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OIL & COLOUR CHEMISTS' ASSOCIATION

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OLYMPIA LONDON APRIL 1975

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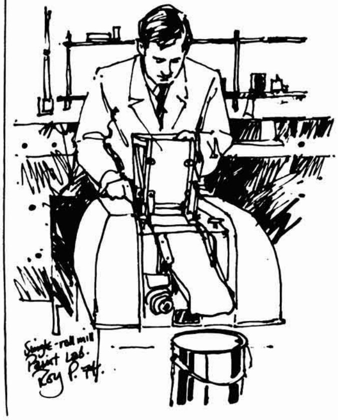

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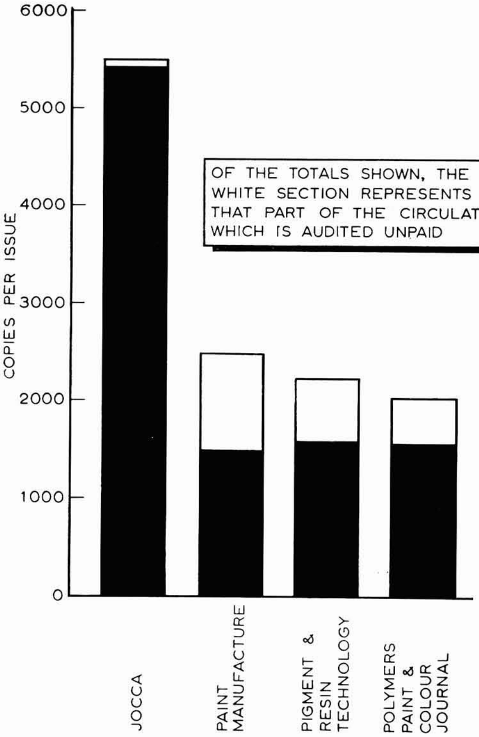
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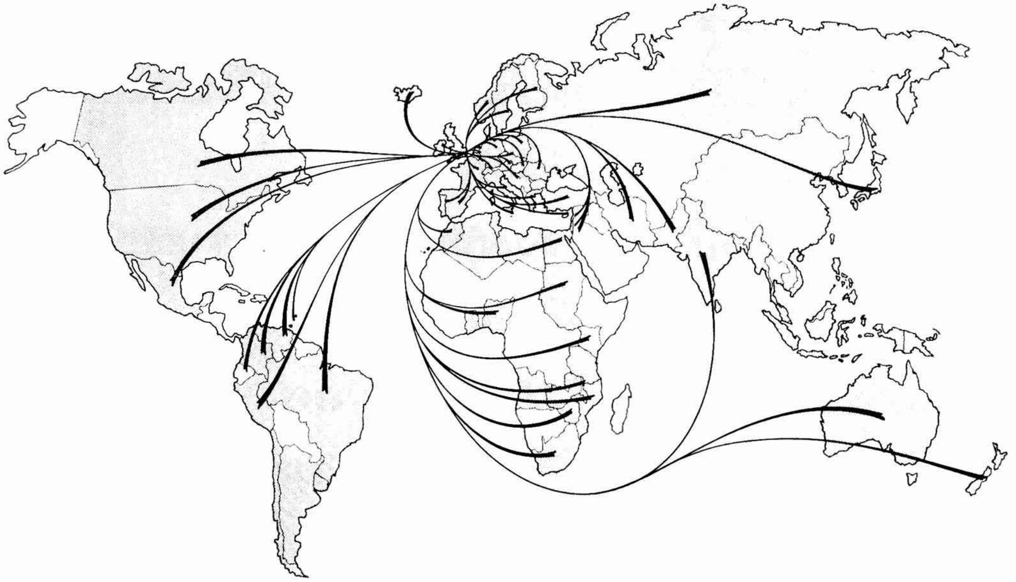

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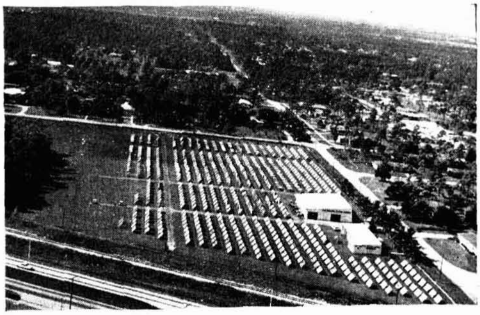

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Transactions and Communications

Blistering of varnish films on substrates induced by salts

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Summary

A method has been devised for a quantitative study of the blistering caused by osmosis, which consists of depositing exactly known amounts of a salt on to a substrate, and then applying a semi-permeable coat over the salt on the substrate.

After immersion of the system (polyurethane, epoxy or chlorinated rubber on stainless steel) in distilled water, the growth of the blisters, caused by the salt, has been studied.

This study made it possible to calculate the relation between the product of mean diffusion coefficient and mean water concentration in the film ($\bar{D} \times \bar{C}_W$) with the activity of water in the salt solution inside the blister. The relation represents the transport of water through the varnish film into the blister. The water transport has been determined also through free films of the same type of varnish by permeation measurements with Payne Cups at different water activities.

By correlating the results of these two series of experiments, it became evident that for the particular materials used the mechanism of water transport was identical, because the same type of relation $\bar{D} \times \bar{C}_W = f(a_1)$ was found. The result proves that in these experiments the water transport into the blister showed no pronounced influence due to adhesion on the substrate, nor to the visco-elasticity of the films.

Keywords

Processes and methods primarily associated with analysis, measurement or testing

diffusion
osmosis

Properties, characteristics and conditions primarily associated with:

materials in general
permeability

dried or cured films
blistering

Le cloquage des feuils de vernis provoqué par les sels déposés sur les supports

Résumé

On a mis au point une méthode pour étudier quantitativement le cloquage provoqué par l'osmose, et elle comprend la déposition sur le support des quantitiés exactes d'un sel, et ensuite l'application sur ce support d'une couche semi perméable. Après le système (polyuréthanne, époxyde ou caoutchouc chloré sur acier inoxydable) avait été immergé en eau distillée, on a étudié la prolifération des bulles provoquées par le sel.

Grâce à cette étude, il était possible de calculer le rapport entre le produit du coéfficient moyen de diffusion et de la concentration moyenne d'eau dans le feuil ($\bar{D} \times \bar{C}_W$) et l'activité de l'eau dans laquelle est dissous le sel qui est présent à l'intérieure de la bulle. Le rapport décrit le transport d'eau à travers le feuil de vernis et vers l'intérieure de la bulle. Le transport d'eau a été déterminé au moyen des coupes Payne par les mesures de la perméation des feuils détachés du même type de vernis à de diverses activités d'eau.

En raison d'une corrélation des résultats à partir de ces deux séries d'expériences, il devenait évident, dans le cas des matériaux employés, que le mécanisme du transport d'eau était le même, puisqu'on trouvait le même genre de rapport $\bar{D} \times \bar{C}_W = f(a_1)$. Le résultat prouve que l'osmose seule décide, dans ces cas, la prolifération des bulles. D'ailleurs le résultat indique que dans ces expériences le transport d'eau vers l'intérieure de la bulle ne montrait pas d'influence profonde à cause de l'adhérence au support ou de la viscoélasticité du feuil.

Durch auf Substraten befindliche Salze verursachte Blasenbildung in Lackfilmen

Zusammenfassung

Es wurde eine Methode zur quantitativen Untersuchung der durch Osmose verursachten Blasenbildung entwickelt. Sie besteht darin, dass auf ein Substrat genau bekannte Mengen eines Salzes und danach darüber eine halbdurchlässige Beschichtung aufgebracht werden. Nach Immersion des Systems (Polyurethan, Epoxy oder Chlorkautschuk auf nichtrostendem Stahl) in destilliertes Wasser wird das durch das Salz verursachte Wachsen der Blasen geprüft.

Diese Untersuchung ermöglichte es, die Beziehungen zwischen dem Produkt des durchschnittlichen Diffusionskoeffizienten und der durchschnittlichen Wasserkonzentration im Film ($\bar{D} \times \bar{C}_W$) mit der Aktivität von Wasser in der innerhalb der Blase befindlichen Salzlösung zu berechnen. Die Beziehung drückt die Wasserbewegung durch den Lackfilm in die Blase aus. Der Wassertransport wurde ausserdem durch freitragende Filme derselben Lacksorte mittels Permeabilitütsmessungen bei verschiedenen Wasseraktivitäten mit dem Payne Cup bestimmt.

Durch Korrelation der Ergebnisse dieser beiden Experimentreihen, wurde bewiesen, dass der Mechanismus des Wassertransportes insbesondere für die benutzten Materialien identisch war, weil nämlich die gleichartige Beziehung ($\bar{D} \times \bar{C}_W$) = f (a_1) gefunden wurde. Das Ergebnis beweist, dass das Wachsen von Blasen in diesen Fällen tatsächlich nur von Osmose bestimmt wird. Ausserdem zeigt das Resultat, dass in diesen Experimenten der Wassertransport in das Innere der Blasen weder durch Haftung zum Substrat noch durch die Viskoelastizität des Films merklich beeinflusst wurde.

Introduction

Refs. 1-10

Blistering of paint films on a substrate is a very common phenomenon. Although a large amount of literature exists on this subject, a quantitative explanation has been lacking up to the present time. This state of affairs is certainly due to the complexity of the phenomenon which involves a number of physico-chemical processes, such as diffusion of water, loss of adhesion and deformation (bending and stretching) of the film.

A detailed review of the literature about the causes and the mechanism of blistering has been given by Kresse[1]. From the review it follows, for example, that in case of blistering osmosis often plays a role. Data about this phenomenon have been described by Kittelberger and Elm[2], Finn[3], Prosser and Bullett[4], Funke[5], Hamann[6], Gray[7], James[8] and Brusher and Nurse[9]. Their investigations were mainly of a qualitative nature. Although other causes than osmosis may be responsible for blistering, it seemed useful to study the growth of blisters, reproducibly formed by water transport induced by dosed amounts of salt. This procedure facilitates a quantitative study of blistering. From such experiments, conclusions as to the influence of the adhesion of the system or of the visco-elasticity of the film can be studied if semi-permeable varnish films are used. Therefore, the types of varnish used by Perera and Heertjes[10] (who proved that these varnishes behave as semi-permeable membranes) have been used in this work.

The process of water transport through the film to the salt inside a blister has been calculated by applying the law of osmosis. The transport of water through the varnish film into the blisters is compared with the transport of water in the Payne Cup tests through free films of the same varnishes.

Theory

Refs. 10, 11

The main feature of blistering is the accumulation of water between the paint film and the substrate. This accumulation is the result of a unidirectional transport of water through the film.

Research on steady-state permeation of water through free paint films has been carried out by Perera and Heertjes[10], using the Payne Cup test method. In their work, it was also shown[10c] that a free paint film of polyurethane, epoxy-based or chlorinated rubber behaves like a semi-permeable membrane. The transport of water through these free films, flux q, is determined by the law of osmosis given by equation (1).

$$q = \frac{\bar{D}\,\bar{C}_W\,\bar{V}_m\;\Delta\pi}{L\,R\,T} = \frac{\bar{D}\,\bar{C}_W \ln\frac{a_2}{a_1}}{L} \quad \ldots\ldots\ldots(1)$$

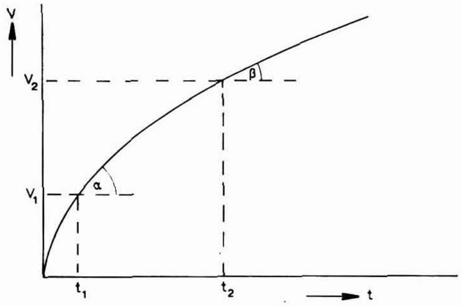
in which a_1 is the activity of water in a salt solution and a_2 the activity of pure water. The activity of water vapour with a pressure p is given by

$$a = p/p_o$$

in which, at the same conditions of pressure and of temperature, p = vapour pressure of water above the salt solution, p_o = vapour pressure of water in the pure state. The activity a_2 of pure water is equal to unity according to this definition. $\bar{D}$ is the mean diffusion coefficient, $\bar{C}_W$ the mean water concentration in the film, $\bar{V}_m$ the partial molar volume of water, π the osmotic pressure, L the thickness of film, and R and T the gas constant and temperature, respectively. A series of experiments has been carried out in which blistering was produced by known amounts of a salt, deposited on stainless steel as the substrate. Diffusion of water to the salt leads to the growth of blisters.

In contrast to the Payne Cup test, the permeation of water in these cases is a non-steady-state process because the salt solution inside the blister is being diluted continuously by the water diffusing into the blister.

This dilution corresponds to an increase of the water activity a_1 inside the blister. Since a_1 increases, the flux of water and correspondingly the growth of the blister is not constant in time (Fig. 1). When the total unsteady process is considered, for any step of short time interval, the flux of water can be given by equation (2), taking the activity for that step to be constant:



$$\tan\alpha = \left(\frac{dV}{dt}\right)_{t_1} = q_1 MS$$

$$\tan\beta = \left(\frac{dV}{dt}\right)_{t_2} = q_2 MS$$

Fig. 1. Blister volume as a function of time

$$q = \frac{1}{MS}\frac{\Delta V}{\Delta t} = \frac{\bar{D}\,\bar{C}_W\,\bar{V}_m\,(\Delta\pi - P_k)}{LRT} = \frac{\bar{D}\,\bar{C}_W\left(\ln\frac{a_2}{a_1} - \frac{P_k}{RT}\right)}{L} \quad \ldots\ldots\ldots(2)$$

where MS is the mantle surface area, $\Delta V/\Delta t$ is the change in blister volume with time, and P_k the compressive pressure.

When blistering occurs it is also of interest to investigate whether the forces of adhesion and rigidity, represented in the term P_k, will oppose the transport of water into the blister.

In preliminary exploratory work, the varnish film was detached from a substrate and at the same time deformed like a blister. These experiments were carried out by forcing a fluid, under controlled pressure, between the coating and the substrate, via a small hole in the latter. It was found that liquid pressures below atmospheric pressure were sufficient to detach the film. This pressure can be neglected in comparison with the osmotic pressure. The study on this subject of adhesion is being continued.

In addition, a theoretical estimation can be made of the liquid pressure inside a blister needed to deform a film into the shape of a blister. From Timoshenko's theory of "Plates and Shells[11]" the pressure needed to deform a thin circular or elliptic plate can be calculated.

A blister surface can also be regarded as a thin plate of which a circular or elliptic part is stretched and bent. The relation between the internal liquid pressure P_k and the geometrical dimensions at the blister is given by:

$$P_k = \frac{E}{0.176} \frac{L^4}{r_1^2 r_2^2} \left(\frac{h}{L} + 0.583 \frac{h^3}{L^3} \right) \quad \ldots\ldots\ldots\ldots (3)$$

where E is Young's modulus, L the thickness of film, h the height of blister or drop of salt solution, and r the radius.

Equation (3) has been used to calculate the pressure inside a number of blisters of various sizes. The pressures were found to lie between 6 and 40kPa (0.06 and 0.4 atmosphere). These values are low in comparison with the osmotic pressure, so it was concluded that the pressure P_k inside a blister has only a negligible influence on the osmotic transport of water, although it would determine possibly the peeling of the film during the growth of the blister.

Equation (1) has been used for the calculation of the permeation through free films and Equation (2) for the diffusion of water into the growing blister; from these the relationship $\overline{D} \times \overline{C}_W = f(a_1)$ can be calculated. Values have been compared for the series of experiments with different types of varnish.

Experimental

Blistering tests

Materials

The following binders were used:

a two-component polyurethane resin (Metakote);

an epoxy resin (Epikote 1001) cured with diethylene triamine (ratio 25 : 1 by weight);

a chlorinated rubber (Pergut S-20).

The coatings investigated are all semi-permeable.

The salts used were:

magnesium acetate, $Mg(CH_3COO)_2 \cdot 4(H_2O)$;

sodium sulfite, $Na_2SO_3 \cdot 7(H_2O)$.

The substrate was stainless steel degreased at 120°C in perchloroethylene.

Dosage of salt on the substrate

Accurate dosage of the salt is very important in order to obtain reproducible results. From a salt solution of an exactly known concentration (1 per cent by weight), a small drop was deposited on the substrate by means of a syringe. This drop was photographed immediately. Since it has the form of a segment of a sphere, its volume can be calculated from its height h and the diameter of the base $2r$.

$$V_{drop} = 0.167\,\pi h\,(h^2 + 3r^2) \quad \ldots\ldots\ldots\ldots (4)$$

After evaporation of the water, the salts used remain behind as a flat spherical homogeneous segment several microns high, contrary to, for example, sodium chloride which forms large cubical crystals on the surface.

The amount of salt on the surface can be calculated from the concentration of the solution and the volume of the drop. The quantities of salt used range from 1 to 20µg, with an experimental error of 1 per cent.

Test panel preparation

The binder solutions were cast on the substrate by means of a Gardner blade and left in a room at constant temperature (23°C) and relative humidity (50 per cent) (standard conditions ISO/DIS 3270) for a period of 45 days.

Measurement of the blisters

The test panels were immersed in distilled water; they were removed at regular intervals, wiped dry, and studied under a "Lichtschnitt" microscope. This microscope gives an image of a cross-section through the blister, so that the dimensions of the latter can be measured. The blister has the form of a segment of a sphere or of an ellipsoid. Its volume is given by

$$V_{blister} = 0.167\,\pi h\,(h^2 + 3r_1 r_2) \quad \ldots\ldots\ldots\ldots (5)$$

The mantle surface MS, through which water is transported, is given by

$$MS = \pi\,(h^2 + r_1 r_2) \quad \ldots\ldots\ldots\ldots (6)$$

During the first days of the experiments, the blisters grow fast and measurements had to be taken daily. Since the rate of growth gradually decreases, the interval between measurements was eventually increased to one week.

Steady-state permeation tests with free varnish films

Ref. 12, 10c

Materials

The same varnishes as used for the blistering tests were applied to tin foil.

Film preparation

After conditioning, the films were removed from their substrate by amalgamating the tin with mercury. The films were cleaned before use and immersed for 48 hours in continuously stirred distilled water, in order to remove remnants of solvents and of water-soluble materials.

Permeation measurements

The steady-state water flux was determined by the Payne Cup test[12].

The cups were about half filled with water, and the free films were tightly secured between the rims of the cups with waxed aluminium rings, in such a way that any leakage was avoided.

The cups were then placed in various desiccators containing various saturated salt solutions with different activities (Table 1).

Table 1
Water activities of saturated salt solutions at 23°C.

Salt	Water activity
Magnesium acetate	0.65
Potassium hydrogen sulfate	0.86
Zinc sulfate	0.90
Sodium sulfite	0.95

By measuring the loss of weight after various time intervals, the constant flux of water corresponding to the water activity of the salt solution (a_1) and of pure water ($a_2 = 1$) can be determined.

It has to be noted that in these measurements the transport is caused by the difference in water vapour pressure. However, it has been shown[10c] that identical results are obtained when the films are in direct contact with liquid water of the same activity.

In order to compare the blistering tests with the Payne Cup tests, the relationship between $\bar{D} \times \bar{C}_w$ and the water activity a_1 inside the blister for the various salt solutions in the desiccators has been determined from both series of experiments.

Results

Ref. 10

Growth of blisters

Blister volumes were plotted against time. A representative example of the results is shown in Fig. 2 for three blisters in a polyurethane varnish. These three blisters had been raised using three different amounts of acetate. Evidently, the larger the amount of salt, the larger will be the volume of the blister. The curves also show that initially the blisters grow fast, but their growth gradually slows down. The decrease in salt concentration inside a blister is shown in Fig. 3. The increase in water activity, as calculated from the salt concentration, is shown in Fig. 4.

Curve 1 shows an initial activity of 0.65; which after one day was 0.8, after three days 0.9, and after six days 0.95. For sodium sulfite (curve 2), the initial water activity was 0.95. Since the water activity increases rapidly, its initial value is of secondary importance for the water transport. This explains why the growth of blisters under the same conditions did not differ appreciably with different salts.

Another important result is that the blister grows still more rapidly after six days, when the water activity approaches unity. This means that even very small amounts of hygroscopic materials can cause blistering. The growth of the blister is still measurable after 160 days.

Water transport during blister formation

During blister formation, the rate of water transport at any moment is $\Delta V/\Delta t$ (the increase in volume ΔV during a time interval Δt).

For small intervals of time, the water activity may be considered to be constant, consequently this will also be the case for the rate of water transport $\Delta V/\Delta t$.

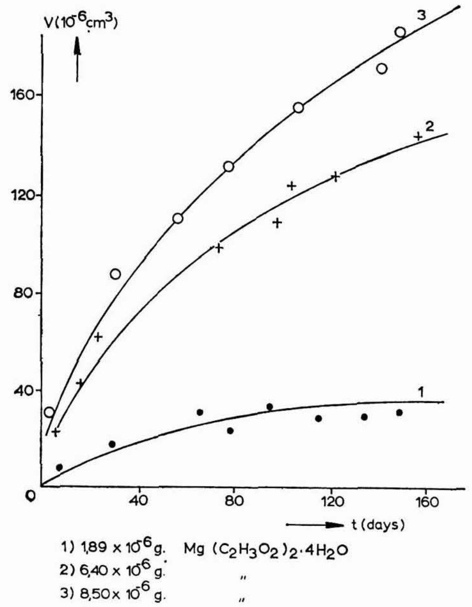


Fig. 2. Polyurethane, film thickness 80 μm. Blister volume as a function of time

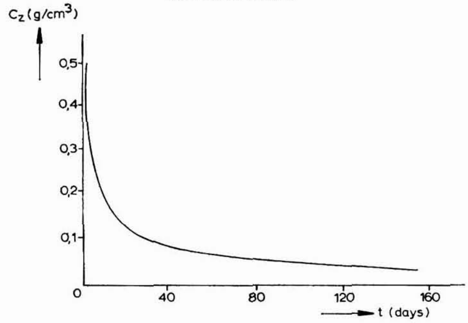


Fig. 3. Salt concentration inside a blister as a function of time

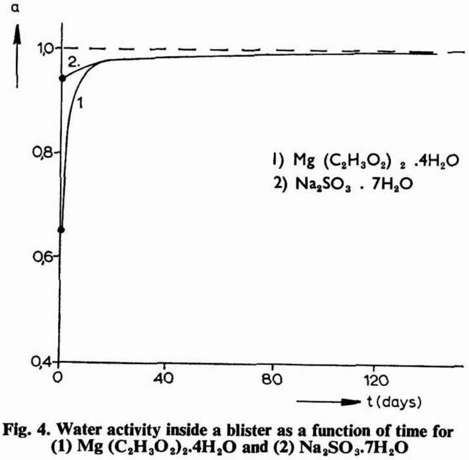
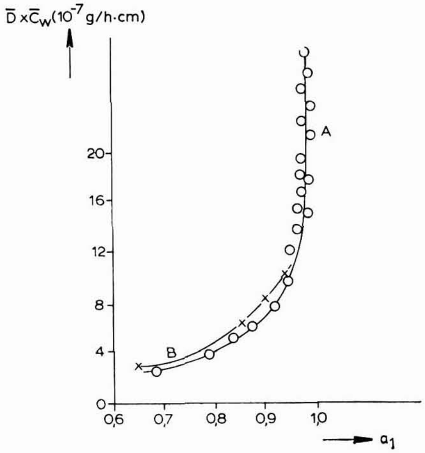


Fig. 4. Water activity inside a blister as a function of time for (1) Mg $(C_2H_3O_2)_2.4H_2O$ and (2) $Na_2SO_3.7H_2O$

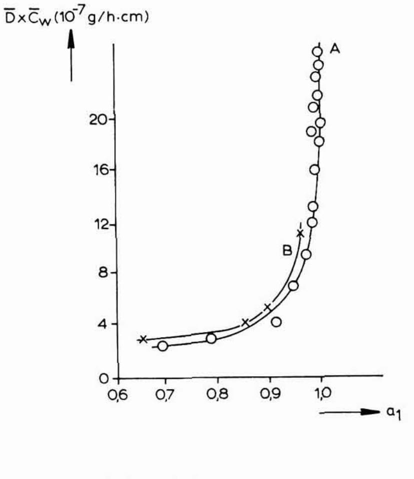
Then with the aid of the graphical relation of blister volume and time, the equation for steady-state osmotic water transport (equation 2) can be applied to calculate $\overline{D} \times \overline{C}_W$ corresponding to a water activity of a_1. This permits the calculation of $\overline{D} \times \overline{C}_W = f(a_1)$.

These calculations were carried out for a large number of blisters of various sizes in the polyurethane varnish obtained with different amounts of salt. From these calculations, one curve (Fig. 5, curve A) was found to be representative for this type of varnish. The corresponding curves A for epoxy resin and chlorinated rubber are given in Figs. 6 and 7.



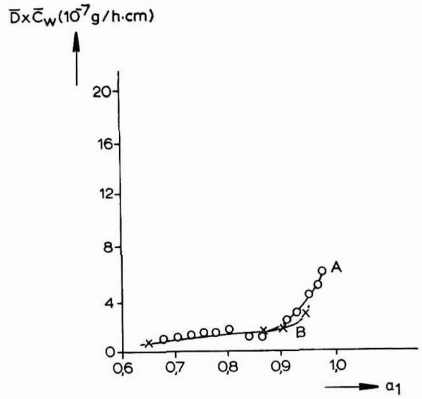
$\overline{D} \times \overline{C}_W = f(a_1)$
A) Blistering measurements
B) Permeation measurements

Fig. 5. Free polyurethane films



$\overline{D} \times \overline{C}_W = f(a_1)$
A) Blistering measurements
B) Permeation measurements

Fig. 6. Free epoxy resin films



$\overline{D} \times \overline{C}_W = f(a_1)$
A) Blistering measurements
B) Permeation measurements

Fig. 7. Free chlorinated rubber films

Stationaryst-ate water transport through free films

A similar relation between $\overline{D} \times \overline{C}_W$ and a_1 can be obtained by application of equation (1) to the results of a series of steady-state permeability measurements with Payne cups. This relation is shown in curve B for polyurethane. The corresponding curves B for epoxy resin and chlorinated rubber are shown in Figs. 6 and 7.

Comparison of the results from blistering tests and from Payne Cup tests

Comparing curve A (derived from blister experiments) with curve B (derived from Payne cup measurements), it can be seen that they agree quite well with each other in the range of the water-activities studied (a_1 from 0.65 to 0.95). The small differences in amounts observed cannot as yet be explained.

For water activities higher than 0.95, comparison between blister experiments and permeation measurements with free films is no longer possible since no experimental data are available for the latter.

The sharp increase of $\overline{D} \times \overline{C}_W$ in the blistering experiments has also been noted by Perera and Heertjes[10] in their osmotic experiments with free films.

Conclusions

From the large number of blister experiments conducted with polyurethane, epoxy and chlorinated rubber varnish films applied on stainless steel contaminated with a spot of salt, and from permeation measurements with free films of the same types of varnish, the following conclusions can be drawn.

The water transport process in case of blistering corresponds to that of the permeability tests. In both cases virtually the same graphical relationship was found between $\bar{D} \times \bar{C}_W$ and the water activity a_1.

The result proves that in these blister experiments only osmosis governs the growth of the blisters. The volume of a blister is determined by the amount of salt deposited on the substrate (Fig. 2) and the diffusion and sorption properties. The result indicates that in these experiments the water transport into the blister is not markedly influenced by either the adhesion or the rigidity of the film. Whether this conclusion is also valid for other substrates where good adhesion exists between varnish and the substrate will be discussed in another paper.

The growth of a blister does not differ appreciably if different salts are used to cause osmotic pressure ($Mg(CH_3COO)_2 . 4H_2O$ or $Na_2SO_3 . 7H_2O$).

The results also show that even if the difference between the activities of water on both sides of the film is small, blisters will continue to grow, implying that even minute amounts of hydrophilic contaminants present on the substrate can cause blistering.

Acknowledgment

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Plastics through atomic radiation*

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Summary

The important role which radiation polymerisation plays in radiation technology is discussed. The processes by which ionising radiation interacts with matter are treated briefly, and kinetics for the mechanisms of radical and ionic polymerisation are discussed; both mechanisms prevail in radiation polymerisation. The potential for synthesising homopolymers and copolymers by means of radiation is presented and illustrated by examples. Finally, the unique role that this technique can play in the manufacture of wood-polymer composites, textile modifications and the curing of surface coating is pointed out.

Keywords

Processes and methods primarily associated with:

manufacturing or synthesis
block polymerisation
free radical polymerisation
graft polymerisation

drying or curing of coatings
atomic radiation
radiation curing

Raw materials: catalysts, accelerators, inhibitors
reaction initiator

Properties, characteristics and conditions primarily associated with raw materials for coatings and allied products
polymerisation rate

Miscellaneous
gamma ray

L'élaboration de polymères par radiation atomique

Résumé

On discute le rôle important que joue la polymérisation par radiation dans le domaine de la technologie de radiation. On considère brièvement les processus par lesquels les radiations ionisatrices réagissent avec la matière, et l'on discute la cinétique des mécanismes de polymérisation et par radicaux et par ions; tous les deux mécanismes entrent en vigueur au cours de la polymérisation par radiation. On présente les possibilités pour effectuer le synthèse de homo et copolymères au moyen de la radiation et l'on offre des exemples. Enfin on indique le rôle unique que saurait jouer cette technique dans le domaine de la fabrication des composés bois/polymère, des textiles modifiés et pour le durcissement des revêtements superficiels.

Kunstoffe durch Atombestrahlung

Zusammenfassung

Die von der Polymerisationsbestrahlung in der Strahlungstechnologie gespielte, wichtige Rolle wird besprochen. Vorgänge, in welchen die gegenseitige Einwirkungen von ionisierender Strahlung und Materie eine Rolle spielen, werden kurz behandelt, und die Kinetik für den Mechanismus von Radical- und Ionenpolymerisation besprochen; beide Mechanismen sind bei Strahlungspolymerisation ausschlaggebend. An Beispielen werden die Möglichkeiten für die Synthese von Homo- und Kopolymeren durch Strahlung gezeigt, und Beispiele dafür gegeben. Schliesslich wird auf die einzigartige Rolle hingewiesen, welche diese Methode bei der Herstellung von Holz-Polymerkompositionen, Textilmodifikationen und der Härtung von Beschichtungsmitteln spielen kann.

Introduction

Refs. 1-5

"Dear Colleague—Leave the concept of large molecules well alone . . . there can be no such thing as a macromolecule."

It is said that this advice[1] was given to Hermann Staudinger just 50 years ago, after a major lecture devoted to his evidence in favour of the macromolecular concept. Today it seems almost impossible that this violent opposition to the idea of the existence of polymer molecules could still have been held in relatively recent times. It is now taken for granted not only that macromolecules exist but also that they have value in food, clothing, shelter, transportation, communication, most other aspects of modern technology and, last but far from least, in the muscles, sinews, genes and chromosomes that constitute our bodies and brains.[2]

The phenomenal upsurge in the utilisation of synthetic materials in modern life can be demonstrated by the dramatic increase in consumption of olefin fibres in the USA.[3] These fibres find their main field of application in textiles and carpets. As can be seen from Fig. 1, total US production of olefin fibres in 1962 amounted to only 10 million kg. By 1972 the demand had increased to 188 million kg, and the predicted yearly consumption by 1982 will be 404 million kg. It is expected that the utilisation of synthetic materials in other fields will follow a similar trend, notwithstanding the effect of the recent oil crisis on the availability of the raw materials.

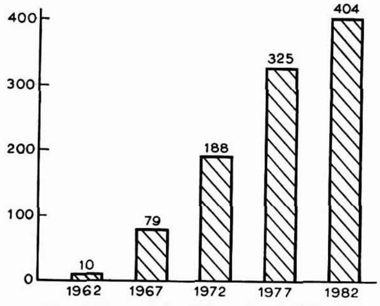

Fig. 1. Demand for US-produced olefin fibre

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*Presented to a meeting of the Transvaal Branch of the South African Section on 28 March 1974.

The development of nuclear power on a large scale after World War II resulted in the greater availability of large irradiation facilities. This in turn led to the development of radiation technology which opened new avenues for the synthesis of materials. The relative importance of radiation polymerisation and the radiation modification of polymeric materials can be judged from the fact that, during the period 1950 to 1970, of all the patents registered in the USA in the field of radiation technology, more than 70 per cent were related to the field of polymer chemistry.[4]

The radiation-initiated polymerisation of vinyl monomers is a direct application of radiation chemistry to the synthesis of high polymers. It is now well established that the initiation step in vinyl polymerisation requires the provision of some external energy. In radiation polymerisation this energy is supplied by the ionising radiation. However, once the reaction chains are initiated, they proceed to grow according to conventional kinetic rules and the radiation-chemical act is limited merely to the primary events that lead to the production of ionic species and free radicals.[5] One of the advantages of radiation-induced polymerisation lies in the simplification of the chain-initiating process. By using radiation as an "external" source for production of initiating species, much greater control can be exercised on the chain-initiating step. Furthermore, it is possible to synthesise polymers which do not entrain any chemical initiators and will thus be of a very high purity.

Although research in the field of polymer chemistry constitutes a major part of the chemical research carried out in most developed countries, the unfortunate situation exists in South Africa that very little effort is being directed to this important field. This can be explained, in part, by the fact that the South African chemical industry appears reluctant to devote the necessary effort required to develop a local centre of expertise in the field of polymer chemistry. Research in this field by the South African Atomic Energy Board is aimed not only at the development of radiation technology, but also at the promotion of a general research effort on polymer chemistry in South Africa.

Transient species in radiation polymerisation

Refs. 6, 7

Some knowledge of the processes by which radiation interacts with matter is essential to an understanding of radiation-chemical phenomena, since the chemical effects are a direct consequence of the absorption of energy from the radiation. From a theoretical point of view the interaction of radiation with matter can become very complicated and, for the purpose of this discussion, the topic will be treated in a very simplified way. As most of the radiation polymerisation processes investigated were initiated with ^{60}Co gamma rays, the discussion will be restricted to what happens when gamma rays are absorbed by the monomer.[6, 7]

The loss of energy which takes place when a gamma ray moves through matter occurs according to the Compton process. In this process a photon interacts with an electron of a monomer molecule, ejecting it as a primary recoil electron, which has a high energy, into the surrounding medium, whilst the photon is deflected with reduced energy as indicated in Fig. 2.

The energy and monentum of the incident photon is thus shared between the scattered photon and the recoil electron.

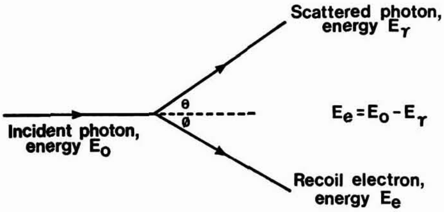

Fig. 2. The Compton effect

The energy lost when the moving primary electron is slowed down by collisions with the surrounding monomer molecules gives rise to a trail of excited and ionised molecules in the path of the primary electron. Excited states are produced when bound electrons in molecules of the surrounding monomer are raised to higher energy levels, whilst ions are formed when the energy gained is sufficient to cause secondary electrons to be expelled. If the secondary electrons gain enough energy, they can further react in a way similar to that of the primary electron in producing excited molecules and ions.

The ions formed by the primary electron can recombine with a thermalised electron, resulting in the formation of either a neutral or an excited molecule. The ions can undergo very fast ion-molecule reactions by reacting with the surrounding neutral monomer molecules. The excited monomer molecules may dissipate their electronic excitation energy through the rupture of a covalent bond, yielding two free radical fragments for every excited molecule.

Ultimately then, the absorption of gamma rays by the monomer leads to the formation of free radicals and ions, both of which can initiate polymerisation processes.

Kinetics and mechanisms of radiation polymerisation

Refs. 8-10, 9, 10, 9

Free radicals and ions are the usual active species responsible for simple radiation-initiated addition polymerisation. A considerable amount of work has been devoted to radiation-induced free-radical chain reactions, and for a very long time it was believed that free radicals were the sole precursors of radiation-induced polymerisation processes. During the past five years, however, many papers have been published which give sufficient evidence to justify the conclusion that, under proper conditions, ionic species may also be formed which are capable not only of contributing to, but of almost entirely dominating the overall polymerisation process. This new development resulted in a better understanding of radiation-induced polymerisation, in general, and the ambiguity involved in some of the earlier "rules-of-thumb" methods was revealed.[8,9]

For the free-radical process, a simplified kinetic scheme is given in Fig. 3. The absorption of the radiation energy results in the production of free radicals.

In the propagation step, a free radical adds itself to a double bond of a monomer molecule, thereby regenerating another free radical. This process goes on until the activity of the growing polymer chain is destroyed. The process is known as termination. In homogeneous liquid-phase polymerisation, chain termination occurs almost exclusively by

FREE RADICAL POLYMERIZATION

Initiation:

$$M \rightsquigarrow 2R^{\bullet} \qquad R_i = G_R I/100$$

Propagation:

$$R^{\bullet} + M \longrightarrow RM^{\bullet}$$

$$RM_n^{\bullet} + M \xrightarrow{k_p} RM_{n+1}$$

Termination:

by recombination: $RM_n^{\bullet} + RM_m^{\bullet} \xrightarrow{k_t} P_{n+m}$

by disproportionation: $RM_n^{\bullet} + RM_m^{\bullet} \longrightarrow P_n + P_m$

$$R_p = k_p \, k_t^{-0.5} \, R_i^{0.5} [M]$$

Fig. 3. Kinetic scheme for free radical polymerisation

mutual interaction of two radicals, leading either to recombination and the formation of a single polymer molecule, or to disproportionation by the transfer of a hydrogen atom from one radical to the other, the latter process giving rise to one saturated and one unsaturated molecule. Assuming steady-state conditions, the overall rate of polymerisation R_p can be expressed as indicated in Fig. 3. This is the classical kinetic equation of polymerisation, which shows that the reaction rate is proportional to the square root of the rate of initiation.

The radiation-induced cationic polymerisation process, as an example of an ionic polymerisation process, is shown in Fig. 4 according to the Williams model.[10] Application of the steady-state assumption and the restriction of overall electrical neutrality leads to the expression for the rate of polymerisation as indicated in Fig. 4. It is interesting to consider briefly the asymptotic behaviour predicted by the equation for the rate of the ionic polymerisation process. Under those conditions where the impurity level is quite high, but still allows for predominating ionic propagation, then $k_{tx}[X] \gg (R_i k_t)^{0.5}$, and it is found that $R_p \propto R_i$. At the other end of the range of behaviour, where the impurity level is insignificant, $(R_i k_t)^{0.5} \gg k_{tx}[X]$, so that $R_p \propto R_i^{0.5}$—a similar relationship to that found for the free radical process. In the case of ionic polymerisations, therefore, it can be stated that:

$$R_p \propto R_i^n \qquad (0.5 \leqq n \leqq 1.0)$$

depending on the importance of impurity termination relative to ion-ion recombination. The role of impurities in the ionic polymerisation is taken into account because of the sensitivity of the propagating ion-molecule reaction to trace amounts of impurities.[9]

CATIONIC POLYMERIZATION

Initiation:

$$M \rightsquigarrow {}^{\bullet}M_i^{+} + Y^{-} \qquad R_i = IG_i/100$$

$${}^{\bullet}M_i^{+} + M \xrightarrow{k_i} {}^{\bullet}M{-}M^{+}$$

Propagation:

$$M_m^{+} + M \xrightarrow{k_p} M_{m+1}^{+}$$

Termination:

by impurities: $M_m^{+} + X \xrightarrow{k_{tx}} M_m + X^{1}$

by neutralization: $M_m^{+} + Y^{-} \xrightarrow{k_t} P$

$$R_p = \frac{R_i \, k_p \, [M]}{(k_t \, R_i)^{0.5} + k_{tx}[X]}$$

Fig. 4. Kinetic scheme for cationic polymerisation

Comparing the two reaction mechanisms shown in Figs. 3 and 4, it is found that, in the case of ultra-pure monomers undergoing an ionic polymerisation process, the reaction kinetics are similar to that of the free-radical process with regard to the radiation intensity relationship. However, the rates of polymerisation in the case of ionic polymerisations are generally a few orders of magnitude higher than that of the free-radical process. This higher rate of polymerisation in the case of ionic polymerisations leads, in turn, to the formation of polymers with very high molecular weights compared with those produced by the free-radical process.[10]

Many monomers[9] will not undergo a free-radical polymerisation process at all, and when they are irradiated without stringent purification no polymerisation will take place. As these monomers are subjected to an increasing degree of purification, ionic polymerisation becomes more pronounced, accompanied by an increase in the rate of polymerisation.

Homopolymerisation

Refs. 11, 12, 5, 10, 13-15

The radiation-induced homopolymerisation of vinyl monomers has been studied in great detail. Virtually all monomers that have been polymerised through chemical initiation have been studied also by radiation polymerisation.

The radiation polymerisation of liquid styrene clearly illustrates many of the principles discussed earlier. As a result of the commercial importance of its polymer, styrene was one of the first vinyl monomers subjected to radiation-induced polymerisation.[11,12] The irradiation dose required to homopolymerise styrene is exceptionally high (~ 500 000 J kg^{-1} or 50 Mrad), resulting in this process being uneconomical. Scavenger studies revealed that this polymerisation process proceeds through a free-radical mechanism. The generation of free radicals in liquid styrene through the absorption of radiation is an extremely inefficient process which results in the low rate of polymerisation observed. For example, the irradiation of liquid styrene generates only 10 per cent of the number of polymer chain-initiating radicals as compared to methyl methacrylate.[5]

Recent investigations[10] indicate that the relative values for the absolute rates of polymerisation for wet and dry styrene can differ by as much as four orders of magnitude, the dry monomer being the more rapid. Scavenger studies revealed that under dry conditions an ionic polymerisation process begins to contribute to the polymerisation, leading to an overall increase in the rate of polymerisation. When both mechanisms prevail, the result is the formation of a polymer which shows two distinct peaks in its molecular weight distribution: the peak at lower molecular weights results from the free-radical contribution, and the peak at higher molecular weights results from the ionic contribution. When the monomer is dried, the relative importance of the second peak increases, whilst the contribution due to the free-radical mechanism decreases.[13]

Although from a theoretical point of view the radiation-induced polymerisation of styrene presents an interesting study, the radiation polymerisation of tetrafluoroethylene (TFE) would appear to be eminently more practical. The present commercial processes for the polymerisation of TFE involve chemical initiation. The reaction conditions for these processes are rigorous, the required temperature range being between 50 and 200°C at pressures exceeding 10MPa (100 atmospheres). In the case of the radiation-induced polymerisation process,[14,15] the radicals initiating the polymerisation process can be generated at temperatures as low as −40°C, allowing the polymerisation to take place outside the radiation field at a temperature of −30°C or lower. The polymerisation has to take place outside the irradiation field due to the high susceptibility of the polymer (Teflon) to radiation-induced degradation. The polymerisation is thus actually a pre-irradiation polymerisation process. It follows that the polymerisation of TFE by radiation can be carried out under less severe conditions than is the case with chemical initiation.

Copolymerisation

Refs. 16, 17

Interest in the field of copolymers has grown rapidly during the past decade. The term copolymer as used here refers to a polymer having two to more different monomers incorporated into the same polymer chain. Copolymers are important industrial products, since the properties of a copolymer are those unattainable by a homopolymer of any of the separate monomers. The importance of copolymers can be judged from the analogous situation in the case of metals. Very few metals are used in the pure form; they are preferred in the form of alloys of two or more different metals.

As an example a special type of copolymer will be considered, a so-called completely alternating copolymer in which the monomer units tend to alternate with great regularity along the polymer chain. Copolymers of this type can be easily synthesised by means of radiation in those cases where the separate monomers do not readily homopolymerise. A good example of such an alternating system is the copolymerisation of chlorotrifluoroethylene with ethyl vinyl ether.[16, 17] As follows from Fig. 5, changing the monomer feed composition over a very wide range results in the formation of a copolymer whose composition remains constant at an equimolar ratio for the monomers in the copolymer. As would be expected from theoretical considerations, the rate of copolymerisation reaches a maximum value when the monomer feed composition is also at an equimolar ratio, as indicated in Fig. 6.

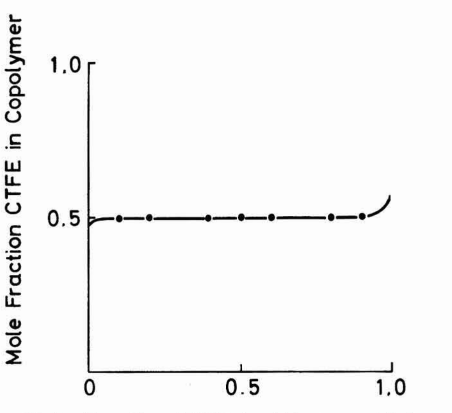

Fig. 5. Mole fraction of CTFE in copolymer as a function of the mole fraction CTFE in monomer mixture at 20°C

This copolymerisation process yields a tough elastomer which has some of the chemical inertness associated with the fluoropolymers, and the toughness and adhesive properties associated with the polyvinyl ethers. This copolymer may be dissolved in a suitable solvent and coated on to virtually any surface.

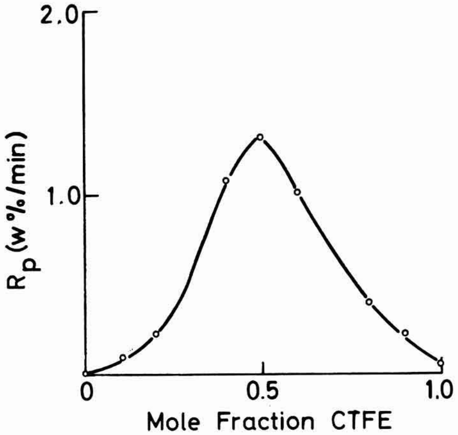

Fig. 6. The rate of copolymerisation at 20°C as a function of the mole fraction of CTFE

Graft copolymerisation

Refs. 18-20

Graft copolymerisation is the process by which the growth of a new polymer chain is initiated at a site located on an existing polymer chain. This grafting of a new polymer segment to a linear polymer chain has now become an important method in the modification or tailoring of polymer molecules. Radiation provides a simple tool to achieve the grafting of vinyl monomers on to both synthetic and natural macromolecules.

The radiation-induced grafting of vinyl monomers on to synthetic polymer backbones has been extensively investigated. Polytetrafluoroethylene (PTFE) is well known for its favourable physical and chemical properties. However, the cost of PTFE limits its general application. If a cheaper backbone polymer, for example polyethylene, could be given a surface coating of PTFE through a radiation-induced grafting process, an inexpensive graft copolymer with the surface properties of PTFE could be obtained. Since the layer of PTFE would be chemically bonded to the polyethylene there would be no possibility of the coating peeling or flaking off. Such a grafting process can be achieved through the pre-irradiation technique where the polyethylene polymer is first irradiated, creating the necessary chain-initiating free-radical sites, and then treated with the TFE monomer until the desired degree of coating is achieved.[18]

Another field of interest is the modification of natural polymers by the grafting technique. An example of this is the modifications of the physical properties of wool by grafting of various vinyl monomers within the wool fibre. The most appealing property of wool is its high moisture re-gain, which makes woollen garments comfortable. Unfortunately, when subjected to hot-water washing, woollen garments undergo dramatic shrinkage which is the result of certain undesirable surface properties of the wool fibres. These surface properties can be modified by the grafting of vinyl monomers on to the surface of the wool fibres.[19, 20]

By using the same technique, textiles may also be given water-repellant or oil-repellant properties, depending on the nature of the monomer grafted on to the material.

Some unique applications of radiation polymerisation

Refs. 21-24

The forming of wood-plastic composites (WPC) with the aid of radiation represents one of the most spectacular applications of nuclear energy.[21, 22] Wood plastics are formed by impregnating the wood with the monomer of a specific plastic. With the aid of gamma radiation, the monomer is polymerised so that a tough plastic is formed within the microstructure of the wood. In this manner a material is obtained which has the appearance of wood, but which is filled with a three-dimensional plastic network. The presence of the plastic in the wood gives it most of the superior properties of the plastic without sacrificing the advantageous and aesthetic properties of the wood. In this way the properties of the softer and cheaper types of wood can be improved to such an extent that they can compete favourably with the hard woods. Bearing in mind the ever-increasing worldwide shortage of hardwoods, the economic advantages of this treatment can be readily appreciated. The material can be produced in a wide range of colours by adding appropriate dyes to the monomer before impregnation. The most important properties of WPC are the following:

(i) it is harder than ordinary wood and its abrasion resistance is, therefore, particularly high;
(ii) it absorbs water at a slower rate than ordinary wood;
(iii) its mechanical strength is higher than that of untreated wood;
(iv) it can be polished to a very high gloss, so no varnish is required;
(v) the material can be worked with wood-working machines; and
(vi) the surface is particularly resistant to burning cigarettes and spilled liquids.

Like wood-plastic composites, a new material can be formed by impregnating concrete with an appropriate monomer and then polymerising the latter in the concrete by means of radiation.[23] In this way a concrete-plastic composite is formed which exhibits the following properties:

(i) a five-fold increase in compressive strength;
(ii) negligible water permeability;
(iii) reduction in water absorption by 95 per cent; and
(iv) up to an eightfold increase in freeze/thaw durability.

The coating industry has continued its search for rapid curing methods, one of which is the use of high-energy ionising radiation. The curing of most currently used, high-quality organic coatings for automotive applications is a thermally initiated polymerisation reaction requiring times ranging from several minutes to several hours. The result of the curing step is the formation of a three-dimensional polymer structure, whose properties are determined by the chemical and physical configuration of the crosslinked material. Ionising radiation provides a unique method of crosslinking an unsaturated polyester using a vinyl monomer as crosslinking agent.[24] The radiation-induced vinyl-monomer crosslinking results in the forming of a rigid three-dimensional polymer network. The advantages of radiation curing are:

(i) curing can be achieved at ambient temperatures;
(ii) curing can be achieved in a matter of seconds;
(iii) in many cases, 100 per cent solid systems for curing can be prepared;
(iv) accelerators require little space compared to large ovens; and
(v) accelerators can be switched on and switched off at will.

The future of radiation polymerisation

It follows from the foregoing that radiation polymerisation contributes not only to a better understanding of our present knowledge of fundamental polymer chemistry, but is already playing a role in the field of practical applications. With the amount of research being carried out in the field of radiation polymer chemistry, an increasing utilisation of radiation techniques by industry is to be expected.

[Received 24 July 1974

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The performance of low lead content wood primers*

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Summary

Attempts to specify the required durability of wood primers by their mechanical properties are described, using test results from 48 commercial products. The extensibility of attached films determined at 0° and 23° by direct tensile tests varied from over 30 per cent to less than 2 per cent, and showed good general correlation with the extent of cracking in a severe weathering test, but a small number of anomalies restricts the suitability of such tests as a specification criterion. As an alternative, a short severe weathering test is proposed, involving a comparison with primers of known good and moderate performance, if such primers can be standardised and found reproducible.

Weathering of the primer films alone on wood has caused bad failures in at least half of them, and none of those intended for factory application was unaffected after three months. Even with a gloss top coat, the worst primers also failed within this period. The best of the brushing types were as good as British Standard lead-based primer for wood, but many were of poor durability. Pretreatment of the wood with a resinous (water repellent) preservative improves the performance of many of the poorer primers.

Vapour resistivity values are quoted, and fall within a fairly narrow range, with few exceptions, so that this property appears less important than extensibility. The lead contents are also given, all being below the limit of 1.5 per cent required by BS 4310 : 1968, and many below 0.5 per cent.

Keywords

Types and classes of coating and allied products
lead free paint
primer

Types and classes of structures of surfaces to be coated
wood

Processes and methods primarily associated with analysis, measurement, or testing
bending test
tension testing

Properties, characteristics and conditions primarily associated with dried or cured films
exterior durability

Le rendement des peintures d'impression à faible teneur en plomb

Résumé

On décrit les tentatives à preciser la durabilité prévue des peintures d'impression à partir des résultats d'un essai sur 48 peintures de commerce. L'extensibilité des feuils, attachés aux supports, déterminée à 0° et à 23° par un essai de traction se varait entre plus de 30% et moins de 2%, et elle démontrait une bonne corélation avec l'étendue du fendillement qui se produisait au cours d'un essai de vieillissement sévère, mais l'existence de certaines anomalies peu nombreuses limite l'aptitude de tels essais en tant que critère de spécification. A titre d'alternatif, on propose un court et sevère essai de vieillissement, qui comprend une comparaison auprès des peintures d'impression dont leur rendement ou bon ou moyen est déjà connu, dans le cas où l'on saurait nomaliser ces impressions et où leur rendement est reproductible.

Le vieillissement des feuils de peintures d'impression a mis en évidence de graves défauts dans le cas de la moitié au moins, et aucune des impressions destinées à être appliquées dans l'atelier n'est restée intacte aprés 3 mois. D'ailleurs pendant cette période, les peintures d'impression les plus mauvaises ont failli, même où elles ont été revêtues d'une couche de peinture brillante. Les meilleures peintures du type pour application à la brosse étaient aussi bien que celle à base de plomb qui conforme à la British Standard Specification, mais beaucoup parmi elles étaient d'une inférieure durabilité. Un pré-traitement du bois avec un préservatif hydrofuge à base de résines augmente le rendement de plusieurs des peintures d'impression inférieures.

On mentionne les valeurs de la résistivité à la vapeur, qui, sauf pour quelques exceptions, se trouvent dans un éventail assez étroit, de sort que cette caractéristique semble être moins importante que l'extensibilité. D'ailleurs on donne les teneurs en plomb, qui sont toutes inférieures à la limite de 1,5% exigée par la norme BS4310 et beaucoup parmi elles sont moins de 0,5%.

Die Haltbarkeit von Holzprimern mit niedrigem Bleigehalt

Zusammenfassung

Versuche werden beschrieben, um Liefervorschriften hinsichtlich Dauerhaftigkeit von Primern für Holz mit Bezug auf mechanische Eigenschaften aufzustellen. Dabei wurden Resultate der Prüfung von 48 Erzeugnissen des Handels benutzt. Das Dehnungsvermögen haftender Filme wurde bei 0° und 23° durch direkte über 30 bis zu weniger als 2% variierende Zugspannungsprüfungen untersucht. Dabei zeigte sich gute, allgemeine Korrelation hinsichtlich Reissen bei stark beanspruchenden Bewitterungsprüfungen, aber eine geringe Anzahl von Anomalienbe schränkt die Eignung solcher Tests als Kriterium in einer Liefervorschrift. Als Alternative wird eine kurze, scharfe Bewitterungsprüfung im Vergleich mit sich erfahrungsgemäss gut und mittelmässig verhaltenden Primern vorgeschlagen, vorausgesetzt, dass solche Primer genormt werden können und reproduzierbar sind.

Primer-Filme allein auf Holz zeigten nach Bewitterung in wenigstens der Hälfte der Prüflinge starke Beschädigung und von den für Werksanstrich beabsichtigten war nach 3 Monaten keiner fehlerfrei. Die besten der für Pinselauftrag bestimmten Typs waren ebensogut, wie die bleihaltigen, die Bedingungen des British Standard erfüllenden, bleihaltigen Primer für Holz; die Haltbarkeit vieler war jedoch schlecht. Verbehandlung des Holzes mit einem harzhaltigen (wasserabstossenden) Schutzmittel verbessert die Leistung vieler der weniger haltbaren Primer.

Werte für die Beständigkeit gegen Dampf werden aufgeführt und fallen, mit wenigen Ausnahmen, in einen ziemlich niedrigen Messbereich, sodass diese Eigenschaft weniger wichtig zu sein scheint, als Dehnbarkeit.

Die Bleigehalte werden ebenfalls gegeben, sie liegen alle unter dem Grenzwert von 1,5%, welcher vom British Standard 4310:1968 verlangt wird, und viele unter 0,5%.

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*Modified version of a paper first presented to a meeting of the West Riding Section on 9 October 1973.

Introduction

Ref. 1

As a result of the declining use of lead-based wood primers caused by concern with regard to their possible toxicity, a British Standard Specification for alternatives has become a necessity. In addition to controlling the lead content, it is important for such a specification to ensure a good level of durability, since low quality primers have often been the main reason for premature failure of paintwork on joinery, even where good quality finishing paints have been used.

On behalf of BSI Committee PVC/16, some preliminary studies of commercial primers have already been made; in particular the property of extensibility, proposed by the authors,[1] was explored in the expectation that it played a major part in performance. It was felt necessary to increase the range of products examined before a draft specification could be proposed, and also to investigate further the possibility of using the existing bend test rather than the more elaborate direct tensile test. Twenty-four manufacturers responded to an invitation to submit samples of their current types of low-lead primers for both brushing and large scale application in factories. Forty-six primers plus an aluminium and a lead-based primer to BS 2521 were examined. This report represents the main results and conclusions. The composition of the primers was not known, but these would be expected to differ widely within the modified alkyd range, especially between the slow-drying (brushing) and the fast-drying (industrial) types. Performance would also be expected to vary even within any possible broad grouping by composition; hence the intention was to relate performance to physical properties only.

Experimental

Ref. 2

Extensibility tests of attached films on a chromate-etched soft aluminium substrate were made as previously described,[2] at 0° and 23°C, at the fastest rate available on an Instron tensile test machine (500mm/min), equivalent to 16.7 per cent elongation per second. Bend tests according to BS 3900 Part E1 were carried out on the same substrate at 0° and 23°C, using 6.4mm and 4.8mm diameter mandrels. Both tests were performed before and after 300 hours' artificial weathering to BS 3900 Part F3. (The films were dried for 1 week, including three days at 40°C, before the initial tests.) In both tests magnifications up to ×70 were used to detect cracking.

In order to relate extensibility to performance on wood, the primers were exposed to natural weathering on tongued and grooved boarding at 45° facing south. The timber panels were flat sawn redwood, selected to be as similar as possible within each set of panels. It was painted on either the bark or the pith side consistently within each set. Repetition at different film thicknesses and in differing conditions, rather than full replication, was adopted to cover the influence of wood variation. (In the event, the juxtaposition of primers of very different performance on the long test pieces offers irrefutable evidence that the variability of the wood was not the cause of the severe failure of some of the primers. (See Figs. 2a-d.) If the boards had all been divided and randomised, the comparison would have been less direct and less convincing.) Some duplication of those primers expected, from their extensibility, to show good, moderate and bad behaviour provided extra confirmation of the results.

All the primers had to be applied by brushing, although some of them were intended for spray or dip application. Difficulty always arises in comparing products of different rheological characteristics: if they are brushed naturally those which penetrate the wood may be applied more thickly and to that extent may perform better; if a fixed weight is used, adjusted to the paint density, the comparison is fairer but still not precise. In this work the solids volume content of each primer was first determined and throughout the tests the film weight used was that which would produce a given film thickness on a metal substrate. This thickness was 25 or 37μm in different series. It resulted in a rather lean appearance for certain primers at the lower level, but a second coat was also applied on part of the test pieces in set 1, and the results proved very illuminating.

The four exposure tests consisted of:

1. One and two coats of primer, each 25μm, four to each test board (length 2.4m).
2. A single coat at 25μm applied to a short length of board (0.3m) from a different parcel of wood.
3. A similar coat applied to similar timber which had been treated by a 3-minute dip in a water repellent preservative.
4. A 37μm coat, eight primers to each long board with a coat of proprietary alkyd gloss paint on top.

The area of each section of primer was 0.3 by 0.12m. The backs of the boards and the ends of the short boards were left unsealed so that the movement of the timber with varying moisture content was not determined entirely by the permeability of the primer. To make the test rapid and severe (but not more so than the worst conditions in practice) the wood was painted whilst at a moisture content of about 8 per cent, the films dried for one week, and exposed during wet weather. The exposure began in February 1973, and although it is an agreed requirement that primers ought to withstand six months' weathering in practice, the first set had to be withdrawn after three months.

Recoating of weathered primers

After six months' exposure all panels in sets 2 and 3 exhibiting little or no cracking were cleaned lightly with fine wet abrasive paper, dried off for two hours, and overcoated with undercoat and gloss paint. Primers with a greater degree of cracking were rejected (except one for control purposes); the boards were planed to a new surface free from paint residues and primed with the "good" primers selected for overcoating. (Boards which had had a preservative treatment, that is set 3, were given a brush coat of the same preservative 24 hours before priming.) After 24 hours, the re-primed boards were given an undercoat and a gloss finish to compare the behaviour of new and weathered primers. In addition a small portion of every primer was left bare to check its weathering behaviour as compared with the first exposure.

The moisture permeability was determined by a permeability cup technique, based on BS 3177:1959, using hardboard as a substrate, painted on the inside with calcium chloride in the cup and 75 per cent relative humidity outside. Because a number of primers sank rather badly into the pores of the substrate, the tests were also carried out after treating it with a size consisting of a dilute solution of high viscosity methyl cellulose. Determinations were made at the single temperature of 23°C, but it is known that for some paints the permeability may vary with temperature. The results were calculated as the inverse property, vapour resistance (since it is additive for multiple coats and allows the small contribution of the hardboard to be deducted), and are quoted as "resistivity", R (resistance per unit thickness). The specific permeability SP ($g/m^2/24$ hr for the test conditions) can be obtained from the relationship

$$SP = \frac{181.9}{R \times t \times 10^{-6}} \text{ where } t = \text{film thickness in micrometres.}$$

Results

Performance was judged mainly by the development of cracking, and awarded points on the scale 0 (no cracking) to 4 (very bad). Fig. 4 shows the additional strains in the film created by differential movement of early and late wood. Flaking followed cracking in many cases, but was not assessed separately. Chalking was recorded on a similar subjective scale, and only a slight chalk was considered acceptable in the short period of exposure used.

Table 1 presents the numerical results, and a better picture of them is offered by the "graphical distribution" Tables which follow.

Weathering tests (Tables 1 and 2)

Fig. 1 shows the long boards of set 1 with some of the short boards, after 90 days. Figs. 2a–d show a selection of primers on the long boards. The sharply contrasted behaviour at the junctions of the different sections can be seen. Cracks occasionally extend from a bad into a good primer and would be ignored in the assessment of the latter if clearly caused by the former. The wood used in set 1 proved more severe on the primers than the rest, although its properties were not considered to be markedly different. (It had 7 to 10 growth rings per mm compared with 5 to 17, and a slightly lower density.)

The behaviour was fairly consistent in all four series, defects appearing at a later stage in sets 2, 3 and 4. The differing effects of two coats and one coat in set 1 was of considerable significance; the second coat of bad primers cracked equally readily and made no improvement, but two coats of the best primers appeared in better condition and likely to last longer than the single coat. (The right-hand half of each primer in Figs. 2a–d is the double coat.)

In set 1, only seven primers in one coat survived for 90 days without any failure, and another six (including the lead based and aluminium primers) with only slight cracking: with two coats there were 10 and 6 respectively in these categories. Twenty-four primers were highly unsatisfactory in one coat and 19 of these also in two coats. In set 2, 19 remained intact for three months and 12 failed badly, whilst in set 3 (with preservatives) 32 survived and nine failed badly.

Sets 2 and 3 were continued for six months, and the numbers which survived fell to 12 and 22, respectively, whilst the number of bad failures rose to 16 and 11. Although the major failure was cracking, this was often followed by flaking. Some primers failed also by loss of adhesion, probably when wet; this property was not measured rigorously, and attempts to demonstrate loss of adhesion when wet by pull-off techniques were only moderately successful. Chalking must be

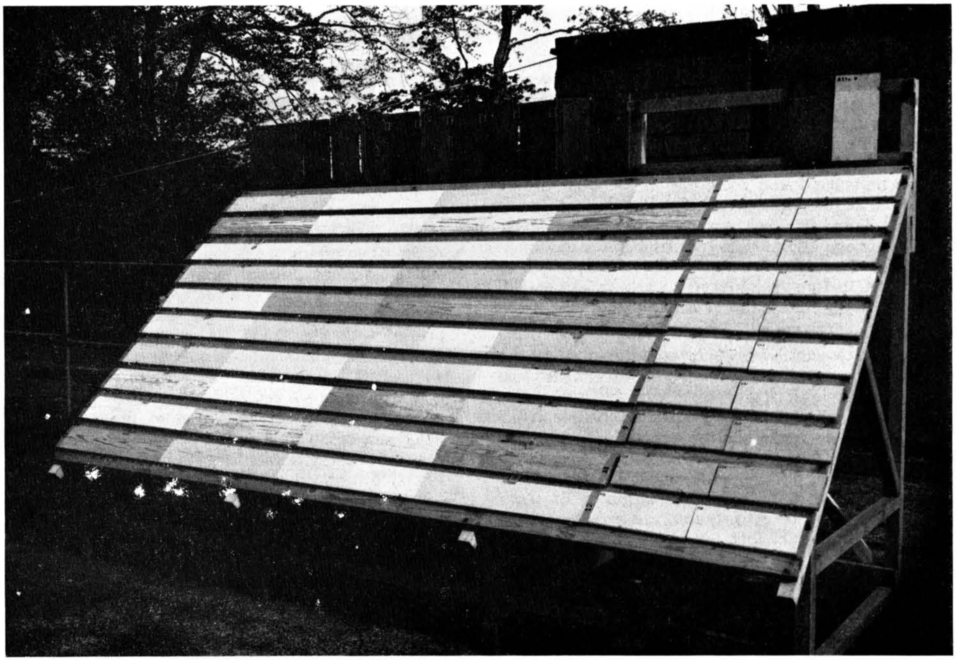
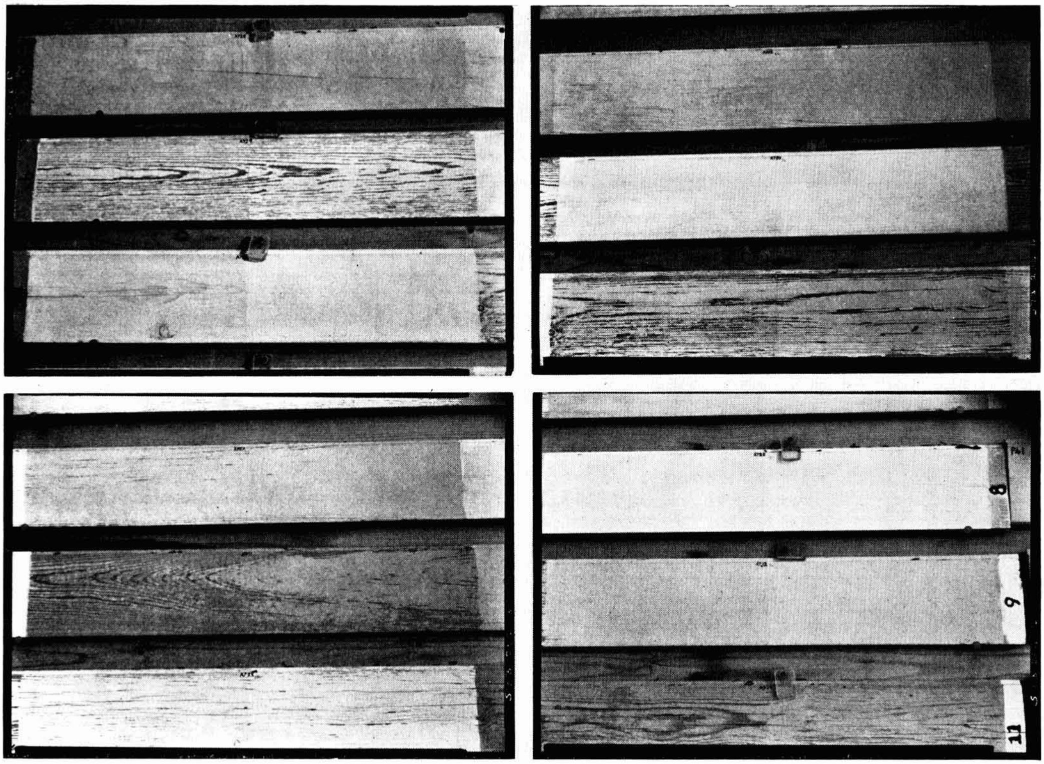


Fig. 1. Exposure test of primers at Garston (Set 1 and part of Sets 2 and 3)



Figs. 2a (top left), 2b (top right), 2c (bottom left) and 2d. Section of primers, set 1 (one eighth actual size). The sections are contiguous parts of three complete boards

considered because of its effect on over-coating, but it also tends to conceal the formation of cracks both on exposure and in the extensibility tests; seven primers chalked more than the acceptable slight degree.

The behaviour of the primers under a gloss coat (set 4) followed a very similar pattern (Table 2). After only three months, cracking to some degree was visible on 20 (compared with 34, for the uncoated primers in set 1) and was severe on four (compared with 17). After one year (Fig. 3a–d), 32 showed cracking and of these 13 were so bad that they could not have been repainted without stripping to the wood. Thus although the gloss coat gives protection, it could be said that the bad primers caused failure of the top coat. The omission of an undercoat in this set is not considered to have affected the results unduly; the primer was a generous coat (37 micrometers), and although undercoats may add some resistance to moisture penetration they are, generally, much less flexible than finishing coats, so they may contribute to cracking.

Nearly all the fast drying primers used for factory application were unsatisfactory in weathering properties and extensibility, and many of the slower-drying brushing ones also performed badly, but there were sufficient good ones to show that the performance of lead-based primers can be equalled with the latter type. Improvements in the quicker-drying types may require some compromise in the application properties. Table 3 shows the variation of performance according to type of primer.

Recoated weathered primers and controls

After six months' exposure, mainly in winter, there was no cracking of the gloss paint on either the weathered or the newly applied selected "good" primers. The exposed areas of primer also showed little or no cracking, except for the control "bad" primer, which had cracked to about the same extent as in the first series. Mould growth was very marked on most of the primers on the unpreserved wood in this exposure, sometimes being so bad to make repainting without stripping a doubtful treatment. Over the preservative treatment, only nine of the 23 primers showed any mould and none was seriously affected.

Extensibility and bend tests (Table 1)

Extensibility before artificial weathering ranged between over 30 per cent and less than 2 per cent at 23°C, and between 26 per cent and less than 1 per cent at 0°C. The differences in extensibility at these two temperatures showed considerable variation and this itself may be considered a significant property of films, worthy of further exploration. It is clearly desirable to have a high level of extensibility maintained to as low a temperature as possible. After only two weeks of artificial weathering, the extensibility fell very greatly for many primers, indicating a rapid increase of oxidation or further polymerisation, and this is considered to be the cause of many failures.

Table 1

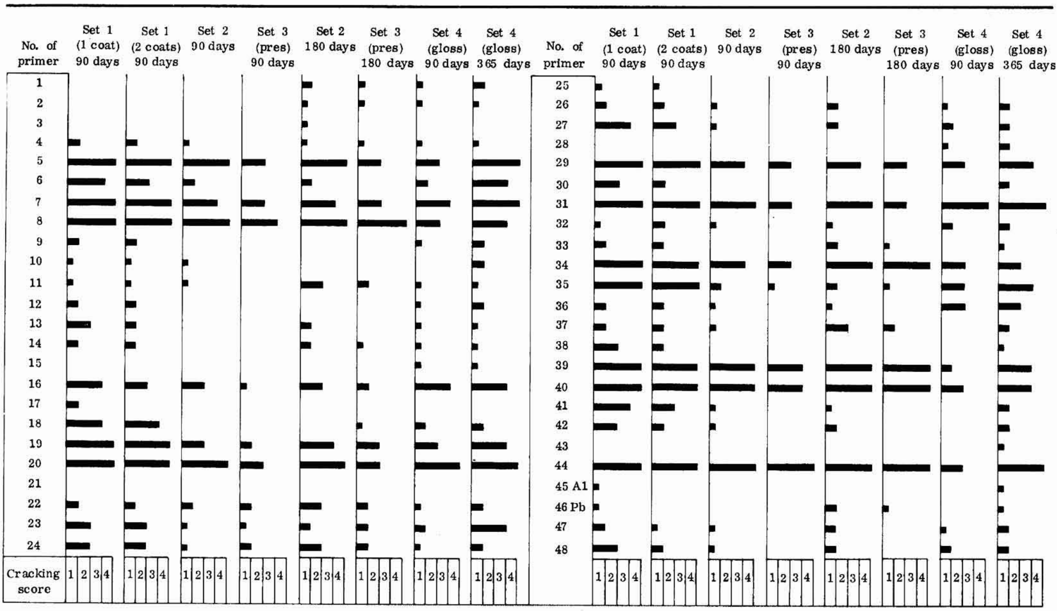
Results (B = Brushing; I = Industrial)

Number	Type	% Extensibility				Bend Test		NATURAL WEATHERING TEST - Cracking (0–4)											Chalking	Vapour Resistivity On hardboard		Lead Content %Pb	Number
		Before At 0°C	AW 23°	After 300 hrs AW 0°	23°	Before 6mm 0°	After 6mm 0°	7 Days Set 1	Set 2	21 Days Set 1	Set 2	90 Days Set 1	2	3	4	180 Days Set 2	Set 3	365 Days Set 4	90 days Set 1	Unsized GNs/kg m x 10^{-5}	Sized		
1	B	7	>30	3.5	4	Fail	F	0	0	0	0	0	0	0	½	1	½	1	0	2.0	4.2	0.4	1
2	B	18	>30	3	3	?	F	0	0	0	0	0	0	0	½	½	½	½	0	3.5	2.5	0.8	2
3	B	19	>35	6	21	Pass	F	0	0	0	0	0	0	0	0	½	0	0	0	1.3	2.5	0.5	3
4	I	6	12	4	5.5	P	F	0	0	1	0	1	½	0	½	½	½	½	0	-	0.4	0.6	4
5	B	<2	5	0.5	1.5	F	F	2	½	4	1	4	4	2	2	4	2	4	1	4.1	6.3	0.5	5
6	I	2.5	8	2.5	3	F	F	½	0	1	½	3	½	0	1	1	0	3	0	-	-	0.2	6
7	I	<1	< 2	1	<2	F	F	2	½	2	½	4	3	2	3	3	2	4	0	5.7	8.4	0.1	7
8	B	1.5	4	<1.5	1.5	F	F	2	0	3	1	4	4	3	1½	4	4	3	1	-	-	0.1	8
9	B	8	18	2.5	3	P	F	½	0	½	0	1	0	0	½	0	0	1	0	3.5	3.5	0.6	9
10	B	14	21	2.5	4	P	F	0	0	½	0	½	½	0	0	0	0	1	1	2.7	2.7	0.1	10
11	I	16	28	3	4	P	F	0	0	0	0	½	½	0	½	2	1	½	0	1.9	2.0	0.2	11
12	B	5	17	1	3	?	F	½	0	½	0	1	0	0	½	0	0	1	0	4.0	4.0	0.1	12
13	B	7	12	<2	<2	?	F	½	0	½	0	2	0	0	½	1	0	½	1	-	-	0.1	13
14	B	8	16	<1.5	<1.5	P	F	0	0	½	0	1	0	0	½	1	½	½	0	-	-	0.1	14
15	B	26	27	4.5	4	P	F	0	0	0	0	0	0	0	½	0	0	½	0	1.8	2.0	0.1	15
16	B	2.5	4	<1.5	2	F	F	1	0	1	½	3	2	½	2½	2	1	3	0	-	-	0.2	16
17	B	13	18	3	3.5	P	F	0	0	0	0	1	0	0	0	0	0	0	0	1.3	2.4	0.05	17
18	I	2	5	<1	<2	F	F	½	0	½	0	3	0	0	1	0	½	1	0	-	-	1.1	18
19	B	<2	8.5	<1.5	<2	F	F	2	0	2	1	4	2	1	2	3	2	3	0	-	-	0.3	19
20	B	2.5	10	3.5	8	F	F	2	½	4	3	4	4	2	4	4	2	4	0	54	209	0.1	20
21	B	10	14	3.5	3.5	P	?	0	0	0	0	0	0	0	0	0	0	0	1	1.6	2.0	0.3	21
22	I	2	4.5	2	2	F	F	½	0	½	½	1	1	1	½	2	1	1	2	-	-	0.2	22
23	B	5	12	5	7	P	P	½	0	½	0	2	½	½	1	1	1	3	2	0.09	1.0	1.0	23
24	I	7	9.5	2.5	3	P	P	0	0	½	0	2	½	1	½	2	1	1	2	-	-	1.3	24
25	B	12	30	4	4.5	P	F	0	0	0	0	½	0	0	0	0	0	0	0	3.4	3.4	0.3	25
26	I	3	7	2	<2	P	F	½	0	1	½	1	½	0	½	1	0	1	0	-	-	0.0	26
27	I	3	12	3	2	F	F	½	0	1	½	3	½	0	1	1	0	1	0	2.5	6.3	0.0	27
28	B	7	24	4	4	P	F	0	0	0	½	0	0	0	½	0	0	1	0	4.1	5.4	0.2	28
29	I	1.5	2.5	3	<1.5	F	F	1	0	2	1	4	3	2	2	3	2	3	0	8.6	8.0	0.0	29
30	I	8	14	4.5	4	P	P	0	0	½	0	2	0	0	0	0	0	1	3	-	-	0.1	30
31	I	1	2	<1	<2	F	F	2	½	3	1	4	4	2	4	4	2	4	1	0.9	15.8	0.0	31
32	B	2.5	16	3.5	2.5	F	F	½	0	½	0	½	½	0	1	½	0	1	0	-	-	0.5	32
33	B	16	16	2.5	1.5	P	P	0	0	0	0	1	0	0	0	1	½	½	2	2.5	1.9	0.3	33
34	B	3	7	3	<2.5	?	?	3	½	3	1	4	3	2	2	4	4	2	0	5.1	6.5	0.3	34
35	I	3.5	5	<2	2	F	F	2	0	3	0	4	1	½	2	1	½	3	0	-	-	0.0	35
36	I	2	6	0	0	F	F	½	0	½	0	1	½	0	2	½	0	2	0	5.2	6.2	0.0	36
37	B	4.5	12	<2	4.5	P	?	½	0	½	0	1	½	0	0	2	1	1	0	3.1	3.4	0.6	37
38	B	8.5	20	2	5	P	F	0	0	0	0	2	0	0	0	0	0	½	2	1.5	1.6	0.8	38
39	I	<1.5	5.5	<1.5	<2	F	F	2	0	4	½	4	4	3	1	4	4	3	1	-	-	0.2	39
40	I	2	9	1.5	<2	F	F	1	½	1	½	4	4	3	2	4	4	3	0	-	-	0.2	40
41	B	3.5	13	2.5	4	?	F	½	0	½	0	3	½	0	0	½	0	1	0	2.9	4.5	0.2	41
42	B	2.5	17	2.5	4.5	F	F	½	0	½	0	2	½	0	0	1	0	1	0	-	-	0.2	42
43	B	18	24	7	9	P	P	0	0	0	0	0	0	0	0	0	0	½	1	2.6	2.7	0.1	43
44	B	2.5	3	<1.5	<1.5	F	F	2	½	3	1	4	4	4	2	4	4	4	1	0.6	0.2	0.1	44
45	B(Al)	14	30	13	14	P	P	0	-	0	-	½	-	-	0	0	-	½	0	0.7	3.3	0.0	45
46	B(Pb)	14	22	4.5	6	P	F	0	0	0	0	½	0	0	0	1	½	½	1	1.8	1.8	-	46
47	B	22	22	4.5	4.5	P	?	0	0	0	0	1	½	0	½	1	0	1	2	3.9	2.7	0.3	47
48	B/I	2.5	12	<1	<2	F	F	0	0	½	0	2	½	0	1	1	0	1	0	4.6	4.6	0.5	48

Cracking and chalking 0 = nil ½ = trace or doubtful 1 = slight 2 = moderate 3 = bad 4 = very bad

Table 2

Exposure test—cracking rating



Results of the various extensibility measurements were compared with the cracking which occurred on weathering at each period, and the influence of this property on performance is clear. Some of the correlations are shown in Table 4. A level of 8 per cent extensibility at 0°C before artificial weathering seems to be a suitable minimum requirement and not far from the earlier suggestion of 10 per cent, which might be required by possible wood movements. Nevertheless, some anomalies are apparent and whilst tne correlation is good enough to establish the general significance of extensibility, it does not permit a clear cut distinction between good and bad primers, sufficient for control by a specification. A level can be set, however, to reject all the bad primers, whilst not necessarily selecting all the good ones.

The bend test proved less precise and discriminating. The correlation with exposure test results was poor. Comparison of the bend test and direct tensile tests indicated that the calculated level of 5 per cent elongation for a 6mm bend and 7.5 per cent for a 4mm bend is approximately correct, bearing in mind the different rates of extension employed in the two tests; the bend test is carried out in approximately one second irrespective of the extension produced.

Table 3

Type of primer vs cracking in exposure test (90 days)

	Set 1, one coat (Long boards)						Set 3, one coat on preservative treatment (Short boards)					
Brushing (29)	1 2 3 15 21 28 43	10 25 32 45(A1) 46(Pb)	9 12 14 17 33 37	13 23 38 42	41	5 8 16 19 20(b) 34 44	1 2 3 9 10 12 13 14 15 17 21 25 28 32 33 37 38 41 42 43 (46) 47	16 23	19	5 20 34	8	44
Industrial (17)		11(a)	4 22 26 36	30(c) 48	6 18 27	7 29 31 35 39 40	4 6 11 18 26 27 30 36 48	35	22 24	7 29 31	39 40	
Cracking	0	½	1	2	3	4	0	½	1	2	3	4

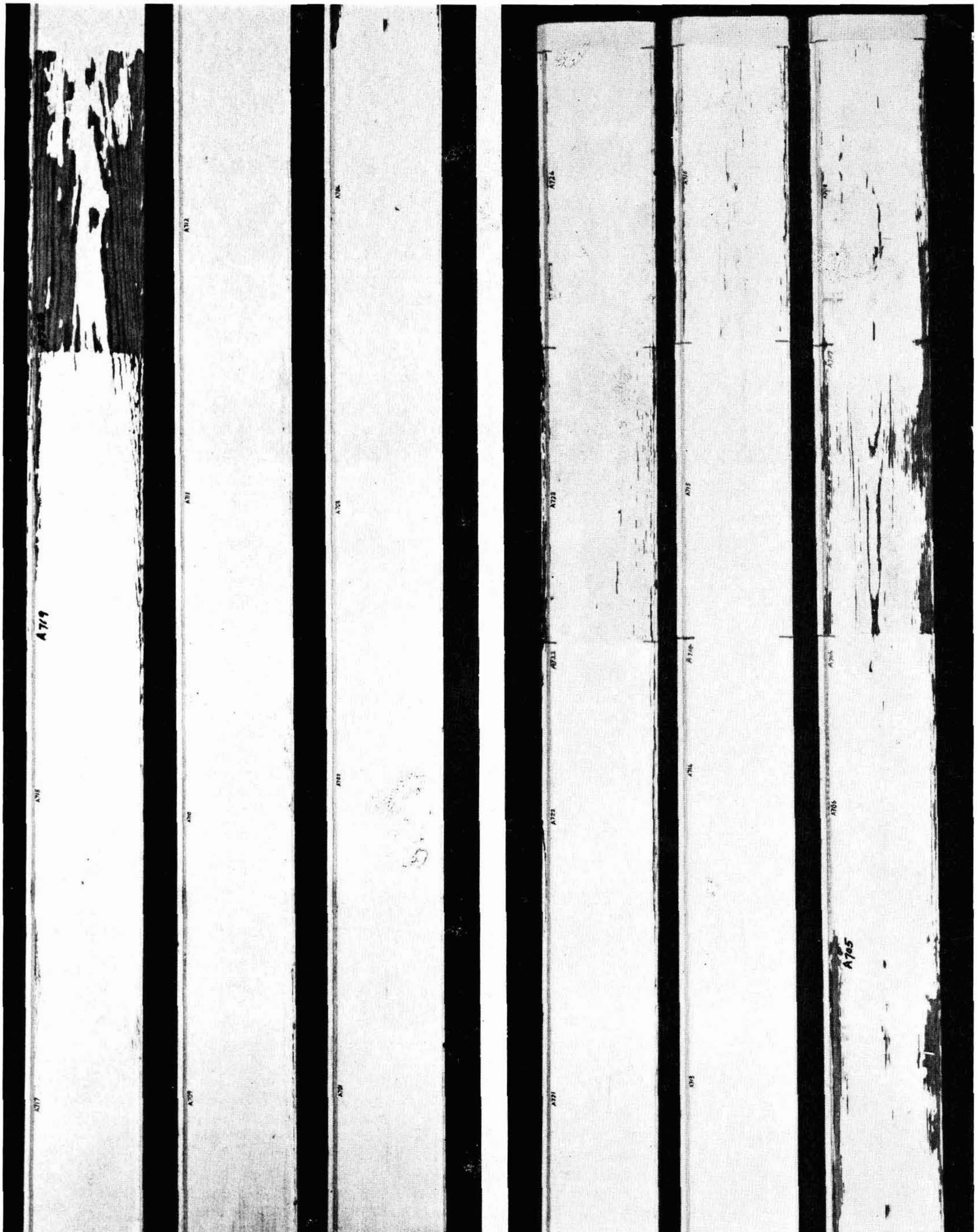
Note: (a) Very slow drying, (b) Bad adhesion, (c) Bad chalking

Table 4

Extensibility versus cracking in exposure test. (Points are primer reference nos.)

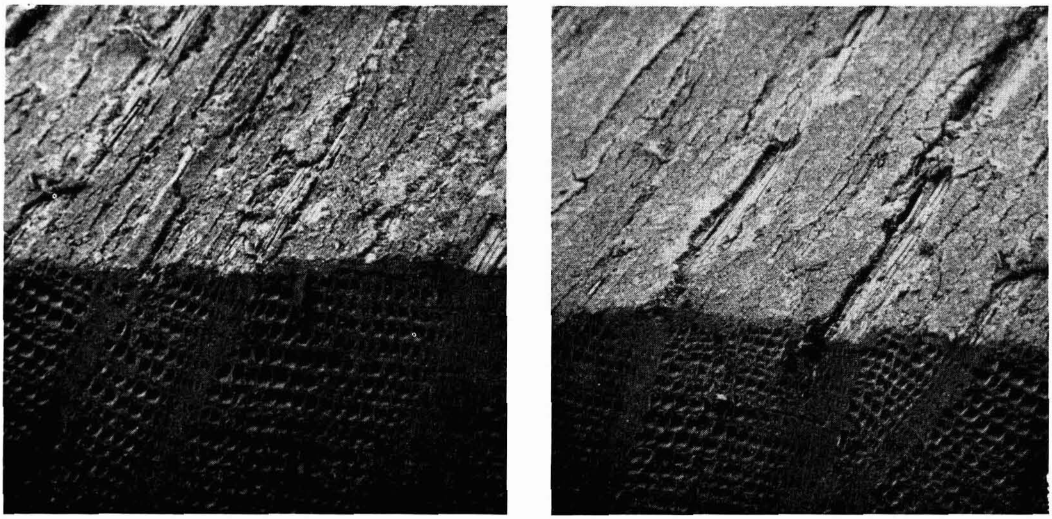
TIME			7 days					90 days				
Cracking			0	½	1	2	3-4	0	½	1	2	3-4
% Extensibility at 0°	After	%										
		14	45 (A1)						45 (A1)			
		10										
		8										
			43					43				
		6	3					3				
		5	15 30 46 47	23				15	46	47	23 30	
		4	1 4 21 25 28	32				1 21 28	25 32	4		
		3	2 10 11 17 24	6 9 27 41 42	29	20	34	2	10 11	9 17 33	24 42	6 20 27 29
			33									34 41
		2	38	22 26	40					22 26	38	40
		1	14	12 13 37	16	7 8 19 35				12 14 37	13	7 8 16 19 35
						39 44						39 44
		<1	(48)	18 36		5 31				36	(48)	5 18 31
	Before artificial weathering	%										
		26	15					15				
		24										
		22	47							47		
		20										
			3					3				
		18	2 43					2 43				
		16	11 33						11	33		
		14	10 45 46						10 45 46			
			17							17		
		12	25						25			
		10	21					21				
			38								38	
		8	14 30	9						9 14	30	
			1 24 28	13				1 28			13 24	
		6	4							4		
				12 23 37						12 37	23	
		4		41		35						35 41
			(48)	6 26 27 32 42	16	20 44	34		32	26	42 (48)	6 16 20 27 34 44
		2		18 22 36	29 40	8				22 36		8 18 29 40
		1				5 19 31 39						5 19 31 39
		<1				7						7

TIME			7 days					90 days				
Cracking			0	½	1	2		0	½	1	2	3-4
% Extensibility at 23°	After	%										
		21	3					3				
		14	45						45			
		10										
			43					43				
		8				20						
				23							23	20
		6	4 46						46	4		
		5	25 38 47	37 42					25	37 47	38 42	
		4	1 10 11 15 17	41				1 15 21 28	10 11	17	30	41
			21 28 30									
		3	2 24	6 9 12 32				2	32	9 12	24	6
		2	33	22 27	16	35 5 7 8	34			22 33		5 7 8 16
												27 34 35
		1	14 (48)	13 18 26	40 29	19 31 39 44				14 26	13 (48)	18 19 29 31
												39 40 44
		<1		36						36		
	Before artificial weathering	%										
		>30	1 2 3					1 2 3				
		30	25 45						25 45			
		28	11						11			
			15					15				
		26										
		24	28 43					28 43				
		22	46 47						46	47		
			10						10			
		20	38								38	
		18	17	9						9 17		
				12 42						12	42	
		16	14 33	32					32	14 33		
		14	21 30					21			30	
				41								41
		12	4 (48)	13 23 27 37						4 37	13 (48) 23	27
		10	24			20					24	20
					40	19						19 40
		8		6								6
				26			34			26		34
		6		36		39				36		39
				18 22		5 35				22		5 18 35
		4			16	8						8 16
					29	44						29 44
		2				31						31
		1				7						7



Figs. 3a (left) and 3b. Primers plus gloss coat after one year's exposure, corresponding to those in Fig. 2 (plus others). (N.B. Although the panels are shown vertical here, they were kept in the horizontal position during tests and photographing.)

Figs. 3c (left) and 3d. Primers plus gloss coat after one year's exposure, corresponding to those in Fig. 2 (plus others).
(N.B. Although the panels are shown vertical here, they were kept in the horizontal position during tests and photographing.)



Figs. 4a (left) and 4b. Stereoscan photographs of sections through paint film and wood, showing association of cracking with junction of early and late wood.

It is possible to criticise the use of a metallic substrate to test primers for wood on the grounds that any penetration of binder into the wood will produce a lower effective extensibility than on metal. For this reason the level of extensibility measured in this way and used as a criterion of performance on wood should be kept high. In general marked penetration is not necessary or desirable, and usually results in poor weathering of the unprotected primer. The adhesion may also differ on the two substrates; failures of adhesion were commoner on wood than on metal, and only one primer (No. 36) failed on aluminium but not on wood; this had also low extensibility. Primer No. 20 showed low adhesion to the wood, especially under gloss paint, and its adhesion to aluminium was poor before the weathering but better afterwards; its low permeability may also have increased the failure on wood in these tests.

Moisture permeability/resistivity

The results are shown in Tables 1 and 5. The primers fell mainly into a group, including both the lead-based and the aluminium primers, with a range of resistivity of one order of magnitude. Although high permeability should lead to faster or more frequent movement of the wood, it appears not to have been a determining factor in these tests, and does not explain any of the anomalies observed in the cracking caused by weathering. Very low permeability may result in blistering and has been considered a disadvantage if it prevents escape of moisture which has entered the wood via defective joints. One primer (No. 20) had an exceptionally and inexplicably high resistance, but this did not prevent it from cracking very badly in agreement with its brittle character, and four were rather more permeable than the rest, one showing moderately good extensibility and performance. The failure of many primers, even with the protection of a less permeable gloss paint, may be a further indication of the minor part played by permeability in these tests. Some primers were particularly susceptible to mould growth under the film, which may have been a consequence of high permeability or of composition.

The coated hardboard specimens were weathered for six months and the vapour resistivity re-determined. Fifteen of the 32 originally tested had cracked and flaked so badly that the result was meaningless; the resistivity of the remainder had fallen considerably and only Nos. 2, 9, 12, 15, 28, 45, 46 and 48 gave values greater than 1.0×10^5GNs/kg m (Table 5). Thus even primers which remained repaintable for six months would have very little ability to control moisture movement.

Table 5

Vapour resistivity (before weathering). Substrate: sized hardboard with resistivity 8.3×10^2 GNs/kg m

Resistivity R (GNS/kg m)	Primer Ref. No.
$> 100 \times 10^{-5}$	20
$> 10 \times 10^{-5}$	31
$> 5 \times 10^{-5}$	5 7 27 29 34 36
$1 \rightarrow 5 \times 10^{-5}$	1 2 3 9 10 11 12 15 17 21 23 25 28 33 37 38 41 43 45 46 47 48
$< 1 \times 10^{-5}$	4 44

Lead content

The lead content of the dry films is shown in Table 1. All were below the accepted level of 1.5 per cent, only three were above 1.0 per cent and a surprising number showed no lead content at all by the method of test of BS 4310. Thus there appears little difficulty in achieving a lead content less than 0.5 per cent. (Although the drying properties may be affected by the use, or omission, of lead driers, it is assumed that the performance recorded bears no relation to the amount of lead present in the primer which, if it is not derived from driers, is probably adventitious.)

Conclusions

Ref. 3

Wood primers at present available vary very widely in properties; there are few good examples and the worst must be regarded as highly unsatisfactory. A standard specification is shown to be essential, and would of necessity be based on performance rather than composition.

Extensibility is one of the most important properties affecting the behaviour of primers on weathering, but its determination by tensile testing of attached (or detached) films is considered too elaborate for a standard specification test, and some anomalous results, although few, prevent it from being accepted as a single criterion. It should not be less than 8 per cent at 0°C when determined by the method described here.

Bend tests are not sufficiently precise or reliable to be a substitute for extensibility tests, and cannot be used as a criterion of probable cracking behaviour as a result of weathering. Nevertheless, a bend test could be used with caution in development work, partly as an initial sorting test for low performance products, and partly as a confirmatory test. Primers should not fail a 6mm bend test at 0°C before weathering. Contradictory results between weathering and bend tests would indicate the need for repeated testing or further study of the products.

The need for rapid drying primers in factory production too often results in hard brittle films of low durability. The best examples tested in this work only just approached the necessary performance, and it is doubtful whether the two opposing requirements could be met by oxidising polymers. Some compromise will be necessary in production requirements if durability of paintwork is not to suffer. (Emulsion polymers provide one alternative.) However, a number of brushing type primers were also found unsatisfactory.

Permeability is a theoretically important property of primers, but very few of those tested fell outside a narrow range, which included the lead-based and aluminium primers. Permeability did not appear to be a controlling factor in performance in these tests. It is not, therefore, considered necessary to define permeability levels by a separate determination within a specification.

The best criterion of performance is obtained from a natural weathering test, but this has many disadvantages including the time required to perform it and variations in the substrate and the weather. A severe form of test piece rather than that advised by BS 3900 Part F6, should be adopted,* and the weather should be monitored, in effect, by comparing the primer under test with two others, of good and moderate known performance. Weathering should continue until breakdown of the moderate product occurs, at which point the test primer should not be inferior to the "good" standard. Difficulty in producing such a standard is foreseen, especially for the moderate performance, but extensibility could be used as a test of this suitability. Lead-based primers could be used for the standard of good performance, with the range of composition permitted by BS 2521 restricted for this purpose.

The beneficial effect of treatment of timber by a preservative containing a resin[3] (apart from its action against decay) has been confirmed and is good enough for it to be recommended as an immediate step towards better paint performance on joinery. It will not have much effect on the worst of the present primers. Quick drying primers, in particular, should not be used without such a treatment.

Until the guidance of a specification becomes available, wood primers should be required by specifiers to have an "elasticity" (extensibility) and hence a durability not markedly inferior to that of BS 2521 materials. This has been shown to be possible and can be demonstrated by fairly short term exposure tests of a severe nature. Rapid drying primers for joinery will need the support of a suitable preservative treatment as above.

Further work

Primers still in good condition after weathering have been overcoated and weathered further but are still to be assessed. It is hoped to explore possible modifications of primers by "plasticising" ingredients.

Acknowledgment

The work described has been carried out as part of the research programme of the Building Research Establishment of the Department of the Environment and this paper is published by permission of the Director. Part of the work, including especially that on permeability, was carried out by S. A. Kimpton.

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3. Sherwood, A. F., *BRE Seminars*, 21 February and 28 March 1973.

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*The horizontal test piece with a groove, described by the PRA[3], could be used as an alternative to the one preferred in this work.

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Efficient utilisation of technical resources in the paint industry*

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In considering the successful utilisation of resources in the paint industry, attention should be directed to technical facilities since this can be extremely rewarding. This problem must be approached from two sides, firstly the cost of providing technical facilities, (staff, laboratories, etc.), and secondly the efficient use of those resources with consequent realisation of economic rewards.

Technical resources may be roughly divided into the following categories:

1. Production and quality control.

2. Customer service, i.e. designing materials to meet customers' requirements and assisting customers in the proper use of the materials.

3. Research and development, which can cover such varied fields as the formulation of revised versions of existing products to initiating novel concepts and materials.

It is the last of these three items to which attention is primarily directed in this paper.

With the cost of employing one graduate together with necessary back-up facilities today running at upwards of £12 000 per annum, it is important that this expenditure be reflected in a company's economics and not just as an overhead charge. This is expenditure which must show a return in some way in the company's trading—at the worst, as an insurance against customer dissatisfaction and at the best as an increase in sales and stature.

The allocation of a company's technical resources should, therefore, be directed to specific objectives with defined priorities. The question raised here is whether those objectives and priorities can be best met totally from within company or "in-house" facilities or whether there is a case for spreading the expenditure outside the company; possibly even reducing it or accelerating the speed of its return, by contracting out part of the work load or specialised parts of it.

The paint industry is believed to make far less use of outside facilities than many other industries. This may arise in part because some other industries, such as the food industry, are compelled by the legislation of this country to come into contact with consultants. Also, the nature of some industrial problems in other industries require the *ad hoc* specialised advice. The paint industry, though, is more of a technological formulating industry than, in most cases, one employing scientific research and, in consequence, there seems to be the feeling in many establishments that to put work out or to ask for assistance implies some failure to cope on the part of the company, its staff or facilities. Such an attitude is suggested to be fallacious and in these days of rising costs probably economically unjustified.

Facilities available

One other possible reason for the limited usage of consultants by the paint industry is that there are apparently few outside facilities which are directly related to its day-to-day requirements. It is, therefore, useful to consider the range of establishments in the UK which might be called upon in one way or another.

These may be listed as follows:

1. Universities and technical colleges.
2. Government and official establishments.
3. Large contract research organisations.
4. Independent paint and testing laboratories.
5. Individual private consultants.

In principle, these establishments have the following facilities to offer, bearing in mind that what may be required is particular knowledge or expertise as much as laboratory investigations.

1. Universities and technical colleges, by their very nature, will tend to have a primarily academic approach to problems, though they may well be equipped to study technological problems. They may have some difficulty in relating this to an immediate industrial problem. In terms of cost, they are probably the cheapest source of advice, but in return for this, it has been suggested that work may not be confidential. This arises since it is the nature of these establishments to propagate and exchange knowledge whilst any work allocated to students would normally be published in the usual course of events.

2. Government and other official establishments, known collectively now as the Research Requirements Boards, cover a wide range of specialised knowledge and facilities. They include the UK Atomic Energy Authority, the National Physics Laboratory and the many trade research associations, including, of course, the Paint Research Association. All these establishments represent a source of academic and industrial expertise backed by excellent facilities and they are, today, in active competition with other contract research and similar organisations.

3. The contract research organisations are mostly very well equipped large organisations capable of undertaking highly scientific and complex investigations. Whilst some specialise in particular fields, many are able to work in almost any industrial or technological subject. Their work is entirely confidential. Their prime merit, in addition to those mentioned, is their ability to bring a range of expertise, both scientific and industrial, to bear upon a problem.

4. In this country today, there are a large number of independent laboratories, mostly serving a specialised in-

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*Presented at the Association's Joint Symposium with the Paintmakers Association of Great Britain Limited, held at University College, London, on 17 September 1974.

dustry. Their services range from almost solely independent and public analysts, to independent test houses and to those who can additionally offer sponsored development facilities, consultancy, trouble-shooting and other services. Though a fairly large number of these offer paint and similar products as part of their practice, it must be admitted that this mostly means a knowledge of their analysis and simple testing. Only a few are equipped as paint laboratories and employ paint technologists.

5. There are, in addition, a large number of independent consultants who offer no laboratory facilities. However, this does not render them of no value for they generally have a wealth of knowledge, experience and ideas to offer, besides being able to carry out specialised activities, such as critical appraisals or surveys, marketing knowledge, literature searches, etc.

Thus, there are available a wide spectrum of services from which it is possible to draw knowledge, expertise, ideas and investigations to meet any requirement. It may be worth stating at this stage one further basic aspect regarding the different types of establishment. Universities, colleges and official bodies do not have consultancy as their prime *raison d'être* and may, therefore, not find it so easy to apply themselves with urgency to a client's requirements, whereas all independent consultancies must totally commit themselves to the demands of their clients, since this is their prime business. It is now necessary to see how and why those services might be used and to what advantage.

Use of consulting services

Assuming that the apparently inherent resistance to seeking outside facilities has been overcome within the company mentality, it is necessary to consider for what reasons a company may seek to use consultants.

The obvious first instance is when a problem arises which lies outside the immediate competence or facilities of the company. It must be made clear at this stage, and as will become apparent shortly, this does not imply any disparagement of the company; neither does the size of the company influence the position for, naturally, the need and extent of outside services will be proportional to the company's resources and demands.

The types of problem which may call for external assistance are very varied. The immediate one is when a company's technical resources are under pressure so that they cannot cope with some additional matter of urgency. This can arise when the staff are fully occupied, when the technical facilities are fully committed or when some work is required for which the necessary equipment, knowledge or expertise does not exist within the company. Under such circumstances, management is faced with capital investment for facilities or engagement of staff which represents a lasting charge, whereas it would be possible to put the work out, representing a known, fixed, "once-for-all" charge against profits.

This illustrates the main consideration in deciding to contract out some work. The first requirement in a company must be to maximise profits and this must mean to achieve results at the minimum cost and to control those costs. The cost of technical resources, both in terms of capital expenditure and the return on it and in operating costs, needs today to be controlled, kept in balance and assessed in terms of return to the company. On these grounds, the possibility of minimising the cost and maximising the return means that all companies ought to review all possible sources of achieving the best result whether it involves in-house or external facilities.

There are other situations where external sources might be of value to a company and these are mentioned briefly below.

It may be useful to obtain a second or independent opinion or test on materials or products, confirming or otherwise the "in-house" assessment.

In cases of dispute, an independent investigation or opinion is often invaluable in agreeing on the facts, allotting responsibility and settling differences. Of course, it cannot be expected that such an investigation and report will necessarily favour the employing party, but it will serve the stated purpose and may save any further and even acrimonious dispute or action and prevent the ultimate solution of resort to the law. However, should it reach this stage, many consultants can assist in preparing the case and assisting at the hearing.

It can arise that help is needed in an area where existing staff are not experienced. In this case, knowledge and advice can be obtained, perhaps enough to set in-house staff on the right road, and this would be much cheaper in all probability than the time and effort involved in starting from scratch.

There is always the fact that a knowledgeable person from outside an organisation can bring some critical appraisal to bear on a company's activities, whether they be technical, organisational or in production. It is possible to use technical consultants when planning to increase the success of the company.

The search for basic understanding may call for scientific investigation on a scale not available in the company, for example due to absence of facilities or in calling for a blend of techniques and equipment available only, say, within the universities or contract research organisations. Under such circumstances, it is clearly cheaper and more efficient to contract the work out. It may, perhaps, be emphasised at this point, that it can be advantageous, at any time when working on any problem, not to overburden existing staff whose prime duty is to prosper the company's day-to-day activities; under these circumstances, there is a double saving in that there is no resulting loss from seconding staff from their principal function.

Another use of consultants is for protecting proprietary interests. Independent inspection of materials and work in progress is an example of this, whereby assurance is obtained that the cost of any project is reflected in the desired performance and reducing the incidence of dissatisfaction and failure.

The problem of the new activity, the potential new market, the novel idea, and the pioneering project is of importance in this context: how is progress to be made with such activities, which may well represent tomorrow's staple fare, without detracting from today's bread and butter? The first question is to assess the idea and its potential. Consultants can help by bringing an outside objectivity to it, so clarifying the aims of the project. They can search the literature for information bearing upon it and, perhaps, produce ideas, information and facts already established, which could provide a platform on which to base development, at the same time reducing duplication by repeating such work in the laboratory and so moving the project forward more rapidly. Some consultancies can also help by investigating and assessing the potential marketability of products and advising on them. All these approaches represent potential savings far in excess of the cost of the consultations, both in reducing in-house costs and time expended and in ensuring activities are directed to the more immediately rewarding objects. Consultants are an established and valuable source of innovation, both in carrying out innovation studies and acting as catalysts in its promotion.

It is, of course, entirely possible to contract out the entire research and development effort on a given project, particularly where it requires expertise and equipment beyond the in-house facilities, thereby also saving regular activities from interruption. This approach does call for very careful appraisal of the project and clear definition of the aims, but there can be no doubt that this approach is being successfully employed in many industries with undoubted benefit and returns.

It is worth remembering that consultants and contract research organisations are in business to offer a service. It is in the nature of their business to progress the work. Thus, it is always possible that an outside laboratory will achieve results more quickly than an in-house investigation. This can be particularly true where it is the practice to take off staff from development work to assist in day-to-day problems and crises. The job which was "started but never finished" or the bright idea that is going to be investigated "one day when there is time" are more often than not dead before they start. The second-priority investigation is often doomed *ab initio*. Yet, put in the hands of a consultancy, it would be completed and earning money, in all probability, instead of remaining a glint in the director's eye, or a sheer loss on such effort as has been expended.

Multi-client projects

There is a growing tendency in other industries to use multi-client projects. So far, these have usually arisen from initiative by consultancies and contract research organisations as a means of employing their facilities. It has also become common for investigating markets and potential markets.

The idea behind these projects is to investigate a problem in depth, the cost being shared between a number of clients, each being entitled to all the findings of the investigation. The approach clearly has certain merit where there is some element of risk in the project.

However, the paint industry is notorious for, amongst other things, duplicating and re-duplicating effort in its laboratories. Not only are many new raw materials evaluated first of all by their suppliers but also by practically all paint manufacturers likely to find them of interest, but new ideas and techniques are equally explored, often even though the company are not presently involved in the market to which the development applies, in the hope that by good fortune or the shortcomings of others, they will suddenly find themselves in a new marketing area where they were unlikely to enter by normal commercial competence.

All this represents a very high cost to the industry as a whole and one which does not really reflect in improved profitability. Much of this multiplication of time, effort and cost might be reduced if the industry could take a notable initiative, either as a whole or in smaller groups, to take it upon themselves to initiate multi-client research and examination in specific areas. The whole industry might well benefit from the results of independent objective assessments and investigations, reduced cost of technical know-how, better use of existing facilities and, hence, better economic returns.

It may be that, with the aid of consultancies, a clearing house of knowledge, test-results and other data on raw materials could be built up and available to subscribing participants, thereby considerably reducing in-house evaluations to those materials or applications which are of immediate moment to the company.

Choosing a consultancy

The first problem in choosing a consultancy or contract research organisation is to formulate and define precisely the problem for submission to the consultant. Good returns can only be expected if the consultant is fully appraised of the background to the problem and the exact requirements and aims of the investigation.

This done, the next problem is to locate consultants, which strangely seems to be a major problem for some companies. Apart from the trade associations and directories, there are a number of published directories, the chief of which are those published by the Royal Institute of Chemistry, the Association of Consulting Scientists and the Fulmer Research Institute.

Having selected a short list of potential consultants, taking into account the type of work required—the more scientific or basic research orientated the problem, the larger the organisation sought for, in all probability—it is advisable to ensure that the practices chosen are equipped and competent to undertake the work. It is clearly no use employing a consultant without laboratories for an experimental programme or an analyst for development work.

The rule should be to discuss the project with the selected consultant or consultants to satisfy oneself of their expertise and facilities. In the case of large programmes, of course, a visit to them is strongly recommended and every effort should be made to ensure that they can supply the required service. As was pointed out earlier, many consulting houses claim to offer paint as one of their fields, but only a few are able to offer paint making and testing facilities or, indeed, much expertise in paint technology. It is, therefore, vital to choose an organisation commensurate with the nature of the commission and its requirements.

There is, however, no escape from clear thinking in defining the problem to be studied. It is essential to give clear instructions, precise objectives and full background details to the consultant, so that his work can be directed to the object of the exercise with the minimum deviation. A consultant cannot be expected to be thoroughly efficient in assisting a client if the client does not provide him with all the information necessary for a successful study.

The cost of consultants

The first point to remember in counting the cost of using consultants is that consultants have the same costs in staff, facilities and equipment as anyone else. The overheads in such matters as premises, administration, maintenance of libraries obviously increase as the size of the organisation increases but, in return, the client is buying from the enhanced sources of information and knowledge.

Thus, a consultancy cannot necessarily carry out an investigation more cheaply than could be done by in-house work if the latter were accurately costed. Consultants are often thought to be dear merely because the purchaser has only the vaguest idea, if any, of how much his own technical resources actually cost.

The advantage of using consultancies lies in the fact that the client is really buying a package of technology, expertise, work, etc., and that there is a limit to their financial commitment. They are, in fact, buying a given number of hours' or days' work which includes a proportion of the cost of maintaining the facilities available. They are substituting, too, in place of their own capital investment in specialised and maybe expensive laboratory equipment, a proportion only of that cost already incurred by the consultancy, thereby saving their own money and yet taking advantage of the knowledge that could be obtained by a permanent engagement both in staff and equipment. In other words, the client limits his liability without limiting his return. Under such circumstances, consultancy might appear expensive, but must represent a good return on the *ad hoc* investigation plus, of course, the other advantages which might accrue from it as discussed earlier.

As with most other activities, "one gets what one pays for" and this is equally true of consultancy so that the more that is sought and the better or more exotic the facilities required, the higher the cost. Perhaps it would be as well to realise that a cost of £12,000 per annum per graduate equals about £7.50 per man hour.

Conclusions

Technical resources must today be considered in the light of their reflection on a company's profitability and their efficient use must be continuously ensured, as well as being assessed in economic terms. In like manner, the use of consultants must be similarly assessed, but by considering outside services as a useful concomitant source of knowledge and information, it is suggested that the total return to the company or, indeed, to the industry on income and capital expended can be increased. No company or consultancy, whatever its size, can claim to have all-encompassing knowledge or facilities and the augmentation of their technical resources as and when required but without permanent commitment must represent a significant means of increasing the return on the expenditure, to say nothing of the possibility that the independent minds might trigger off or quantify the idea that augers progress and even greater economic returns in the future. The use of consultants can provide on the technical front cross-fertilisation of ideas and support existing services whilst on the economic front, they can assist profitability by helping to eliminate unrewarding projects, by accelerating new projects, by reducing long-term commitments and by minimising or delaying capital investment so that in-house resources might be also used to maximum benefit. This is surely what the efficient uses of resources really means.

[Received 17 September 1974

Next month's issue:

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

Evaluation of polyurethane systems as clear lacquers on four types of wood *by K. Borgin, A. Lowe and P. A. J. Gate*

Trends in petrochemical raw materials *by A. L. Waddams*

Some aspects of the industrial application of the Egyptian rice germ oil in the field of surface coatings. Part I Separation and modification of rice germ wax *by A. M. Naser, M. A. El-Azmirly and A. Z. Gomaa*

Some aspects of the industrial application of Egyptian rice germ oil in the field of surface coatings. Part II Preparation and evaluation of rice germ and rice germ/linseed oil alkyds *by A. M. Naser, M. A. El-Azmirly and A. Z. Gomaa*

Information Received

Agents for Price's Chemicals

Price's Chemicals Limited has announced the appointment of Ellis and Everard (Chemicals) Limited as principal distributors in England, Scotland and Wales for small quantities of the company's oleine, stearine and glycerine.

The appointment is immediately effective and initially Ellis and Everard will handle orders for delivery in quantities less than 1 tonne.

BXL modernisation

Bakelite Xylonite Limited, a wholly owned subsidiary of Union Carbide Corporation, has announced its intention to carry out a £2 million modernisation programme at its industrial laminates' plant at Tyseley, Birmingham.

The investment is aimed at expanding Bakelite's production facilities to meet anticipated growth of demand in Europe, and the project is scheduled for completion in mid-1976.

Chemical fluid aids textile machinery sales drive.

The availability of a high performance chemical heat transfer fluid has enabled a textile finishing machinery company in Manchester to guarantee performance of its products in a crucial operational sequence and to win more overseas sales, reports ICI.

Hunt and Moscrop Limited of Middleton, near Manchester, produce a range of transfer printing machines—under the trade mark "Transfaprint"—used in the steadily expanding business of transfer printing synthetic textiles. This technique, introduced about eight years ago, is expected by some market forecasters to be the means by which nearly 1 000 million square metres of printed material are made available to the world by the end of 1975.

The printing system involves the transfer of coloured patterns from a usually gravure-printed or flexograph-printed paper to a textile material in one operation. The "Thermex" heat transfer medium can be used in either liquid or vapour phase, and is produced and marketed by the Petrochemicals Division of ICI at Billingham, Cleveland.

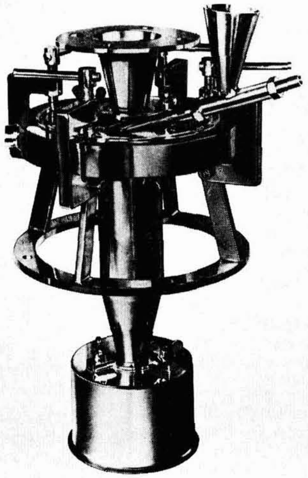
Introl Valve Servicing Department

Introl Limited of Halifax—the control valve specialist company in the George Kent Group—has established a Valve Servicing Department to inspect, repair or replace all makes of valves used in process control systems.

Reinforcing fillers from Akzo

Akzo Chemie UK Limited is marketing a range of white reinforcing fillers produced by its associates Akzo Chemie GmbH, Duren, Germany. In the past these products have been distributed by British Lonabarc Chemicals Limited. Akzo Chemie has assumed this responsibility as part of the Akzo Group policy, world-wide, to market its total range of products through wholly-owned companies.

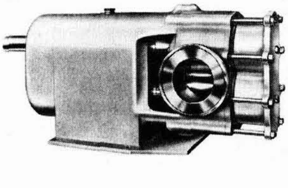
New products



The "Microniser" shown above is available from Airfilco Limited, Newbury, Berkshire. It is recommended by the company for grinding titanium dioxide using super-heated steam as the energy fluid

Syringeless injection system for Perkin-Elmer gas chromatographs

The MS-41 manual capsule sampler is now available from Perkin-Elmer Limited, for use with the company's Models F30 and F17 gas chromatographs. This accessory dispenses with syringe injection, and makes possible the analysis of many previously difficult, if not impossible, sample types by direct introduction into a gas chromatograph.



A high pressure version of the model 500 ND pump, which is now available from the Mono Group Pump Division of Stainless Steel Pumps Limited.

Non-glass pH system

A solid-state antimony sensor for pH measurements, the "2200" system, is being marketed by Martron Associates Limited, 81 Station Road, Marlow, Bucks.

Literature

Directory for Germany

A completely revised seventh edition of "Farben & Lack Adressbuch" has been published by Vincent Verlag, Hanover. The first section of this directory includes names and addresses of those in the paint, colour and related industries in respect of wholesale, retail, importers, agents and so forth within the Federal Republic of Germany and West Berlin. The second section refers to sources of supply of raw materials and finished products, including trade names, as well as machines, accessories and other items.

BSI drafts

The British Standards Institution has announced that the following drafts are now available for public comment:

BS 2900, Part C8, "Print-free test" (DIS 3678)

BS 217 "Red lead for paints" (DIS 510)

BS 303 "Lead chrome green pigments for paints" (DIS 3710)

The latest date for receipt of comments is 27 March 1975.

Degussa Aerosil

The Pigments Division of Degussa, Frankfurt am Main, has published a 12-page brochure entitled "Aerosil for Plastics" with colour illustrations and describing various types of the company's highly-dispersed silicas for use in the plastics industry.

The Division has also published a folder "Aerosil R972 in zinc dust primers."

Profile of the European paint industry

Information Research Limited has published an updated second edition of its latest report in the "Profile" series on the European paint industry.

The report identifies the major paintmakers in each of the national markets, and gives details of their sales levels, market shares and number of employees. Recent changes in the industry are commented upon, and the most significant mergers and acquisitions in recent years are listed.

Xenotest 1200

A brochure and technical information sheet concerning the "Xenotest 1200" machines for accelerated light-fastness and weathering tests are now available from John Godrich (consulting engineer), Ludford Mill, Ludlow, Shropshire, the UK agent for the manufacturer Original Hanau Quarzlampen GmbH, Germany.

Bristol

Design for wall coverings

The 203rd Ordinary Meeting of the Section took place on Friday 25 October 1974, when Mr G. R. Marks of ICI Ltd delivered a paper entitled "Design for wall coverings" and members' ladies were invited to attend. Mr F. E. Ruddick was in the Chair.

The lecturer described the three main types of wall coverings on the market: paper, paper-backed vinyls and the more recently developed polyethylene types, which were stated to be an inexpensive way of decorating a wall.

The factors influencing fashion and taste in wallpapers were discussed as well as the problems of satisfying the customer regarding the individual choice, and producing designs, which fell into groups suitable for efficient manufacturing programmes. It was necessary for ICI to produce 250 to 300 colourways on their machines. Many examples of design and style were shown during the discussion, in which the lecturer sought to have the point of view of the ladies present.

The subject created much interest and lively discussions took place. The meeting was concluded with members and their guests enjoying an informal supper at the Mauretania Restaurant in Bristol.

J.R.T.

Precious metals for surface coatings

A technical meeting was held on 29 November 1974, chaired by Mr F. E. Ruddick, when Mr D. Blower of Engelhard Industries Ltd, gave a lecture on "Precious metals for surface coatings." This was the annual joint meeting between the Birmingham Paint, Varnish and Lacquer Club and the Section, and as usual the BPVLC were well represented.

The lecture was most interesting and informative and covered the use of precious metals, gold, silver, platinum and other rare metals for coating a variety of substrates for decoration and industrial use. In the electronics industry, their use in miniaturising electrical circuits was of importance. The methods of application of these extremely thin coatings varied from the use of a hard brush to electrolytic, vacuum coating and transfers. The effect of change in the type of alloy used on the properties and colours obtained was demonstrated. The historical use of these metal coatings on early china articles and the changes which have taken place in the technology in modern times, was clearly described.

An excellent discussion on points raised in the lecture took place in which many members of the Birmingham PVL Club participated.

The vote of thanks was proposed by the President of the Birmingham Paint, Varnish and Lacquer Club, Mr R. A. J. Allen, after which members adjourned to the Mauretania Restaurant to take part in the dinner which is the custom after these annual meetings.

J.R.T.

Hull

Effect of molecular structure on film characteristics

The fourth ordinary meeting of the 1974/75 session was held at the George Hotel, Land of Green Ginger, Hull, on Monday 6 January 1975, with Mr E. Armstrong in the chair. Fifteen members and guests assembled to hear a lecture given by Mr W. K. H. Lakin of Manchem Limited entitled "The effect of molecular structure on the action of wetting agents and on film characteristics as shown in an alkyd resin system."

Mr Lakin reported on the work of Haselmeyer and Oehmichen at the laboratories of Byk-Mallinckrodt in Wessel, West Germany. Their work investigated the effect of the molecular structure of wetting agents on a wide range of properties of a paint system; a large number of selected compounds were evaluated.

The basic materials were, firstly, mineral and sulfonic acids and secondly, aromatic and aliphatic, saturated and unsaturated mono- and poly-carboxylic acids, the molecules of some of which contained additional functional groups. These acids were neutralised with primary alkyl amines of various chain lengths and used in a primer and finish based on a quick drying, medium oil alkyd.

The alkyd had relatively good wetting qualities and micronised pigments were used so that it was not possible to determine differences in the dispersion. For this reason, attention could be directed to one of the main problems in the paint industry, namely stabilisation (that is, the control of flocculation and the related problems of sedimentation and flooding and floating).

Paints were manufactured using a pearl-mill and exactly one per cent of the wetting agent (calculated on the total formulation weight) was incorporated at the mill base stage. Tests were performed to determine the effects on settling, viscosity, drying, flooding, gloss, hardness, adhesion and corrosion resistance of the paint system.

The results showed that methylamine salts were fundamentally less effective in preventing settling than oleylamine salts. The viscosity was greatly increased by the use of methylamine salts. The flocculation was so marked when methylamine salts were added that there was considerable loss of gloss in the paint films. Methylamine salts again gave less corrosion resistance. Oleylamine salts gave the best results, both in the prevention of settling and with respect to paint film properties.

A distinct improvement in corrosion resistance was obtained only by the use of oleylamine salts. The values obtained from the use of salts made from various acids showed the following tendency: unsaturated aliphatic acids could inhibit sedimentation only when the molecule chain attained a certain length, whereas in the case of saturated acids, even low molecular weight acids were fully effective. Polycarboxylic acids acted in a similar fashion to unsaturated acids; effectiveness improved as the chain length increased.

The effect on the properties of the paint film of unsaturated, high molecular weight polycarboxylic acids was more beneficial than those of low molecular weight. There was no advantage in using aromatic acids rather than aliphatic ones, since in respect of film properties, especially corrosion resistance, they produced poorer values. Among the mineral acid salts, only phosphoric acid salts of oleylamine were suitable as wetting agents on the grounds of effectiveness and the properties of the film.

As was illustrated in a number of slides, strong flocculation resulted in the prevention of settling and of floating and also greatly increased viscosity. The optimum wetting agent had to so control flocculation that settling and floating were effectively prevented without adversely affecting film properties.

Mr Lakin said, in conclusion, that further investigations were in progress with other compounds (secondary and tertiary amines) in various coating systems and with varying quantities of additives.

This informative lecture stimulated many questions, which were confidently answered by Mr Lakin. A vote of thanks for an enjoyable evening was proposed by Mr P. Adamson.

D.M.W.

Irish

Printing ink technology

A talk entitled "Some aspects of modern printing and ink technology" was given to the Section on Friday 6 December 1974 by Mr K. Pond of Ault and Wiborg Limited.

Mr Pond's introduction dealt with the problems that ink-makers had faced, in common with other industries, during the past few months due to raw material shortages. One beneficial effect of this situation, combined with some dramatic price increases, had been the increased cost consciousness of all formulators, whether they were engaged in development work or with day-to-day matters.

Basic development work had been hindered to a certain extent because of the time that had to be spent on looking for alternatives to raw materials no longer available or available at prohibitive prices.

In Mr Pond's opinion, the introduction of the European Standard set of four process colours for offset printing had been a major progressive step, and very few printers today, in his experience, used special shades of offset process inks. It had also been of help to the inkmaker because it was possible to formulate the inks from single pigments, which was of great assistance in manufacture and standardisation.

There were not any further major developments which could take place in the field of conventional sheet fed offset, where there were presses, such as the Roland 800, which were capable of producing printed sheets at a rate of over 12 000 iph; speeds faster than this required the use of accelerated ink drying, using heat, microwaves, infrared, or ultraviolet radiation. UV radiation as a means of converting wet films to dry almost instantaneously had been used for many years in other industries, but the renewed interest in the field of printing had been brought about by several factors, such as anti-pollution laws, and the demand for faster production of cartons for packaging work. In some parts of America, it was now illegal for solvents used in heatset printing inks to escape to the atmosphere, and it was probable that similar legislation would follow in the UK and Ireland.

Mr Pond dealt briefly with developments in the fields of gravure and flexography and, in particular, the development work taking place to use water as the major solvent in flexographic inks, not only for paper inks for relatively cheap work, such as Kraft printing, but also in the field of film printing.

Following the talk, there was a lively question and answer period, and a vote of thanks was given on behalf of the Section and the 30 members present by Mr A. Richards.

R.C.S.

Midlands

Trent Valley Branch

Surface preparation of steel

Members of the Branch met at the British Rail School of Transport, London Road, Derby, on the night of Thursday 9 January 1975, to hear Mr A. Bendelow begin the lecture series for the New Year, with an illustrated talk, entitled "Surface preparation of steel." Mr Bendelow is Training and Development Manager (Blasting Division) of the Samuel Hodge Group of Companies.

The speaker expertly introduced his audience to the staggering cost of corrosion in the UK which was estimated to be in the order of £1 300 million per annum (plus VAT!) The five principal mechanical and chemical methods for cleaning iron and steel prior to painting were detailed and shown to be inferior in every case to the technique of grit-blasting. The audience were then shown a film, which was a "Wild West" parody with 200 m/s grit bullets leaving their "anchor pattern" brands on cold steel. "The ABC of surface preparation" also illustrated portable gritblasting equipment, operating on land, sea and air, on external surfaces and within the confines of small tubes.

Mr Bendelow discussed the application of wet-grit-blasting anti-pollution and under-water techniques used for cleaning and outlined the different grades and types of shot and grit particles used to obtain the internationally acceptable standards of surface preparation.

A lengthy question period followed, in which every member participated. Mr J. Fowles-Smith proposed a vote of thanks on behalf of the gathered company.

J.R.K.

Review

Handbook of moisture determination and control

By A. Pande

Marcel Dekker Inc., New York; 1974. Pp. xi + 266. Price $28.50

This volume is divided into four chapters and is a useful book for the industrial or research chemist approaching water determination for the first time or requiring updating in this subject. It is printed in typescript and has 15 Tables, 75 Figs. or reproductions and 352 numbered references to other work, and these show much reasearch into the subject which covers different substances for which the moisture content is required; in addition the author has given of his experience in the different fields in which he has worked.

Chapter 1 concerns the properties of water and its interaction with hygroscopic materials, with lengthy details on sampling.

Chapter 2 is on gravimetric methods and techniques, with details of drying by ovens, infrared heating, and chemical desiccation. The principles and working of direct reading balances and moisture testers cover 26 pages, followed by thermal analysis techniques.

Chapter 3 deals with azeotropic and chromatographic methods but gives an excessively long discussion of the theory and practice of chromatography before moisture is mentioned.

Chapter 4 is devoted to the Karl Fischer method and describes many techniques very thoroughly, from the preparation of the reagent to the various titration methods used.

There are few typing errors and most are very obvious. The author must be responsible for "Acetyl" on page 11 where "Acetate" should have been used, and "Parts per billion", without qualification, is misleading. A Cumulative Index is to appear in the fourth volume.

E.C.S. ESHER

Notes and News

OCCA—XXVII Exhibition

Olympia, London. 22-25 April 1975

The International Forum for Technical Display and Discussion in the Surface Coatings Industries

★ Australia ★ Belgium ★ Finland ★ France ★
★ Germany ★ Holland ★ Hungary ★ Italy ★
★ Norway ★ Poland ★ Rumania ★ Sweden ★
★ Switzerland ★ UK ★ USA ★

Direct exhibits from 15 countries

Since the February issue of the *Journal* was published, space has been allocated to three further exhibitors:

Neumo Ltd.
A. Strazdins Pty (Australia).
Tin Research Institute

Special visits by overseas trade delegations

Following the great success of the delegation from Osaka, Japan, on the occasion of OCCA-26 when special arrangements were made for works visits etc, requests have already been received for similar facilities for a delegation from Czechoslovakia, Switzerland and for a further Japanese party.

Any company wishing to be placed on the list of those willing to accept such delegations should write to the Director & Secretary as soon as possible, setting out the countries in which they are interested and the scope of the activities which would be displayed.

The "Official Guide" and season admission tickets

The "Official Guide" to the Exhibition is now being circulated to all members of the Association, at home and abroad and—through the courtesy of trade associations—to manufacturing companies in the surface coatings industries. They are also being dispatched to those non-members who have completed and returned the application forms which have been widely circulated with the information leaflet in six languages.

Although members of the Association will automatically be sent an individual copy of the "Official Guide", together with a season admission ticket, it has been decided on this occasion, however, to make a small charge to non-members of £1.00 to cover both the "Official Guide" and the season admission ticket. Non-members wishing to receive tickets and copies of the "Official Guide" in advance should send to the Association's offices the relevant form together with the necessary remittance, as soon as possible.

Copies of the "Official Guide" and season admission tickets will also be available at the entrance to the Exhibition.

Aim of the Exhibition

The aim of the Exhibition is the presentation of technical advances in those industries supplying the paint, printing ink, colour, linoleum and allied industries and the Exhibits may relate not only to new products but also to new knowledge on existing products and their uses and existing knowledge which is not generally available in the consuming industries.

Venue

As in 1974, the exhibition will be of four days' duration and will open on the Tuesday morning at 09.30 and will close on the Friday at 16.00. The exhibition of raw materials, plant and equipment used in the paint, printing ink, colour, and allied industries will take place at the Empire Hall, Olympia, London.

Tuesday 22 April	..	09.30-17.30 hrs
Wednesday 23 April	..	09.30-17.30 hrs
Thursday 24 April	..	09.30-17.30 hrs
Friday 25 April ..	..	09.30-**16.00** hrs

April and June issues of the Journal

The April issue of the *Journal* will include a special Preview of the Exhibition, including latest information on the Exhibitors, not available at the time when the "Official Guide" was printed, a list of exhibits under various product headings, alphabetical and numerical lists of Exhibitors and other organisations mentioned in the "Official Guide," floor plans of the Exhibition Hall and other information.

The June issue will contain a comprehensive technical Review of the Exhibition, classified under product headings, and including many photographs of stands taken during the period of the Exhibition.

Travel agents and hotel accommodation

The Wayfarers Travel Agency Ltd., Cranfield House, 97/107 Southampton Row, London WC1B 4BQ, will be allocated a stand opposite to the OCCA Information Centre at the Exhibition and will be prepared to advise on, and arrange, hotel accommodation and travel facilities to the Exhibition. They will also be able to make theatre ticket reservations for the evenings of the Exhibition.

Please address all enquiries to The Wayfarers Travel Agency AT THE ADDRESS SHOWN ABOVE, and not to the Association.

Leaflets offering accommodation at special rates at the Grand Metropolitan Hotel Group, as in previous years, may be obtained from the Association's offices.

News of Members

Mr P. J. Robinson, an Ordinary Member attached to the Newcastle Section, has been awarded the degree of PhD. by the Council for National Academic Awards for a thesis on work carried out in the laboratories of Durham Chemicals Limited.

F. W. Clark Memorial Prize

The F. W. Clark Memorial Prize of a silver medal and award has been presented to Eugenio Lopes Henriques Da Conceicao, a student at East Ham College of Technology, for his performance in the Chemical Technicians Certificate (Part III) Paint Technology Examination in 1974.

Midlands Section

Trent Valley Branch

Visit to Webb Corbett glassworks

Some 30 members and their wives from the Section and the Branch toured the factory of Webb Corbett Limited at Tutbury on Monday 2 December. The party met for an excellent lunch at the Riverside Inn, Branston and then went on to spend a most interesting afternoon at the glassworks. After the tour, members were allowed to buy glassware at the works shop. Arrangements were made jointly by the Social Secretaries of the Midlands Section and the Trent Valley Branch.

C.V.W.

Biennial Conference 1975

A view of the castle remains at Scarborough, the venue for the 1975 Conference. The keep has been adopted as a symbol for the Conference, its significance being explained in previous issues of the Journal

Performance of surface coatings—does reality match the theory?

International

The Association is pleased to announce that papers will be presented at the Conference from members of the international liaison as follows:

FATIPEC

"Prediction of corrosion protective properties of paint films by permeability data" by Dr H. Haagen.

FSCT

"A new versatile lead free pigment" by Mr S. L. Davidson.

SLF

"Theories—laboratory investigations—practical performance" by Mr B. Lindberg.

Full details of the Association's Conference were circulated with registration forms in the January issue of the *Journal* and further copies may be obtained from the Association's office (Telex: 922670).

The full programme of sessions, summaries of papers and biographies of lecturers have appeared in the January and February issues.

Readers are reminded that the closing date for registration will be **1 April 1975** though later applications, particularly from abroad, will be considered after that date, but it may not then be possible to allocate accommodation in the two hotels—the Grand and the St. Nicholas—in which the majority of delegates will be staying.

Preprints

Preprints of the papers are now being prepared, and it is expected that these, together with details of accommodation, badges, programmes, etc., will be sent to those who have registered late in May. It is a feature of the Association's Conferences that preprints are sent well in advance of the function, in order to enable delegates to read them before the Conference, at which the lecturers illustrate their topics but do not read the papers in their entirety. This allows for a much longer discussion period than at many other Conferences, and has proved of immense value to those attending previous Association Conferences.

Registration fees

The Council has fixed the registration fees for the Scarborough Conference at £30 for members, £10 for wives, and £50 for non-members (all fees subject to VAT at the standard rate). Registered students of the Association and retired members are allowed to register at 50 per cent of the member's rate.

Dates and times of sessions

The Conference assembles on the evening of Tuesday 17 June when, in accordance with its usual tradition of hospitality, the Association will hold a reception for all those attending from overseas, which will be followed by a meeting of the lecturers and the chairmen of sessions. The Conference sessions will be held on Wednesday and Thursday 18-19 June, morning (9.30-12.30) and afternoon (2.30-4.30), and the morning of Friday 20 June (9.30-12.30). The Association's Annual General Meeting will take place at 2.15 p.m. on Friday 20 June, and this will be followed by three workshop sessions, which have proved very popular in the past. The title of the sessions were given in the Conference brochure and once the total number (25) of participants for a session has been reached, later applicants will be offered an alternative session, if possible.

Receptions and dinner

There will be an informal reception for all delegates at lunchtime on Wedesday and a civic reception will be held, at which delegates will be welcomed by the Mayor and Mayoress of Scarborough, on the evening of the same day. The Association's dinner and dance will be the closing function of the Conference on the Friday evening. Other social activities, such as coach tours, are being arranged for the benefit of ladies attending the Conference.

Register of Members

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

Ordinary Members

BELLOTTI, VELIA, Viale Cadorna, 8 Busto Arsizio (VA), Italy. *(General Overseas)*

BOOTH, ROGER GUY, BSc, 56 Guilford Avenue, Surbiton, Surrey. *(London)*

BORER, KEITH, MA, BSc, DPhil, Whitton House, Whitton, Stockton, Cleveland. *(Newcastle)*

BRIGGS, CHARLES CLIFFORD, PhD, Rowan House, 10 Hemmingfield Road, Worksop, Notts. *(Hull)*

CHAPMAN, GEORGE PRICE, PhD, BSc, Microfine Minerals & Chemicals Ltd, Mica Works, Raynesway, Derby DE2 7BE. *(Midlands—Trent Valley Branch)*

ELSAYAD, SAMIR, PhD, BSc, 16 Amman Street, Madinat Alawkaf, Eldikki, Cairo, Egypt. *(General Overseas)*

FAULKNER, DAVID, BSc, PhD, 12 Magnolia Drive, Biggin Hill, Kent TN16 3SL. *(London)*

FLATLEY, THOMAS JOHN, ARTCS, 79 Broadhill Road, Manchester M19 1AR. *(Manchester)*

GARDINER, DUNCAN, BSc, ARSC, PhD, 18 Claudian Place, St. Albans, Herts. *(London)*

GREAVES, AUSTIN MCDONALD, LRIC, 28 Locust Hill, Maliou, Barataria, Trinidad & Tobago, West Indies. *(General Overseas)*

KENNEDY, JOHN, BSc, Building Research Station, Garston, Watford, Herts. *(London)*

KING, BERNARD MICHAEL JOHN, PhD, BSc, 42 Kimberley Drive, Sidcup, Kent. *(London)*

LANGLEY, RICHARD KENNETH, ARIC, Hawthorn Baker Ltd, London Road, Dunstable, Beds. *(London)*

LEWIS, GEOFFREY JOHN, BSc, PhD, ARIC, Federated Paints Ltd, Strathclyde Research & Development Laboratories, Blairlinn, Cumbernauld, Glasgow. *(Scottish)*

Marson, Frank, BSc, MSc, PO Box 19, Mt. Macedon, 3441 Victoria, Australia. *(General Overseas)*

Moita dos Santos, Carlos Jaime, Robbialac Portuguesa RL, Vale de Lide, S. Jao da Talha, Sacavem, Portugal. *(General Overseas)*

Saagar, Anoop Kumar, BSc, YMCA, Rush Green Road, Romford, Essex. *(London)*

Sawyerr, Olatunji Pekun, BSc, 23 Silver Birch Court, Middleton Road, London E8. *(London)*

Ward, Graham Barlow, PhD, BSc, Laporte Industries Ltd., Stallingborough, Lincs. *(Hull)*

Wilkinson, David Martin, 1 Deanston View, Doune, Perthshire. *(Scottish)*

Williamson, Leonard John, FRIC, 18 Lacey Court, Lacey Green, Wilmslow SK9 4BH. *(Manchester)*

Associate Members

Goldman, Edward, 23 Harwood Close, Tewin, Nr. Welwyn, Herts. *(London)*

Rogers, Michael Ambrose, YMCA, Rush Green Road, Romford, Essex. *(London)*

Smith, David John, 32 Courtney Court, Bankfoot Estate, Kenton, Newcastle upon Tyne NE3 2UD. *(Newcastle)*

Zilg, Peter U. 54 Winston Avenue, 2128 Rivonia, Tvl Santon, Republic of South Africa. *(South African)*

Registered Students

Bone, Alan, 8 Nunthorpe Road, Grangetown, Sunderland. *(Newcastle)*

Carroll, Geoffrey, 46 Glebe Terrace, Easington, Peterlee, Co. Durham. *(Newcastle)*

Holyoak, Peter, 76 Rutherglen Road, Redhouse Estate, Sunderland *(Newcastle)*

Pipe, Stephen, 22 Rotherfield Road, Redhouse Estate, Sunderland. *(Newcastle)*

Wilding, Antoinette, 19 Rydal Road, Streatham, London SW16. *(London)*

Forthcoming Events

Details are given of meetings in the United Kingdom up to the end of the month following publication, and South Africa and the Commonwealth up to the end of the second month.

March

Monday 3 March

Hull Section: Ladies' Evening "Cosmetics" by Mr D. S. Morris of Helena Rubenstein Laboratories to be held at the George Hotel, Land of Green Ginger, Hull at 6.30 p.m.

Thursday 6 March

Newcastle Section: Papers by members of the Section to be held at the Royal Turks Head Hotel, Grey Street, Newcastle upon Tyne at 6.30 p.m.

Tuesday 11 March

West Riding Section: "Advances in condensation polymers" by Prof. I. Goodman to be held at the Griffin Hotel, Leeds at 7.30 p.m.

London Section: "European Lecture—interfacial phenomena of inks" by Mr W. Hansen, Scandinavian Institute for Paint and Printing Ink to be held at the Polytechnic of the South Bank, Borough Road, London SE1 at 7.00 pm.

Thursday 13 March

Scottish Section: "Golf" Film and talk by Mr S. L. McKinlay of the Glasgow Herald to be held at Beacons Hotel, 7 Park Terrace, Glasgow G.3 at 6.00 pm.

Midlands Section—Trent Valley Branch: "Newer emulsions for decorative systems" by Mr D. A. Wallace of Vinyl Products Ltd. to be held at the British Rail School of Transport, London Road, Derby at 7.00 pm.

Friday 14 March

Manchester Section: "The pigmentation of ultraviolet curable systems" by Dr B. E. Hulme, Tioxide International Central Labs, Stockton-on-Tees, to be held at the Woodcourt Hotel, Brooklands Road, Sale, Manchester, at 6.30 pm.

Saturday 15 March

Scottish Section—Student Group: "Recent developments in wall-coverings" by a lecturer from the Walpamur Co. Ltd. to be held at Three Pigeons, 573 Sauchiehall Street, Glasgow at 10.15 am.

Wednesday 19 March

Irish Section: "Science and the detection of crime" by Mr R. Simon of the Institute for Industrial Research and Standards, and Detective Supt. D. Murphy of the Garda Siochana Technical Bureau to be held at the Clarence Hotel, Dublin at 7.45 pm.

Scottish Section—Eastern Branch: AGM followed by a film show. This meeting will start at 7.00 pm and be held at the Carlton Hotel, North Bridge, Edinburgh.

Thursday 20 March

Thames Valley Section: "Artists' colours" by Mr A. Brown, Winsor & Newton Ltd. to be held at the Beech Tree Hotel, Maxwell Road, Beaconsfield, Bucks at 7.00 pm.

Friday 21 March

Midlands Section: J. Newton Friend lecture at 7.30 pm "Interior design" by Mr J. Simkins, Alexander Fine Arts to be held at the Birmingham Chamber of Commerce and Industry, 75 Harborne Road, Birmingham B15 3DH.

Bristol Section: "High performance pigments for printing inks and paints" by Mr A. E. Honiball and Mr B. H. Withan of Ciba-Geigy (UK) Ltd. to be held at the Royal Hotel, Bristol at 7.15 pm.

April

Thursday 3 April

Newcastle Section: Annual General Meeting to be held at the Royal Turks Head Hotel, Grey Street, Newcastle upon Tyne at 6.30 p.m.

Tuesday 8 April

West Riding Section: Annual General Meeting to be held at the Griffin Hotel, Leeds at 7.30 p.m.

Thursday 10 April

Midlands Section—Trent Valley Branch: Combined AGM and social evening. *Venue to be announced.*

Friday 11 April

Bristol Section: Annual Dinner Dance, Mayfair Suite, Civic Entertainments Centre, Bristol.

Manchester Section: Annual General Meeting to be held at the New Albion Restaurant, 34 High Street, Manchester 4, at 6.30 pm.

Saturday 12 April

Thames Valley Section: Annual General Meeting. *Venue to be announced.*

Wednesday 16 April

Irish Section: Annual General Meeting to be held at the Clarence Hotel, Dublin at 7.45 p.m.

Scottish Section—Eastern Branch: "A topic on the testing of organic pigments". Speaker from Ciba-Geigy Ltd. in the Carlton Hotel, North Bridge, Edinburgh at 7.30 p.m.

Friday 18 April

London Section: Annual General Meeting *Venue to be announced.*

Midlands Section: Annual General Meeting to be held at the Birmingham Chamber of Commerce and Industry, P.O. Box 360, 75 Harborne Road, Birmingham B15 3DH at 6.30 p.m.

Tuesday 22 April-Friday 25 April

OCCA—XXVII—See page 108

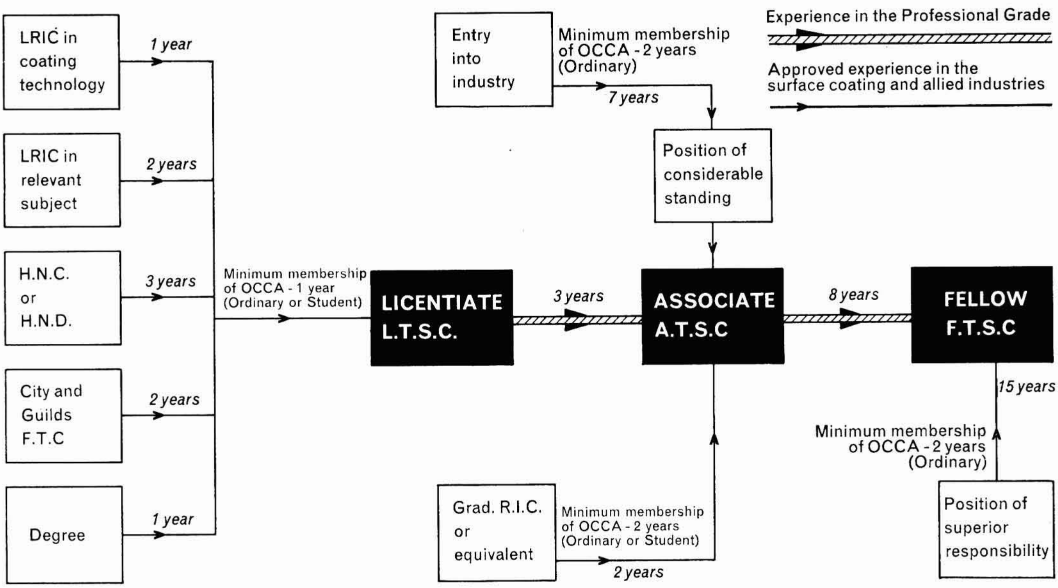
Friday 25 April

Briston Section: Annual General Meeting to be held at the Royal Hotel, Bristol at 7.15 p.m.

Optional Professional Grade for Ordinary Members

The innovation of the Professional Grade has proved to be most successful, as evidenced by the impressive list of names in the December issue of the *Journal*. For the convenience of potential applicants, the full regulations for admission and a chart indicating different routes to the various grades are shown below. **Members are reminded of the recent amendments to the regulations, which are shown here in red.**

Routes to the Professional Grades



Note: At present there is no restriction on Students up to 21; between 21 and 25 a certificate from the employer or college confirming the course being taken is required.

Regulations for admission to the Professional Grade

Note: For the sake of simplicity, reference is made only to UK examinations etc., but equivalent qualifications overseas will naturally be accepted.

A. Licentiate

1. Shall be an Ordinary Member of the Association and have been an Ordinary Member or Student of the Association for not less than one year.

2. Shall have attained the age of 22.

3. (a) Shall be a Licentiate of the Royal Institute of Chemistry in Coatings Technology (*viz.* Higher National Certificate + Endorsement in coatings technology + 1 year approved experience in the science or technology of coatings after passing the endorsement examination).

OR (b) Shall be a Licentiate of the Royal Institute of Chemistry in another relevant subject such as advanced analytical chemistry, colour chemistry or polymer science, and shall have two years' approved experience of coatings since so qualifying.

OR (c) Shall hold the Full Technological Certificate of the City and Guilds of London Institute in a relevant subject as approved by the Professional Grade Committee and shall have two years' approved experience in the science or technology of coatings since gaining the FTC.

OR (d) Shall have passed Higher National Certificate or Higher National Diploma with three years' approved experience in the science or technology of coatings since qualifying, but two years' approved prequalification experience shall be deemed equivalent to the third post-qualification year.

OR (e) Shall be graduate in relevant subject with not less than 1 year's approved experience.

OR (f) Shall have passed such other qualifications as approved by the Professional Grade Committee from time to time.

4. Shall be required to satisfy the Professional Grade Committee, or some other body approved by the Professional Grade Committee in a *viva voce* examination and submit a dissertation on a topic previously approved by the Professional Grade Committee.

5. Shall normally be sponsored by three Ordinary Members of the Association in the professional grade (either Associate or Fellow) at least one of whom must be a Fellow.

6. Shall have paid the fee stipulated by the Council and have paid the current subscription payable by an Ordinary Member.

B. Associate, being already a Licentiate

1. Shall, since his election to the Licentiateship, have practised the science or technology of coatings for not less than three years.

2. Shall provide evidence acceptable to the Professional Grade Committee of his superior professional skill and maturity.

3. Shall hold the City & Guilds of London Institute Insignia Award OR shall submit a thesis or dissertation of comparable level on a topic previously approved by the Professional Grade Committee OR shall have published work which, in the opinion of the Professional Grade Committee, is of comparable merit.

4. MAY be required to satisfy the Professional Grade Committee or some other body as approved by the Professional Grade Committee in a *viva voce* examination.

5. Shall normally be sponsored by three Ordinary Members of the Association in the professional grade (either Associate or Fellow) at least one of whom must be a Fellow.

6. Shall have paid the fee stipulated by the Council and have paid the current subscription payable by an Ordinary Member.

C. Associate, not already a Licentiate

EITHER

1. Shall be not less than 24 years of age.

2. Shall be an Ordinary Member of the Association and have been an Ordinary Member or Student of the Association for not less than two years.

3. Shall hold the Graduateship of the Royal Insitute of Chemistry or Institute of Physics or a University or Council of National Academic Awards degree recognised by the Royal Institute of Chemistry or Institute of Physics as giving full exemption from the Graduateship examination.

4. Shall have not less than two years' approved post-graduate experience in the science or technology of coatings.

5. Shall normally be required to satisfy the Professional Grade Committee or some other body approved by the Professional Grade Committee, at a *viva voce* examination.

6. Shall normally be sponsored by three Ordinary Members of the Association in the professional grade (either Associate or Fellow) at least one of whom must be a Fellow.

7. Shall have paid the fee stipulated by the Council and have paid the current subscription payable by an Ordinary Member.

OR

8. Shall be not less than 30 years of age.

9. Shall be an Ordinary Member of the Association and have been an Ordinary Member of the Association for not less than two years.

10. Shall have been engaged in practising the science or technology of coatings for not less than seven years and shall have attained a position of considerable standing in the industry.

11. Shall normally be required to satisfy the Professional Grade Committee in *viva voce* examination of his professional competence.

12. Shall normally be sponsored by three Ordinary Members of the Association in the professional grade (either Associate or Fellow) at least one of whom must be a Fellow.

13. Shall have paid the fee stipulated by the Council and have paid the current subscription payable by an Ordinary Member.

D. Fellow

Note: This is the senior award of the professional grade and signifies that the holder has made outstanding contributions to the science or technology of coatings or has reached a position of eminence in the industry through the practice thereof. The Professional Grade Committee will require substantial evidence of professional maturity in the science or technology of coatings although commercial experience will be taken into account in assessing the merits of candidates.

1. Shall be not less than 33 years of age.

2. Shall have been an Ordinary Member of the Association for not less than two years.

3. Shall be engaged in a position of superior responsibility in the coatings industry.

4. EITHER (a) shall have been an Associate of the professional grade for at least eight years;

   OR (b) shall have not less than fifteen years' experience of the science or technology of coatings in a position of superior responsibility.

5. Shall submit, with his application, an account of his experience, with due reference to scientific and technological interests, achievements and publications.

6. Shall normally be sponsored by three Ordinary Members of the Association in the professional grade, all of whom must be Fellows.

7. Shall have paid the fee stipulated by the Council and have paid the current subscription payable by an Ordinary Member.

The fees payable with applications are as follows:

Fellow—£10.00 Associate—£6.00
Licentiate—£3.00
(Plus VAT at standard rate)

Application

Completed application forms should be returned, together with the appropriate remittance, to the Director & Secretary at the Association's offices (except in the case of those Members attached to the Auckland, South African and Wellington Sections who should address their forms to their Section Hon. Secretaries).

The Committee wishes it to be known that Members rejoining the Association after a period in other industries may include length of service as an Ordinary Member before their resignation as part of the qualifying periods for entry into the Grade.

Students wishing to apply for entry into the Professional Grade must first make application in writing for upgrading to Ordinary Membership, giving the reasons for their eligibility for such regarding. Applications, together with the appropriate remittance, should be addressed as for application for admission to the Professional Grade.

Potential applicants are recommended to give the fullest possible details of their appointments, including the number and type of staff under their control, and indicating to whom the applicant is responsible, as this aids the committee considerably in its deliberations.

It is felt that applicants for admission to the Licentiate grade might wish to have further information on the pattern which it is suggested should be followed for dissertations, the subjects of which have first to be approved by the Professional Grade Committee.

The dissertation should be preceded by a short summary and commence with a brief introduction and some account of the current state of knowledge. Where practicable it should follow the general format of a paper in *JOCCA*.

The dissertation may be a review of a subject, a theoretical treatment, descriptive of practical work or a combination of these. It must indicate that the candidate has a reasonably wide and up-to-date knowledge of his chosen subject and understands the basic scientific principles underlying it, and that he is able to think critically and constructively.

Where practical work is described, some attempts should be made to draw theoretical conclusions or to form some provisional hypothesis, together with an outline of what further work would be required to confirm the views put forward or further to advance the knowledge of the subject.

Where the dissertation is a review or a theoretical treatment, there should be an attempt to contrast and compare any opposing views expressed in earlier works, to examine the views critically, to suggest any compromise interpretation, to account for all the known facts and to outline any further work by which the opposing views could be tested.

Where applicable, references should be given to published work, graphs, diagrams etc. to be appended.

Length: Text should be approximately 5 000 words.

Applicants should refer to the paper by Moss which appeared in the January 1973 issue; the Professional Grade Committee feels that candidates for the Licentiate grade could with advantage use this paper as a model for their dissertations.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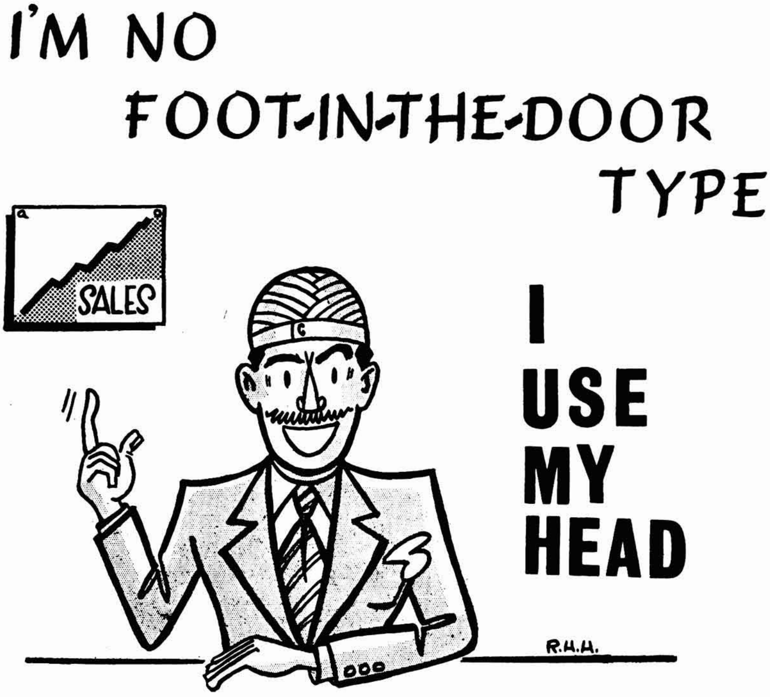
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"Ultraviolet polymerisation and the surface coatings industry"
(Thursday 10 and Friday 11 April).

Enquiries to: H. Fuller, Esq., Newcastle Section Honorary Social Secretary, Tioxide International Limited, Carlton Weathering Station, Yarm Back Lane, Stockton-on-Tees, Cleveland TS21 1AX.

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