> -ethoxymethyl acrylamide	12.84	10.25	12.18	13.59	8.07
17.	Poly <i>n</i> - <i>iso</i> -propyl acrylamide	12.89	9.37	11.15	13.70	8.17
18.	Poly <i>n</i> -acetyl methacrylamide	13.07	10.76	12.82	13.40	7.99
19.	Poly <i>n</i> -ethyl-2-ethoxy crotonamide	13.22	10.83	13.18	13.53	6.50
20.	Poly <i>n</i> - <i>n</i> -phenyl acrylamide	13.29	10.44	12.33	13.92	8.08
21.	Poly <i>n</i> -methyl methacrylamide	13.37	9.71	12.34	14.10	9.25
22.	Poly <i>n</i> -acetyl methacrylamide	13.59	11.03	13.30	13.95	7.93
23.	Poly <i>n</i> -ethyl acrylamide	13.80	9.78	11.48	14.25	8.61
24.	Poly <i>n</i> -methyl acrylamide	16.67	11.26	13.48	16.50	9.43
25.	Poly <i>n</i> -cyclohexyl acrylamide	—	9.59	10.94	—	7.59

For the sake of convenience, the solubility parameters of these polymers determined by using Small's contributions are used when analysing the data. The interesting feature noticed is that solubility parameter values exhibit a decreasing order with respect to increasing molar volumes in the case

of all types of polymers reported here, although in calculations the solubility parameter, being inversely proportional to molar volume, is likely to decrease with an increase in molar volume. But as the size of the molecule increases the total of contributions (F) due to groups present in the molecule also

increases, hence the increase in molar volume is likely to be equivalent to the increase in the total of contributions in the case of bigger molecules. This is the reason why the decrease in δ -values is not of the order of the increasing molar volumes.

The accumulation of groups around carbon atoms result in the lowering of total contribution due to groups, *ie* F constant.⁴ The comparison of δ -values of a linear polyacrylamide with the branched polyacrylamides having the same molar volumes illustrate this effect (*cf.* compounds 11, 17 and 23, Table 1). When comparing the δ -values of acrylamides with methacrylamides it is further found that the substitution of the methyl group in the functional acrylamide group lowers the F constant.⁴

The presence of groups surrounding the central atoms also lowers the δ -values of the isomers. The order of decrease observed in the case of isomers reported here is $\delta_{\text{normal}} > \delta_{\text{secondary}} > \delta_{\text{tertiary}}$. However, the position of substituted groups does not alter δ -values of one type of polymers (*cf.* compounds 23, 24, Table 1), because here only the shifting of groups from one position to another occurs.

The steric hindrance due to bulky substituent groups is responsible for high F constant values owing to the high energy level of the compound. For example, when methyl and phenyl groups are substituted at two different positions in the molecule, the δ -value of the compound is found to be relatively higher than the compounds substituted with smaller groups (*cf.* branched substituted compounds in Table 1 and Table 2).

The values of the solubility parameters of a few polymers of general interest are listed in Table 3 according to their classification based on the main substituted group, *viz.*, alkoxy polyacrylamides, polycinnamides, substituted alkyl polyacrylamides, *etc.*

Solubility parameters of monomers calculated from heat of vaporisation data, and also of the corresponding polymers calculated from group contribution technique are listed in Table 4. It is not reasonable to make a definite comparison of the results, as the methods of calculation of solubility parameters of monomers and the polymers are different. However, for the sake of having some idea of the comparative increase in the solubility parameter of a monomer when it is converted into a polymer, the results are reported here.

Conclusions

In general, the solubility parameters of an acrylamide polymer series are in the range of 10–17 (cal/cc)^{1/2}. As non-polar

organic solvents, in general, do not fall in such a high range of solubility parameters, they do not usually act as solvents for such polymers. On the other hand, water and other polar organic solvents having fairly high solubility parameter are likely to dissolve these polymers.

Acknowledgments

The authors would like to thank Dr P. H. Gedam, P. S. Sampathkumar and Dr M. A. Sivasamban for the critical review of the manuscript and discussions.

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Next month's issue

The Honorary Editor has accepted the following papers for publication, and they are expected to appear in the January 1978 issue of the *Journal*:

A new zinc phosphating process designed for automatic control of composition by N. M. Ness and B. A. Cooke

The determination of the formation times of films cast from polymer dispersions by I. Anžur, U. Osredkar and I. Vizovišek

Anomalous swelling in reactive polymers by J. Sickfield

Recent aspects on the preparation and evaluation of some polyesteramides for surfacing coatings. Part II: Preparation and evaluation of amide containing resins by A. M. Naser and A. Z. Gomaa

Newcastle

Second UV polymerisation symposium

Ultraviolet polymerisation and the coatings industry

The Newcastle Section's Second European Symposium, "Ultraviolet polymerisation and the coatings industry", was held at the University of Durham on 14 and 15 September 1977.

The interest currently being generated by ultraviolet curing was illustrated by the fact that all the 206 places available were taken by delegates from 14 countries, including the USA, Japan and Australia and more than 50 applicants were reluctantly turned away due to lack of accommodation. Eleven papers, covering not only the technical, but also the commercial and theoretical aspects of the subject, were presented on monomers, oligomers, photoinitiators and equipment by organisations involved with the technique of UV polymerisation, from Western Europe, the USA and the UK.



Group photograph of lecturers and organisers at the Symposium. Back row (left to right): Mr A. J. Evans, Dr van Neebros, Dr Berner, Mr Parrish

Second row (left to right): Mr H. Fuller (BTP Tioxide, Secretary of sub-committee), G. P. A. Turner, Prof. Ledwith, Mr Pelgrims, Dr Phillips and Mr J. Clark (BTP Tioxide, Treasurer)

Front row (left to right): Dr B. E. Hulme, Mr J. Vona, Mr F. Hellens (Chairman, Newcastle Section), Mr A. McLean (President), Mr S. R. Finn (Hon. Editor) and Mr S. Lynn

As expected, every paper generated many questions and much lively discussion took place in the periods set aside for this purpose at the end of each session.

Mr A. McLean, President of the Association, speaking at the informal symposium dinner, proposed a toast to the visitors after welcoming them in Gaelic as well as in the English language.

In addition to the advertised proceedings, a meeting of interested parties was held to discuss the Health and Safety aspects of UV curable coatings. One of the reasons for the less than anticipated growth of UV curing is the potential hazard associated with some of the monomers used. Many are known skin irritants, and for this reason there is a certain reluctance to handle the new technology inks and varnishes, but it is doubtful whether these monomers are worse in this

respect than some of the stronger solvents in present day use in conventional coatings. For this reason a sub-committee has been set up by the Newcastle Section to consider the Health and Safety aspects of UV curable systems. It is hoped to initiate a programme of toxicological studies in conjunction with other appropriate organisations, with the aim of ultimately producing sufficient data to be able to determine which materials can be used safely in UV curable coatings.

Anyone interested in this aspect of UV curing, or who feels they have some useful information to contribute should contact the Symposium Manager:

Mr S. Lynn,
Resinous Chemicals Division,
Berger,
Wellington Mills,
Dunston,
Tyne & Wear, NE11 9HQ

The organising Committee wishes to thank everyone for attending the Symposium, particularly those who presented papers, and the Session Chairmen, who were not members of the Committee, namely Mr C. H. Morris of Resinous Chemicals and Prof. A. Ledwith of Liverpool University, for ensuring success of the Symposium.

S. Lynn

Hull

Agitation

The first ordinary meeting of the 1977/78 session of the Section was held at the "Humber Bridge Hotel", Barton, South Humberside on Monday 3 October 1977. This was a joint meeting with the Institution of Chemical Engineers. Mr T. W. Wilkinson, the Section Chairman, introduced Dr M. F. Edwards, Senior Lecturer at Bradford University, who gave a lecture entitled "Agitation".

Dr Edwards gave a review of the industrial problems encountered in liquid/liquid, gas/liquid, and solid/liquid agitation. The type of impeller used was dependent on the viscosity of the system; high speed propellers were best for very low viscosity liquids, whereas slow speed Z-blade mixers were ideal for very viscous solutions. The design of the mixing vessel was just as important as that of the impeller. Dr Edwards discussed the problems pertaining to scale-up and the considerations relating to the mechanical design of new installations.

Dr Edwards' talk was fully illustrated with a large number of coloured slides and some practical demonstrations. The lecture, which was attended by 20 members and visitors, was followed by a prolonged discussion. The meeting was finally brought to a close with a vote of thanks from Mr N. Lythgoe; the audience responded in the usual manner.

D.M.W.

London

Chairman's Evening

The first evening technical meeting of the 1977-78 session was the Section Chairman's evening and was held on Thursday 22 September, 1977 at the "Princess Alice", Forest Gate, E7. Over 40 members and guests heard an entertaining and instructive lecture from the Section Chairman, Mr D. Bayliss on the "Customer's Point of View". Mr D. Bayliss, of the

Scientific Services Department, Central Electricity Generating Board, Gravesend, discussed the problems associated with the painting and protection of power stations and showed, with slides, how various surface coating systems performed on site.

The trend, in recent years, had been away from the relatively small brick built to much larger structural steel, externally clad power stations and had created the need for exterior durable finishes for the cladding. Over the years the CEBB had carried out tests on various systems, both on site and at its testing station at Dungeness, Kent. Coil coated paint systems *eg* plastisol, polyvinylidene fluoride, laminates such as PVC, and post finished paint systems (alkyd) had been evaluated on plain and galvanised steel and on aluminium.

On south facing panels all precoated systems showed failure of the paint films within 3 to 5 years, whilst north facing panels exhibited corrosion of the substrate, primarily from the preformed edges, with little change in the coatings. In contrast, post finished paint systems on preformed sections were in very good condition after eleven years exposure, even when finished with domestic alkyd paints. On coil coated steel none of the systems available—PVF₂, polyester or acrylic—had given any confidence of extended exterior exposure. Testing had shown that uncoated galvanised steel and aluminium had better durability than coated substrates, although the whims of architects meant that some coated cladding was used—much to the relief of representatives of paint companies present!

The paint finishes inside power stations were primarily decorative. However, the structural steelwork needed to be protected while the station was being built. Modern building process entailed construction of the framework, erection of the roof and some walls and laying of the floor. The open ends allowed for easy access and installation of the generating sets *etc.* Often taking 5–7 years to build, the semi-enclosed power station was exposed to the atmosphere, invariably in damp conditions as the concrete floor dried out. Corrosion of the steelwork was inevitable. In addition, the steelwork was often stored in extremely adverse conditions in stockyards at the building site for months or even years. Such steel was invariably only protected with a coating of shop primer. The results of exterior exposure of various coating systems on structural steelwork at a CEBB exposure station at Brighton, Sussex were discussed. Metal sprayed galvanised finishes were showing extremely promising results and had an additional advantage in that no maintenance painting was subsequently required.

As with all maintenance painting the greatest problem in power stations was that of surface preparation. Removal of the soluble salts present on the surface was essential, as these appeared to be the prime cause of subsequent paint failures. When surfaces were cleaned to SA3 quality by conventional methods, testing showed that soluble salts were still present. Extensive evaluation of various cleaning processes by the CEBB had shown that a water cannon technique (low water pressure, high air pressure and abrasive) was the only method that could remove such salts from steel. It was ineffective on cast iron, however, because of the porous nature of the surface.

Other specific problem areas in painting power stations were briefly discussed. Surfaces on control consoles were liable to be rubbed and scuffed repeatedly as operators leaned across them to adjust and read controls *etc.* Coatings used in these applications had to be highly scuff resistant. Nuclear power stations were another area which needed specialised coatings.

In conclusion, Mr Bayliss emphasised that correct surface preparation and paint application methods were just as important in attaining a trouble-free, long life finish as was correct formulation of the paint system in the first place. The large scale construction problems of power stations were such that particular attention *had* to be paid to the substrates and coatings used to ensure that the maintenance costs were kept to a minimum.

After a discussion period, in which the audience fully participated, Mr J. Tooke-Kirby proposed a vote of thanks to the Chairman for his presentation.

A.J.N.

Scottish

The use of microvoids as pigments

A lecture on "The use of microvoids as pigments" was given to the Scottish Section by Dr N. Reeves of BTP Tioxide Ltd in the Bellahouston Hotel, Glasgow at 6.00 p.m. on Thursday 13 October.

During his lecture Dr Reeves covered various aspects of basic theory, manufacture of microvoids, manufacture of paint and resultant paint film properties. The lecturer indicated that the products of real interest were the resin beads of so called 25 μ fraction (< 5 per cent >25 μ) with titanium dioxide in the microvoids. A description of the theory of opacity was illustrated by excellent slides and paint illustrations.



Mr J. D. W. Davidson, Chairman, Scottish Section, presenting a Commendation Award to Mr G. H. Hutchinson at the meeting of the Scottish Section held on Thursday 13 October. Photograph by A. McLean (President)

Following the lecture there was a wide ranging discussion on the potential of these products and their future possibilities. Considerable discussion centered on the possibility of applying this technology to glossy oil based systems: Dr Reeves indicated that the particle size required here was different and the overall technology was not yet fully developed. Following the discussion a vote of thanks was accorded to Dr Reeves with the audience showing its appreciation in the normal manner.

G.H.R.

West Riding

Reclamation and disposal of waste solvents

A meeting of the West Riding Section was held on Tuesday 4 October 1977 at the Mansion Hotel, Leeds. Mr G. A. Bingham of Chemstar Ltd gave a talk dealing with the above subject and started by drawing a distinction between the smaller companies such as his own and the larger ones operating in this field. The larger companies are more concerned with large "campaigns" of, say, minimum of 500 tonnes of any one product and tend to concentrate on a simple range of products. The smaller companies deal with smaller quantities with a minimum of about 5-10 tonnes.

Solvent recovery is a growing business due to the considerable increase in solvent prices over the past 3 or 4 years and the increasing cost of waste disposal.

For cleaning purposes the nature of the mixed solvent is relatively unimportant since the recovered product can be sold

as a blend of solvents to a loose specification. If excessive water is present this can be reduced by inorganic salt drying or by adding excess hydrocarbon solvent to throw out the water. By these simple means water content can be reduced to about 2 per cent, which is adequate for some purposes. The acidity of the recovered solvent can be a problem if not corrected. The low pH arises from the thermal cracking of the resins which are frequently present in waste solvents.

Mr Bingham made an appeal for some segregation of waste solvents to be undertaken. There is a tendency for all wastes to be dumped in the same drum and the resultant mixtures are frequently not recoverable in a satisfactory manner. Good housekeeping of this sort will be increasingly necessary, since there are fewer sites available for disposal and expensive incineration will be needed. There is already a shortage of recovery capacity in the UK and hence some selectivity can be practised by the recoverers. It was also likely that "in house" solvent recovery would become increasingly necessary.

There were a number of general questions and the vote of thanks was proposed by Mr N. Cochrane.

R.A.C.C.

Information Received

Prussian Blue expansion

Manox Ltd, an RTZ Chemicals company, is to proceed with the modernisation and expansion of its plant for the manufacture of Prussian Blue. This decision is in line with the company's policy to consolidate and develop its central activity at Miles Plating in the production of Iron Blues, pigment raw materials and related ferrocyanide products. Prussian Blue is a widely used pigment in printing ink, carbon paper and paint manufacturing industries, and Manox is one of the largest suppliers to the United States market. The expansion of the Miles Plating plant will give an increase of 40 per cent in capacity and is expected to be completed by October 1978.

Berger development

Berger Paints have completed another phase of the £500 000 development plan for their Hengrove, Bristol site which specialises in the production of decorative paints. This has resulted in a 20 per cent increase in the output of water thinned paints, which is due in part to the advanced automated raw material handling systems.

UK agency

Samuel Banner & Co Ltd have been appointed sole UK agents for Jayant Oils, a major Indian company processing castor oil products. Samuel Banner is a long established processor and distributor of vegetable oils with a nationwide network operating from strategically placed depots, servicing industry with products formulated to meet customers' specifications.

Technical co-operation in Turkey

Rohm & Haas Co., Philadelphia, has announced that it has reached an agreement for technical co-operation to secure local manufacture in Turkey of Rohm & Haas acrylic emulsions and other chemical products used in surface coatings. The agreement has been made with Akrl Chemicals Manufacturing and Trading Inc., a Turkish company located in Istanbul,

which has previously acted as the local agent and distributor for Rohm and Haas products in Turkey. Local manufacturing will be carried out under the technical assistance of Rohm and Haas in conformity with its formulations and technical standards using the raw material to be supplied by Rohm and Haas or its subsidiaries. Akrl has been authorised to use Rohm & Haas registered trade marks.

Irish agency

Drynamels Ltd, the thermoset powder coatings manufacturer, has combined with Goodbody Ltd, an Irish supplier of industrial finishing materials and equipment, to provide Irish industry with a unique powder supply and technical back-up service. The Irish company, which has considerable experience in all aspects of industrial finishing, will be increasing the range of powder coatings they offer in Ireland by incorporating the high quality thermoset powder coatings manufactured by Drynamels.

Polyvinyl alcohol expansion

Du Pont has announced the completion of a 20 per cent capacity expansion of its "Elvanol" polyvinyl alcohol (PVAL) plant at La Porte, Texas. The product, which is available in five fully hydrolysed grades, is used for textile warp sizing, paper and paperboard coating, paper tube and core winding, and in the formulation of water-based adhesives. It is marketed in Europe through Du Pont's local subsidiary companies and distributors.

Bayer agents

Bayer UK Ltd have appointed two UK companies as agents for the marketing of Levasint, a fluidised bed dip coating powder specially developed by Bayer for corrosion control. Levasint will be marketed in Britain by Mallatite Plastics Ltd of Stockport, Cheshire, and McPherson Powders Ltd of Barking, Essex. Bayer is confident that Levasint will fill a significant gap in the British coating materials field as it

provides high resistance to weathering, chemicals and atmosphere in almost all applications, while at the same time being clean and safe to use.

Tate & Lyle complex

Talres Development Ltd, a wholly owned subsidiary of Tate & Lyle, have announced plans for a £10 million speciality chemical complex on the Knowsley Industrial Park, Merseyside for the production of non-toxic chemicals. This is an entirely new area for Tate & Lyle and is their first venture into this part of the chemical business. In the first phase of production, sucrose surfactant and microbial polysaccharides will be produced for use in detergents and to stabilise mixes of oils and water. The commercial production and marketing of microbial polysaccharides will be in a joint venture with Hercules Powder Co, who will bring to the joint venture their worldwide marketing experience in this field.

Agency change

The agency for the Langer range of waxes and additives has been transferred with effect from the beginning of October from Cray Valley Products Ltd to Capricorn Industrial Services Ltd.

New products

New pigment paste and binder

BASF UK Ltd has placed on the market a new product for the manufacture of gravure inks containing toluene called Heliogen Blue 716 T Paste, and a new polymer dispersion called Styronal S 342 D ca. 50% which can be used as an all-purpose binder for coating colours on paper or board.

Flying splicing adhesive

Cray Valley Products Ltd have available a new adhesive based on high molecular weight synthetic resin marketed in the form of high viscous blue coloured solution (solvent ethanol) which is easily repulpable

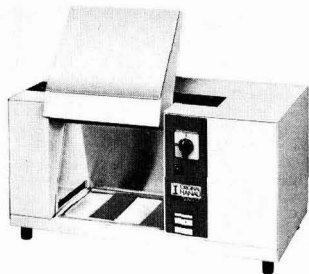
in water due to its water solubility. The F.S.A. can be used by paper converters and printers. Brush and roller applicators and containers can be easily cleaned with warm water. Full adhesive strength develops 3 minutes after application and remains for 2-3 hours without any reduction in adhesion.

Infrared drying

Lorilleux & Bolton Ltd have developed a new ink series specifically designed for infrared drying. The ink, called I-R 2000, is designed to help printers increase throughput whilst simultaneously improving quality. The ink contains a catalyst which responds to the temperature in the pile in the region of 35-40°C. Use of the new ink reduces or eliminates the need to use anti set-off sprays when stacking the sheets, and overprinting or back-up is possibly within an hour.

Suntest

Original Hanau, Germany, have available the new Suntest mini-light exposure instrument for the examination of lightfastness of paints, plastics, wood, rubber and other surface coatings. Suntest supplements the series of well known and proven Xenotest instruments, and within a short time can provide reliable information about behaviour of materials under the effect of sunlight radiation. Suntest possesses as a source a 1.4 kW Xenon radiator, the filtered spectrum of which is very near to natural sunlight. With additional filters the particularly important UV range for plastics can be variably adjusted.



The new Suntest light exposure instrument

New Vossen blue pastes

The Pigments Division of Degussa, Frankfurt am Main, has altered the formulation of the former Blue Paste D3 and has added two new red-tinged pastes for the printing

ink industry to its programme. The series now consists of the D 3 and D 4 pastes, which have the pure blue shade of the Vossen Blue 705, and the two new particularly colourful types D 3/R and D 4/R which correspond in shade with the Vossen Blue 362.

New solventless insulation coating

A solventless insulation coating, where the electrical resistance is in excess of 400 volts per mil coating thickness, has been introduced by E. Wood, Ltd a member of the Samuel Hodge group. An addition to the "Copon" range of products, the material has already been used as a membrane lining for steel electrophoretic tanks and as an electrical resisting coating for steel electrical switch boxes. The material is supplied as a liquid coating which dries quite quickly and single coats of up to 7 mils are easily attained.

Vacuum strainers for paint filtering

Kremlin Spray Painting Equipment Ltd have added the TVK system for quick filtering of thick materials to their expanding range of surface coating application equipment. The special TVK system uses compressed air to create a vacuum within the container thus reducing filtering time. Additionally, suction from underneath allows the use of finer mesh screens than with a normal gravity lid.

New safety labels

A unique new chemical labelling service has been established by Peace Hazards Ltd to overcome the numerous hazards presented when identification labels fall from chemical containers or become obliterated by the chemicals they contain. By close liaison with the customer on the formulation of the chemicals to be manufactured, the firm prepares individual labels to suit each chemical by means of an underprinting process on vinyls, polyesters, polythenes and other synthetic films, followed by a sealing process and the application of adhesives.

Furnace blacks

Degussa have introduced two new qualities to their range of high colour furnace blacks, named Printex 80 and Printex 90, which are available in fluffy and beaded form to complement the existing range of Printex 75, 85 and 95. They are characterised by easy dispersibility, high tinting strength, and conform to current legislation regarding the incorporation of carbon blacks into plastics in the EEC.

Literature, courses etc.

Organic coatings technology

The 4th Annual International Conference in Organic Coatings Technology is to be held in Athens, Greece from 17-21 July 1978.

Corrosion resistance guide

Ensecote Ltd, a subsidiary of Newton Chambers, have published a new Guide to corrosion resistance which lists 250 chemical products indicating suitability, or otherwise, for vessels protected by various types of Ensecote lining. The results have been obtained in most cases after more than 5000 hours of testing.

Electrostatic painting leaflet

Gray-Campling Ltd have published an illustrated leaflet on electrostatic spraying with a new 'Spray-O-Round' gun made by Wagner of West Germany. The leaflet gives full technical data, details optional equipment available and lists the advantages of the Wagner system.

Rubber industry review

The International Institute of Synthetic Rubber Products Incorporated (IISRP) has published the first International Statistical Review of the Synthetic Rubber Industry, also known as the Facts Book.

Chemistry and colour

The Chemical Society and the Royal Institute of Chemistry have organised a Symposium on "Chemistry and Colour" to be held on 17-18 April 1978 at University College, London.

Further information may be obtained from P. B. Baker, 6 Poplar Road, Merton Park, London SW19.

Bolt from the blue

We were pleased to receive a copy of *Team* volume 2, number 2, the house journal of RTZ Borax Ltd, which contains an article by Ronald Bolt, formerly the *onlie begetter* of Manox Blue, and long standing member of the Association. The article describes of how the company began production of Manox Blue and the part played in this by the author.

We would be pleased to receive copies of articles written by members for house journals, or other publications, as a mention of these is often of interest to other members, who may wish to write to the organisations concerned for a copy.

Report of Council Meeting

A meeting of Council took place at the Great Northern Hotel, London N1, on 12 October 1977 with the President, Mr A. McLean, in the chair. There were 26 members of Council present.

Council noted with sadness that the sole surviving Founder Member of the Association, Mr H. R. Wood, had died in July at the age of 90.

Mr W. R. Moon was appointed to represent the Association on the Technical Training Board of the Printing Ink and Roller Making Industry to replace Mr

N. C. Locke who wished to retire due to pressure of work. Mr D. M. Varley was appointed to represent the Association on the Society of Dyers and Colourists Terms & Definitions Committee in place of Mr J. C. Hurst.

It was reported that the Paintmakers Association had asked if Mr A. T. S. Rudram could serve over a period of a year on two of their committees and that this invitation had been accepted.

The half-year accounts were considered by the Council together with the estimates

for the second half of the year. It was noted with particular pleasure that for the first time the balance sheet showed the purchase of Priory House as the Headquarters of the Association, and the Honorary Treasurer asked all Sections to continue to send surpluses from Section symposia for the purpose of redecorating the interior of the building, re-equipping office machinery which had not been carried out since the move from Wax Chandlers Hall in 1972, and for security arrangements which would be necessary.

The Honorary Treasurer reported that

the number of removals from the Register for non-payment of subscription had been less than in 1976 and that applications from 14 countries, including for the first time Japan, had already been received for the 1978 Exhibition.

The Honorary Editor reported that he had received the papers presented at the second Symposium on Ultraviolet Polymerisation held by the Newcastle Section in September and these would be appearing in the *Journal* in due course.

Reports were submitted to Council on the Reunion Dinner and on the arrangements for the 60th Anniversary celebrations which would take place on 11 and 12 May 1978, full details of which would be circulated to members in due course; preliminary information is given elsewhere in this issue.

It was reported that the Professional Grade Committee had met earlier and had admitted four Fellows and eight Associates. It had been noted by that Committee that the Oil & Colour Chemists' Association Australia, were introducing a Professional Grade and it had been agreed that the same designatory letters would not be used without reference to their Australian origin. The Professional Grade Committee

had earlier met representatives of the Paint-makers Association Training & Technical Education Committee, who wished to discuss the possibility of arranging courses for the new Technician Education Council in a way which would lead either to candidates being able to proceed to the Licentiatehip, or possibly to a Technician Certificate offered by the Association at a lower level.

Reports were received on the arrangements for the Annual General Meeting of the Association which will take place on 21 June 1978 at the Piccadilly Hotel, London W1, and will take the form of a luncheon followed by a lecture to be given by Dr D. Davies, Chief Scientist of the Department of Industry, entitled "Replacement of petrochemical intermediates for downstream chemical industries", and the Annual General Meeting will take place at 3.00 p.m. or as soon thereafter as the lecture shall terminate. There was a possibility that the President and Executive Vice President of the FSCCT would be present as the Association's guests.

The New Zealand Division had submitted a draft Constitution which would be considered by the President's Advisory Committee and a full report would be made to a subsequent Council meeting.

Details were received of Section activities, including the Convention held by the New Zealand Division in August, the meetings held by the Rhodesian Branch of the Transvaal Section and the Eastern Cape Branch of the Cape Section.

It was reported that the Chairman of the Cape Section, Mr E. G. Warman, had arrived in the United Kingdom in September and contacted the Director & Secretary, who expressed his thanks to the Midlands Section for their agreement in inviting Mr Warman to be present at their Dinner Dance at very short notice. Council warmly commended this co-operation between Sections.

It was reported that the next Conference of the SLF would take place from 3-5 September 1979 and that it was hoped to arrange for a paper to be given on behalf of the Association.

The President reported that on the recommendation of the Bristol Section Committee the President's Advisory Committee proposed that a Commendation Award for long service to the Section should be made to Mr D. N. Fidler and this was agreed unanimously.

There being no other business the meeting was declared closed at 3.35 p.m.

Report of 1977 Council Reunion Dinner

A Reunion Dinner of past and present members of Council was held on Wednesday 12 October at the Piccadilly Hotel, London W1. There were 42 members present, including five Past Presidents. The Dinner followed a Council meeting held earlier in the afternoon.

After the loyal toast, the President, Mr A. McLean, gave the Address of Welcome stating that on this occasion he was particularly pleased to have been able to welcome for the first time two lady Chairmen to the function, Miss P. Magee of the Irish Section, and Mrs E. Harper of the Bristol Section.

Mr McLean then reviewed the year since the last Reunion Dinner in October 1976, during which period he had taken office. The twenty-ninth Technical Exhibition of the Association had been held at Alexandra Palace from 22 to 25 March. Visitors to the Exhibition had come from 50 countries, and the response from Exhibitors was very favourable, many having written to the Association to offer special thanks for the organisation.

A notable event in the year had been the acquisition by the Association of its own headquarters building, Priory House, and the President gave his particular thanks for the work in this matter of Mr A. T. S. Rudram, Immediate Past President, Dr H. R. Hamburg, Honorary Treasurer, and Mr R. H. Hamblin, Director and Secretary, without whose efforts the opportunity could not have been taken.

Mr McLean reported that the arrangements for the celebrations of the 60th Anniversary of the Association were now well advanced, and he announced that the speaker for the Commemorative Lecture on 11 May would be John Methven, Director General of the Confederation of

British Industry. He stated that further details of the functions on 11 and 12 May 1978 would be given in the November issue of the *Journal* (see page 465).

The Association's Biennial Conference had been held this year at the Grand Hotel, Eastbourne, from 16 to 19 June with the title 'The conservation of energy, materials and other resources in the surface coatings industry'. The overall attendance at the Conference had been somewhat down on the figure expected, in part due to a clash of dates that had occurred with the Paint-makers conference at Bournemouth. As an experiment, the Conference had been organised so as to incorporate a weekend with the objective of attracting younger delegates who might only be able to attend on a day registration on the Saturday, but in this respect, the innovation had not been successful, and Mr McLean announced that the next Conference, which would be held in Stratford, would revert in part to its more traditional timing. Nevertheless, the Conference had been an extremely friendly occasion. The standard of the papers presented had been high and it had been a very successful and happy occasion.

Mr McLean then gave a brief review of the trends in membership of the Association, and he commented that the achievement of maintaining the membership was a notable achievement in these times of amalgamation of firms and economic restriction. He reported that the number of members who had been admitted to the Professional Grade in the years since its introduction was in keeping with expectations, and he was pleased to report that the qualification was now gaining widespread acceptance, and was being used in classified advertisements for situations vacant. Recently a number of eminent members had been admitted, and lists of

new admissions were published periodically in the *Journal*.

Mr McLean concluded his address by offering his sincere personal thanks for the work performed for the Association by all the Honorary Officers of the Association, the Director & Secretary and the permanent staff at Priory House who kept the organisation running so efficiently.

Following Mr McLean's speech, Dr S. H. Bell, OBE, President 1965-67, made a short speech reviewing the Association's achievements in the past years, and for safe keeping he presented to the Association the original plaster make-up of the Presidential Insignia which had been presented to him many years earlier. The model was received by Mr McLean on behalf of the Association with thanks.

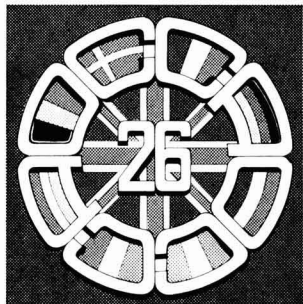
After the Dinner, the assembled company retired to a separate room to meet new and old friends.

D.M.S.

Council wishes to inform past members of Council that in 1978 the Reunion Dinner will not be held in the autumn, but will be incorporated in the 60th Anniversary Celebrations of the Association on 11 and 12 May 1978. Details of the events organised to mark this Anniversary are given on page 502.

“The OCCA”

The annual technical exhibition of the Oil and Colour Chemists' Association (known to many simply as “The OCCA”) has become the world's most important event for all those connected with the paint, printing ink, polymer, adhesive colour and allied manufacturing industries. The OCCA exhibition is held every year in London, England. The symbols for the 1974-78 exhibitions were specially designed by Robert Hamblin, Director and Secretary of the Association, to emphasise the very wide coverage which all the Association's activities attract:



The motif for OCCA-26 used the flags of the enlarged EEC converging on the British flag to symbolise the welcome extended to visitors from overseas to the Exhibitions for more than 25 years. (1974)

The motif for OCCA-30 uses the symbol of a moving indicator on a calendar to emphasise the importance of the continuous dialogue year by year between suppliers and manufacturers. The inward pointing letters recall the international



The 1974 theme continued at OCCA-27 by showing the world-wide interest aroused by the Association's annual Exhibitions in London which attract visitors from all parts of the globe.



The motif for OCCA-28 emphasised that the target for 1976 was London where all the Exhibitions have been held, and continued the theme of its international aspect.

aspect of this unique annual focal point for the surface coatings industries, which in 1977 attracted visitors from 30 countries.

In 1977 the motif for OCCA-29 used inward pointing arrows to show the many places from which people came to the Exhibition, and these arrows formed outward pointing arrows to show the subsequent spreading of knowledge.





OCCA-30 Exhibition

Alexandra Palace, London. 18-21 April 1978

The international forum
for the
surface coating industries

★ Exhibits from 14 countries ★

The Exhibition, which is known as the international forum for technical display and discussion in the surface coatings industries, is the most important annual event of its kind in the industries and it offers an unparalleled opportunity for a continuous dialogue on technical advances and problems between suppliers and manufacturers in an informal atmosphere.

Many young technologists and scientists who visited the earlier Exhibitions have now risen to high positions within their organisations and the advantage to exhibitors of keeping in constant contact with their counterparts in the manufacturing industries needs hardly to be stressed.

In recent years the Exhibitions have been visited annually by representatives from 50 countries and bringing all these interested parties together at a regular meeting is in itself invaluable when exhibitors consider the cost in time and travel which would be entailed in making personal contact with these visitors each year.

Information in foreign languages

As in previous years, the Association will be circulating information leaflets in six languages, which will contain application forms for those wishing to purchase copies of the *Official Guide* and season admission tickets before the Exhibition.

Official Guide

This unique publication contains descriptions of all companies and their exhibits at the Exhibition and is issued to each Member of the Association at home and abroad together with season admission tickets. As in 1977, several Sections will be organising coach parties to visit the Exhibition and any Members interested should contact their local Section Hon. Secretary. (Full Section Committee lists for 1978 were published in the August issue of the *Journal*.) It is also hoped that several parties will be organised from overseas to visit the Exhibition.

Advertising facilities

Advertising space is available in this important publication to both exhibitors and other organisations which are not able to show at the 1978 Exhibition. The *Official Guide* will be published early in 1978 so that visitors can obtain copies and plan the itinerary for their visits. Clearly, the *Official Guide* is a publication that will constantly be referred to both before and after the Exhibition and consequently any company wishing to advertise in the *Guide* should

book space as soon as possible. Details of the advertising rates are available from Mr D. M. Sanders (Assistant Editor) at the

address on the contents page. As in previous years the *Official Guide* and season admission tickets will be available several

Facilities at Alexandra Palace

During the period of the Exhibition the Association has full use of the facilities at Alexandra Palace which include restaurants, a cafeteria, and two licensed bars. In addition, at OCCA 30, following the successful innovation in 1977, Exhibitors will be allowed to serve alcoholic refreshments to visitors on their Stands.

For those travelling to the Exhibition by car, ample free parking space is available and recent improvements to the road system include the extension of the southbound carriageway of the M1 Motorway to the North Circular Road.

The extension of the Piccadilly Underground Line to the Heathrow Central Terminal at the airport will be open by the time of the Exhibition and visitors arriving at Heathrow Airport will have a direct link both to Central London and to Turnpike Lane Station on the Piccadilly Line, from where the Association will be running a free bus shuttle-service to and from Alexandra Palace.

Exhibitors

A full list of Exhibitors will be published in the January issue of the *Journal* following the Exhibition Committee Meeting to allocate the space and the notification of Stand areas to Exhibitors, and applications for space have already been received from organisations in **Belgium, Canada, France, East Germany, West Germany, Holland, Hungary, Italy, Japan, Poland, Spain, Switzerland, the UK and the USA.**

Exhibitors are now sending in details for their editorial entries in the *Official Guide* and, following the innovation for OCCA 29, they will also be submitting news items and photographs of latest developments for publication in the *Journal* in the months leading up to the Preview issue (April 1978).

weeks in advance of the Exhibition (pre-purchase only) from the Association's offices but they will also be available for purchase at the entrance to the Exhibition Hall. A charge is made for both the Official Guide and the season admission tickets to the Exhibition. The policy was introduced several years ago to deter casual visitors who otherwise collected large quantities of technical literature from exhibitors stands; the policy has been welcomed by exhibitors and has in no way acted as a deterrent to bona fide visitors to the Exhibition.



London Transport

Heathrow Central Terminal

London Transport have announced that the extension of the Piccadilly Underground line to the new Heathrow Central Terminal at Heathrow Airport will be opened by Her Majesty the Queen on 16 December 1977.

The first stage of the project was completed with the opening of the Hatton Cross station on the outskirts of the airport in July 1975. Work on the Heathrow Central Terminal was begun in April 1971 and has cost about £27 million, but upon opening it will provide a direct link for visitors arriving at the airport to travel into the centre of London.

The advantage to overseas visitors travelling to OCCA-30 is enormous, as it now greatly simplifies the journey, both to hotels in central London where they may be staying, and to the Exhibition. Visitors arriving at Heathrow Airport will now be able to board a Piccadilly Line train at the airport building itself which will take them directly to Turnpike Lane Station, from where the Association will be running a free bus shuttle service to and from the Exhibition. The journey from central London to Turnpike Lane station takes approximately 18 minutes.

The Piccadilly Line is being equipped with new trains in readiness for the opening of Heathrow Central. Many of the new trains are already in service, and are similar in appearance to the latest "silver" tube trains, but have a different size and layout which give more space for passengers with luggage. This makes the new enlarged Piccadilly Line one of the most reliable and comfortable forms of transport in London.

All OCCA Exhibitions have been held in London, which affords excellent travel and hotel facilities for visitors from both overseas and the United Kingdom. In pursuance of the theme of the Exhibition —*The continuous dialogue*—it is felt that Exhibitors will like to know that the Exhibition Committee has also reserved Alexandra Palace for April 1979 and will hold its annual Exhibitions there subsequently in April each year.

It will also be appreciated that for exhibitors and visitors staying in London, the capital city offers the finest variety of entertainments for the evenings after the Exhibition.

OCCA 60th Anniversary



Celebrations

As members will be aware, the Association celebrates the 60th Anniversary of its foundation in May 1978, and it is felt that members would like some details of the proposed celebrations which will take place on 11 and 12 May 1978.

The actual date of the foundation of the Association was 16 May 1918, but it has been decided that the Thursday and Friday are more appropriate times to hold the celebrations.

The May 1978 issue of the Journal will contain an article by Dr S. H. Bell, OBE (President 1965-67) on main Association events since the 50th Anniversary in May 1968. Already many companies have reserved advertising space in this important issue in order to congratulate the Association on this achievement, and others wishing to do so can obtain full details from the Assistant Editor at the Association's offices at the address on the contents page.

Commemorative Lecture and Dinner



John Methven

The Commemorative Foundation Lecture (instituted in 1963 in memory of the late H. A. Carwood, Esq., the first Honorary Secretary of the Association) will be given in the Court Room at the Painters' Hall,

Little Trinity Lane, London EC4, on the evening of Thursday 11 May by John Methven, Director General of the Confederation of British Industry. The title he has chosen is "The place of business in our society". Admittance to the Lecture will be by ticket only and will be followed by a short reception. Dinner will be taken in the Dining Hall of the Painter Stainers' Company at 8.00 p.m. Informal dress will be worn.

Tickets for the Lecture and Dinner will be available from the Association's offices at a cost of £12.00 plus VAT, and members will be sent an application form giving details in due course. The price of the ticket also includes the reception between the Lecture and Dinner, wines with the meal, and port or brandy after the meal. Past Presidents, Past Honorary Officers of the Association and Honorary Members will be invited as guests of the Association.

Commemorative Dinner Dance

The Association's Dinner Dance will be held at the Savoy Hotel, London WC2, on the evening of Friday 12 May, and Presidents of other societies, together with their ladies, will be invited to attend. Tickets, price £15.00 plus VAT will be available from the Association's offices, and members will again be sent full details.

Non-members who wish to receive application forms should write to the Director & Secretary at the Association's offices as soon as possible, particularly if they wish to make up parties (up to 12 per table) for the Dinner Dance.

H. R. Wood

Founder Member

An appreciation by Mr J. R. Tingate

As I joined Storry Smithson & Co Ltd as a Junior Laboratory Assistant, under Mr Wood in 1949, some of the earlier memories given below are culled from other of his colleagues.

Mr H. R. Wood joined Storry Smithson & Co Ltd from a company called Major & Co., who were in the tar distillation and lubricating oil business, around 1919, at the age of 33 years.

He remained with Storry Smithson & Co Ltd, first as Works Manager and Chief Chemist and latterly as Technical Manager until his retirement in 1957, at the age of 70 years.

During his career he was a founder member of both the Oil & Colour Chemists Association and the Research Organisation of Ships Composition Manufacturers. He was also co-author of a book on drying oils with A. S. Morrell.

Mr H. R. Wood was a brilliant thinker, at times unorthodox in his approach to problems. He crossed the frontier from the art of the old technology "The paint industry is a three legged stool, white lead, linseed oil and turpentine", to the science of the new, with its high polymer emulsions, alkyds and titanium dioxide, and was equally adept in both fields.

He was a kind man, but a strict disciplinarian.

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Biennial Conference PREPRINTS

The Association organises an international Conference every two years and preprints of the papers are prepared for delegates. A strictly limited number of the following are available to those who wish to have the complete bound sets of papers.

1977 Eastbourne *The conservation of energy, materials and other resources in the surface coatings industries.* Fourteen papers presented. **Price: £5.00**

1975 Scarborough *Performance of surface coatings—does reality match theory?* Seventeen papers presented. **Price: £5.00**

1973 Eastbourne *Towards 2000.* Sixteen papers presented. **Price: £5.00**

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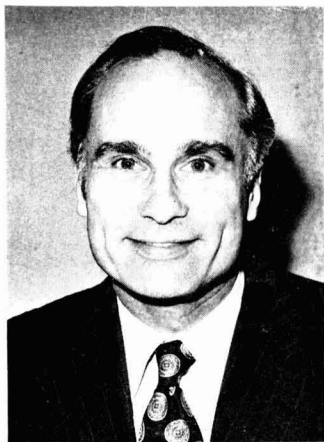
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plinian, always willing to pass on his knowledge if the pupil showed a willingness to learn. Round about the age of 65 years he took up photography as a hobby, joining the local photographic society, after that he was rarely seen without his camera.

Right up to retiring age, Mr Wood rode a bicycle from his home to the Works, through all weathers.

A remarkable man.



Dr J. D. Sanders

News of Members

Dr E. J. Percy, an Ordinary Member attached to the General Overseas Section, has been appointed a Technical Director of Synres International.

Mr D. Sharpe, an Ordinary Member attached to the London Section and an Associate in the Professional Grade, has been appointed Head of Short Term Research & Development with Sericol.

Mr C. A. Soman, an Ordinary Member attached to the General Overseas Section, has been elected to the Board of Directors of Terpenos Espanoles S.A. Olmedo, Spain, and promoted to the position of Director, Operations & Research.

Mr D. Murray, an Ordinary Member attached to the Manchester Section, has become the first recipient of the Queen Elizabeth II Silver Jubilee Award from the Institute of Quality Assurance in recognition of his outstanding contribution to the cause of quality assurance during the period 1972 to 1977.

Dr J. D. Sanders, an Ordinary Member attached to the Manchester Section, has been appointed the Marketing Manager for printing ink and wallpaper of Ciba-Geigy's Pigments Division.

Newcastle Section

The British Titan Cup

The sixteenth annual tournament for the British Titan Cup was held on Saturday, 24th September 1977 at the Bolden Golf Course.

The tournament was originally arranged for the 18th June, at Whitby, but the date had been delayed due to commitments by many members of the section. The competition, a Stapleford, was won jointly by I. B. Bolam and R. G. Carr.



Mr I. B. Bolam and Mr R. G. Carr, joint winners of the British Titan Cup

Register of Members

The following elections to membership have been approved by Council. The Section to which each new Member is attached is given in italics.

Ordinary Members

DAWSON, GEOFFREY JOHN, BSc, Flat One, 50 Palatine Road, Didsbury, Manchester M20 9JL. (*Manchester*)

ELLIS, HUBERT GEOFFREY, BSc, PO Box 6621, Kopje, Rhodesia. (*Transvaal*)

ERICHSEN, BJOERN M, Wasserwerkstr 11, D-5870 Hemer 2, West Germany. (*General Overseas*)

GLOSSOP, KEITH, 5 Bridge Road, Rodley, Leeds 13. (*West Riding*)

HAMMOND, DENNIS ROY, PO Box 2596, Salisbury, Rhodesia. (*Transvaal*)

HOLEY, DAVID, LRIC, 791 High Street, Lower Hutt, Wellington, New Zealand. (*Wellington*)

LAWTON, KENNETH, 67 Norton Crescent, Towcester, Northants NN12 7DW. (*Thames Valley*)

LEYLAND, JOSEPH NEVILLE, 9 Woodside Avenue, Burnage, Manchester 19. (*Manchester*)

MORRIS, ADRIAN JOHN, BSc, 17 Brocks Way, Shiplake, Henley-on-Thames, Oxon. (*Thames Valley*)

MYMIN, MORRIS ISAAC, BSc, PO Box 4396, Johannesburg 2000, South Africa. (*Transvaal*)

NEMETI, DESMOND, BSc, 7 Iris Road, Norwood, Johannesburg 2192, South Africa. (*Transvaal*)

PARKER, TERRY, 3 Boston Close, Chaddesden, Derby DE2 6WB. (*Midlands—Trent Valley Branch*)

PICKETT, ROY ALLAN, BSc, 33 Melrose Street, Melrose, Johannesburg 2196, South Africa. (*Transvaal*)

POTTER, FRANCIS, 14 Bishop's Road, Belvedere, Salisbury, Rhodesia. (*Transvaal*)

PREECE, LESLIE GRAHAME, 5 Traill Road, Mount Pleasant, Salisbury, Rhodesia. (*Transvaal*)

Qureshi, Javed Mumtaz, BSc, 7 Candover Street, London W.1. (*London*)

RYAN, WINIFRED CONSTANCE, BSc, Standards Association of Central Africa, Box 2259, Salisbury, Rhodesia. (*Transvaal*)

SAMUEL, DAVID NUTTALL, BSc, WR Grace Ltd, Technical Centre, Cromwell Road, St. Neots, Huntingdon, Cambs. (*London*)

SCHLENKE, JOHANNES EWALD, 3 Braemar Avenue, Northwood, Salisbury, Rhodesia. (*Transvaal*)

SKOTARAS, YANNIS, 2 Siokou Street, Agia Paraskevi, Attikis, Athens, Greece. (*General Overseas*)

TURNBULL, RODERICK BRYAN, Dulux Rhodesia Ltd, Box ST 92, Southerton, Salisbury, Rhodesia. (*Transvaal*)

TURNER, ALAN ROBERT, PO Box 3229, Salisbury, Rhodesia. (*Transvaal*)

WRAY, JEREMY RICHARD, Canal Basin, Brome Hall Lane, Lapworth, Warwicks. (*Midlands*)

Registered Students

CARR, KEVIN MARK FRANCIS, 17 Sandhurst Drive, Buckingham, Bucks. (*Thames Valley*)

DUCKITT, GRAHAM PAUL, 9 Rosetta Drive, Four Lane Ends, Bradford, West Yorks BD8 9SA. (*West Riding*)

JOHNSTONE, PHILIP JAMES, 9 Cartwood Road, Bramhall, Cheshire SK7 3EL. (*Manchester*)

Optional Professional Grade for Ordinary Members

Routes to the three Grades

Anyone who had allowed his membership of the Association to lapse and now desires to rejoin the Association is reminded that previous service as an Ordinary member (or Registered Student) can be counted towards the qualifying period of membership set out in the regulations.

The attention of senior members of the Association is particularly drawn to the Licentiate Grade and they are asked to encourage younger technical personnel to take advantage of this important Association activity. Several Colleges are now willing to help suitable candidates with the preparation of dissertations and a list of Colleges was given on page 349 of the September 1976 issue of the *Journal*.

Reprints of the regulations covering the Professional Grade are obtainable from the Association's offices, together with application forms.

List of successful candidates

As laid down in the report of the Working Party on Education, Training and Qualifications which was adopted in the institution of the Professional Grade, a list of all those Members who have entered the Grade will be published in the December issue of the *Journal* each year. The sixth such list appears below and includes the names of members resident in 39 countries.

The Section to which the Member is attached is given in italics.

The certification fees at present are: Fellows £10.00 + VAT, Associates £6.00 + VAT, and Licentiates £3.00 + VAT. The amended regulations for admission to every grade last appeared in full in the April 1977 issue of the *Journal*.

Fellows

- Anderson, George (*Scottish*)
 Apperley, Thomas William James (*West Riding*)
 Archer, Harold (*Manchester*)
 Arnold, Michael Henry Miller (*London*)
 Ashworth, Norman (*Manchester*)
 Atherton, Donald (*Scottish*)
 Austin, Denis Leonard (*Bristol*)
 Bailey, John Noel (*Newcastle*)
 Balbi, Giorgio (*General Overseas—Italy*)
 Banfield, Thomas Arthur (*London*)
 Beachen, John Frederick (*Auckland*)
 Beere, Andrea Jaimie (*Thames Valley*)
 Bell, Sydney Hector (*London*)
 Bennett, Norman Arthur (*General Overseas—Malta*)
 Bester, Lawrence Percy (*Transvaal*)
 Bews, Ian Charles Randall (*London*)
 Bhumkar, Chidanand Jayram (*General Overseas—India*)
 Birrell, Peter (*Ontario*)
 Bishop, Eric Harold Abbott (*Thames Valley*)
 Bohringer, Eberhard (*London*)
 Boroky, Joseph Stephen (*General Overseas—Australia*)
 Bourne, John Robert (*Midlands—Trent Valley Branch*)
 Brooks, Leo James (*London*)
 Brown, Arthur Ernest Girdlestone (*London*)
 Butcher, George Alfred (*Midlands*)
 Butcher, Kenneth William George (*Manchester*)
 Butler, Cecil (*West Riding*)
 Caldwell, David George (*Wellington*)
 Campbell, George Alexander (*Manchester*)
 Carr, William (*Manchester*)
 Carter, Eric Victor (*Midlands*)
 Chatfield, Herbert Walter (*London*)
 Chessman, Clifford Reginald (*Transvaal*)
 Clarke, Harry James (*Midlands*)
 Colborn, Douglas Charles (*Thames Valley*)
 Cole, Derek (*General Overseas—Australia*)
 Cole, Reginald Joseph (*London*)
 Collier, Claude William (*Midlands—Trent Valley Branch*)
 Collings, Arthur Geoffrey (*London*)
 Cook, Harold Gilbert (*London*)
 Coupe, Raymond Richard (*London*)
 Coverdale, Peter Frederic Muir (*Midlands*)
 Cutter, John Outram (*London*)
 Davidson, John Dixon Wilson (*Scottish*)
 Day, Keith Julian (*London*)
 Duckworth, Samuel (*Manchester*)
 Dunkley, Frederick George (*Midlands—Trent Valley Branch*)
 Durrant, George Geoffrey (*Hull*)
 Easton, James Douglas (*Ontario*)
 Ellinger, Marianne Livia (*London*)
 Erntwistle, Thurston (*Newcastle*)
 Ernst, Joel (*London*)
 Faulkner, Raymond Noel (*London*)
 Finn, Stanley Russell (*Hull*)
 Fullard, John Edward (*Transvaal*)
 Gate, Peter Atholl Jackson (*Transvaal*)
 Gay, Philip James (*Hull*)
 Geelay, Victor Peter (*London*)
 Gellman, Alexander (*London*)
 Giesen, Mathias Franz (*General Overseas—Germany*)
 Gillan, James Graham (*Manchester*)
 Gollop, Percy Lionel (*London*)
 Gosling, Harry (*Manchester*)
 Graham, Thomas (*Manchester*)
 Grainger, William Alan (*Irish*)
 Gray, Denis Roy (*West Riding*)
 Grover, Donald Henry (*London*)
 Hampton, Horace Arthur (*Manchester*)
 Hawkey, John Albert Lawrence (*London*)
 Hess, Manfred (*London*)
 Hill, Lawrence Albert (*General Overseas—Australia*)
 Hipwood, Hubert Allan (*London*)
 Hodgson, Kenneth Vickerson (*Newcastle*)
 Holbrow, Gordon Leonard (*London*)
 Holt, Alfred Gordon (*Thames Valley*)
 Hutchison, Geoffrey Herbert (*Scottish—Eastern Branch*)
 Inshaw, John Leslie (*Thames Valley*)
 Jacob, Basil (*Thames Valley*)
 Jolly, Anthony Charles (*Manchester*)
 Kalewicz, Zdzislaw (*General Overseas—France*)
 Kane, Joseph Richard (*London*)
 Keenan, Henry Wilfred (*London*)
 Kinsman, Roy Granville (*Transvaal*)
 Kotwal, Hoshidar Peshotan (*General Overseas—Pakistan*)
 Kut, Siegmund (*London*)
 Landmann, Axel Wolfgang (*London*)
 Lasser, Howard Gilbert (*General Overseas—USA*)
 Lewin, John Buckingham Grey (*London*)
 Lewis, Fred (*Manchester*)
 Ley, John Barry (*London*)
 Lomas, Harold (*Ontario*)
 Long, Denis Terence (*Irish*)
 Lunt, Walter Richard (*West Riding*)
 McKelvie, Archibald Neil (*London*)
 McLean, Angus (*Scottish*)
 McWilliam, Anthony (*Manchester*)
 Mell, Cedric Charles (*Hull*)
 Mitchell, John Edmund (*Manchester*)
 Mole, Seymour Lloyd (*Ontario*)
 Moll, Ivor Stuart D'avers (*Manchester*)
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Forthcoming Events

Details are given of Association meetings in the United Kingdom and Ireland up to the end of the month following publication and in other parts of the world up to the end of the second following publication.

December

Thursday 1 December

Newcastle Section: "Some aspects of the marketing of paint" by Mr G. Campbell, Crown Decorative Products, at St Mary's College, University of Durham, Elvet Hill Road, Durham.

Monday 5 December

Hull Section: "Subjective comparisons—what does influence you?" by Dr W. E. Craker, Laporte Industries Ltd, at the George Hotel, Land of Green Ginger, Hull, at 6.30 p.m.

Manchester Section: Lecture—Joint Institute of Printing/OCCA Manchester Section meeting—details to be announced.

Tuesday 6 December

West Riding Section: "Printing ink systems for textile colouration by sublimation and diffusion transfer methods" by Mr F. D. Hough, Coates Bros. Inks Ltd, at the Mansion Hotel, Roundhay Park, Leeds 8, at 7.30 p.m.

Thursday 8 December

Scottish Section: "Chemical waste disposal" by J. Smith, Re Chemicals International Ltd, at the Bellahouston Hotel, Glasgow, at 6.00 p.m.

Thames Valley Section: "Steel blasting—recent developments" by Mr T. W. Kelsall, KUE Engineering Ltd, at the Beaconsfield Crest Motel (White Hart), Aylesbury End, Beaconsfield, Bucks, at 6.30 for 7.00 p.m.

Friday 9 December

Irish Section: "Up to date position of EEC legislation on dangerous substances/preparations" by Mr F. Shaughnessy,

Department of Labour, at the Clarence Hotel, Dublin 2, at 8.00 p.m.

Wednesday 14 December

Scottish Section—Eastern Branch: "Hot stamping foils and gold leaf" by Mr B. J. Sitch, George M. Whaley Ltd, at the Alfton Hotel, 6 Grosvenor Crescent, Edinburgh 12, at 7.30 p.m.

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January

Tuesday 3 January

West Riding Section: "Flexible liquid epoxy resin systems" by Mr A. G. McKay and Mr P. T. Brown of Ciba-Geigy Plastics Division at The Mansion Hotel, Roundhay Park, Leeds 8, commencing at 7.30 p.m.

Thursday 5 January

Newcastle Section: "The Central Electricity Generating Board requirements for surface coatings" by Mr D. A. Bayless, Scientific Services Dept., CCEGB, at St. Mary's College, University of Durham, Elvet Hill Road, Durham.

Monday 9 January

Hull Section: "Prediction of performance: fact or fiction", by Mr D. M. Bishop, The Railway Technical Centre, Derby, at the George Hotel, Land of Green Ginger, Hull at 6.30 p.m.

Friday 13 January

Manchester Section: "Modern paint manufacturing techniques by Mr B. Lucas, Joseph Mason Ltd, to be held at the Manchester Literary & Philosophical Society, Manchester, commencing at 6.30 p.m.

Scottish Section: Ladies' Annual Evening—Dinner Dance in Albany Hotel, Glasgow.

Wednesday 18 January

Scottish Section—Eastern branch: "Printinks for paper—present and future developments" by Mr G. H. Hutchinson at the King Malcolm Hotel, Dunfermline at 7.15 p.m.

Ontario Section: "Anticorrosive functional pigments" by Dr P. Marr, Reed Ltd, at the Skyline Hotel, Toronto, at 6.00 p.m.

Thursday 19 January

London Section: "Finishing of exterior timber" by Dr E. R. Miller, at the Princess Alice, Romford Road, E7 commencing at 8.00 p.m.

Friday 20 January

Irish Section: Ladies' Evening. "Interior designs" by Mrs A. Dalton, RIDipl, AIDP, of Andrian Interiors, at the Clarence Hotel, Dublin 2 at 8.00 p.m.

Midlands Section: "Export/import of technology" by Mr A. G. North, Cray Valley Products Ltd, at the Birmingham Chamber of Industry and Commerce.

Thursday 26 January

Thames Valley Section: "Chemical colouring of metals" by Mr G. Pollock of Osro Ltd, at the Beaconsfield Crest Motel (White Hart), Aylesbury End, Beaconsfield, Bucks at 6.30 for 7.00 p.m.

Friday 27 January

Bristol Section: "Abatement of paint stoving effluent" by Mr N. A. R. Falla of The Paint Research Association, at the Royal Hotel, Bristol at 7.15 p.m.

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Association Notices

Binding of Journal

Members will be pleased to know that J. S. Wilson & Son, 14a Union Road, Cambridge CB2 1HE, will undertake the binding of back volumes of the Association's *Journal* sent in by individual Members at a cost of £6.00 (including postage and packing) per volume.

Members wishing to avail themselves of this facility should send the parts, securely wrapped, direct to J. S. Wilson & Son, enclosing a remittance of £6.00 (including postage and packing) per volume, and ensuring that notes bearing their names and addresses are enclosed with the parcels. It is particularly important that packets are sufficiently wrapped to negate the possibility of damage in the post.

1978 Members' subscriptions

Members are reminded that 1978 Membership subscriptions to the Association are payable on 1 January 1978. Forms were despatched to all Members in October or November, depending upon address.

The Commissioners of Inland Revenue

have approved of the Association for the purpose of the 1970 Income and Corporation Taxes Act Section 192, so that a Member subject to United Kingdom income tax is entitled to a deduction from the amount of his emoluments assessable to income tax under Schedule E for the whole of the annual subscription to the Association, provided the subscription is defrayed out of the emoluments of his office or employment and that the interests covered by the objects of the Association are relevant to such office or employment.

Members resident in the United Kingdom are reminded that if there is any change in the standard rate of Value Added Tax announced before they send in their 1978 subscription, the VAT payable on membership subscriptions is the amount which applies on the date of payment.

1978 library subscriptions

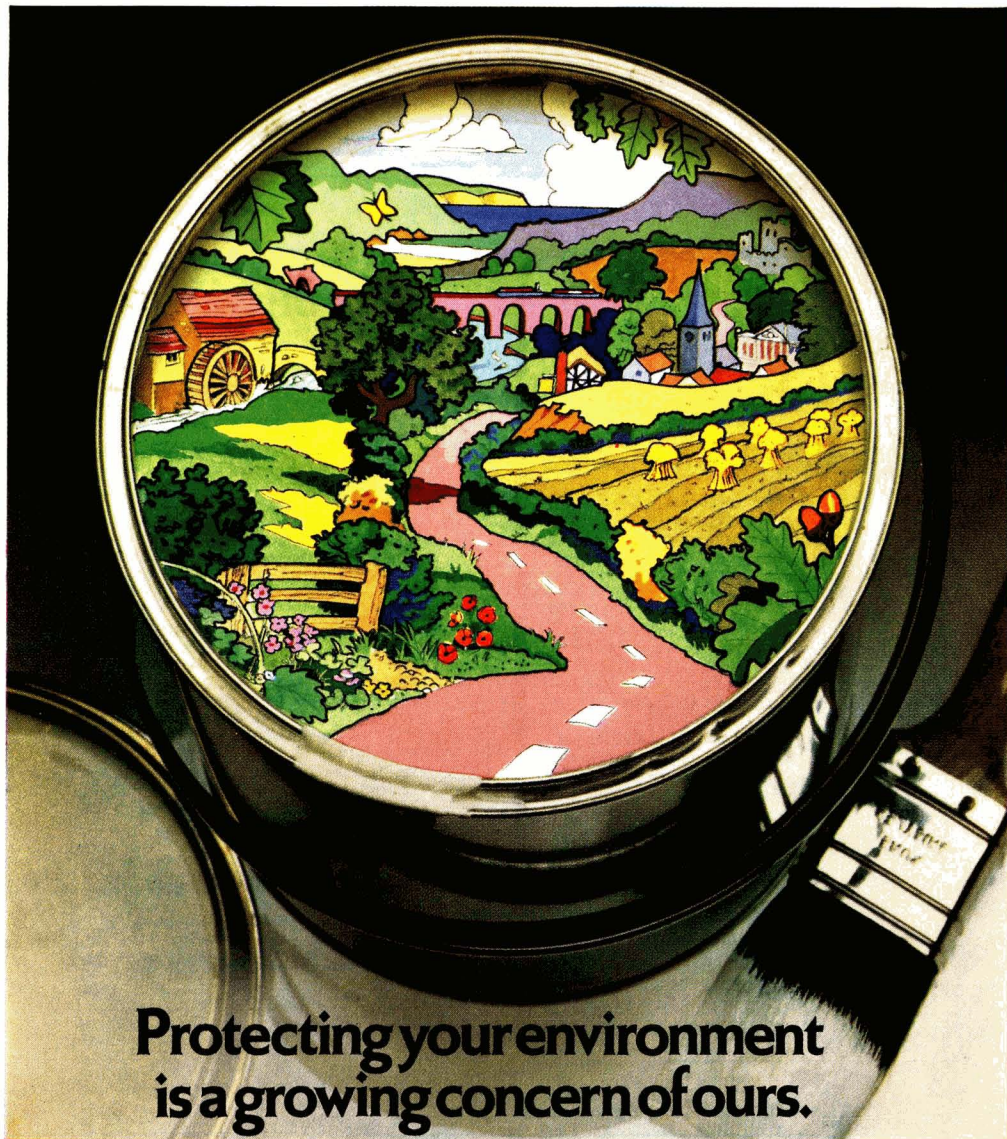
The *Journal* subscription rate to non-Members, including libraries, for 1978 will be £25.00 (\$60) post free by surface mail, home and abroad. Individual copies

can be purchased for £2.50. Remittance should be sent with order to the Association's offices.

Retired members

Council also wishes it to be known widely that in 1962 it introduced a reduced Membership subscription rate for Members who have retired from business. This applies to a Member who has completed 20 years as an Ordinary or Associate Member and has retired from business, and normally has reached the age of 60; he may apply for his name to be retained on the Register of Members at an annual subscription rate of £1.50 and he will retain the same rights of Membership as the class of Membership to which he was attached upon retirement.

Members wishing to avail themselves of this concession should write, in confidence, to the Director & Secretary at the address shown on the front cover of this *Journal*, giving the relevant information under the four headings: (a) name, address and Section, (b) date of election, (c) date of retirement, (d) age.



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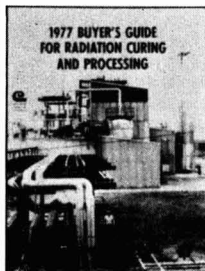
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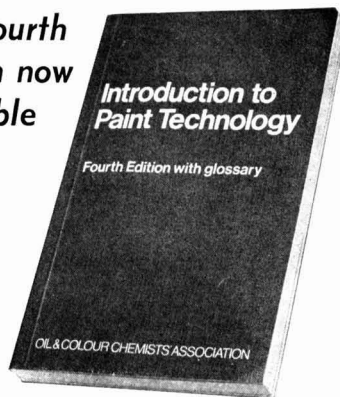
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