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Papers from the Torquay Conference

Effect of pigment dispersion on the appearance and properties of paint films *W. Carr*

Financial evaluation of research projects *A. G. North*

Research and development—recruitment, education and training *P. Bennett*

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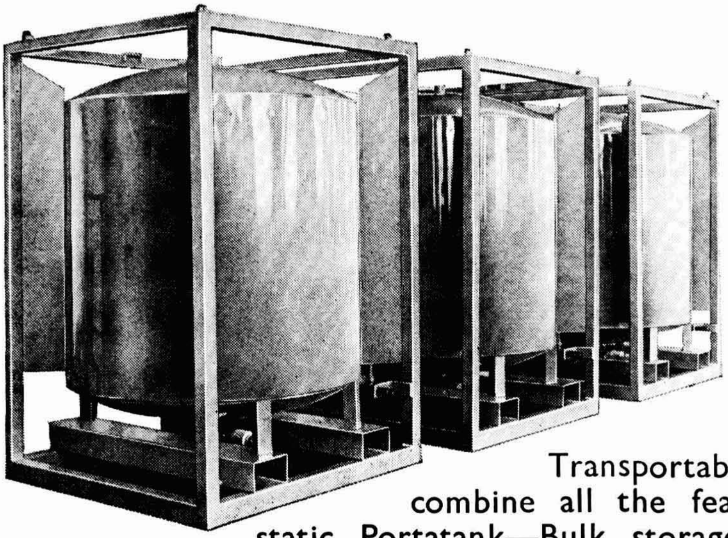

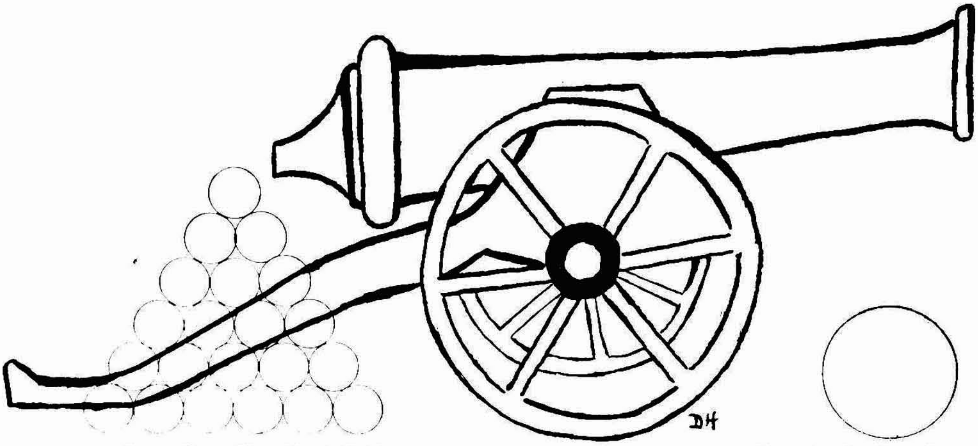
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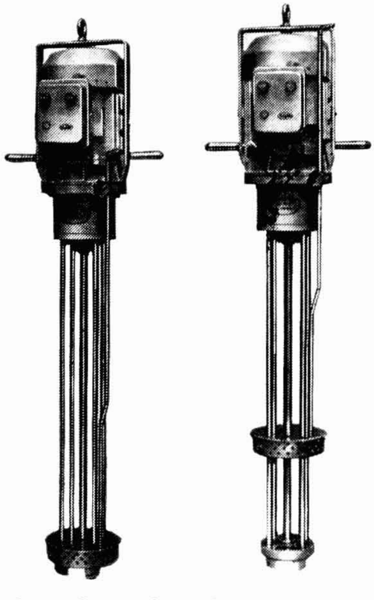

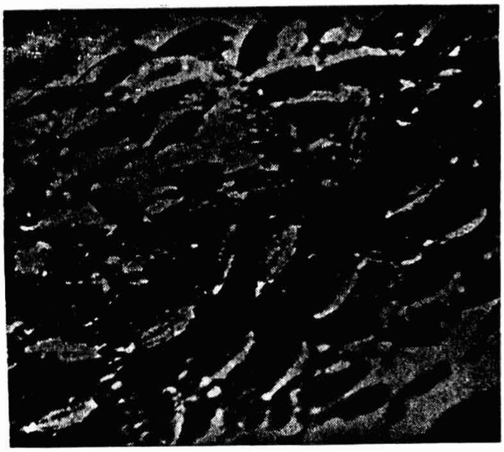

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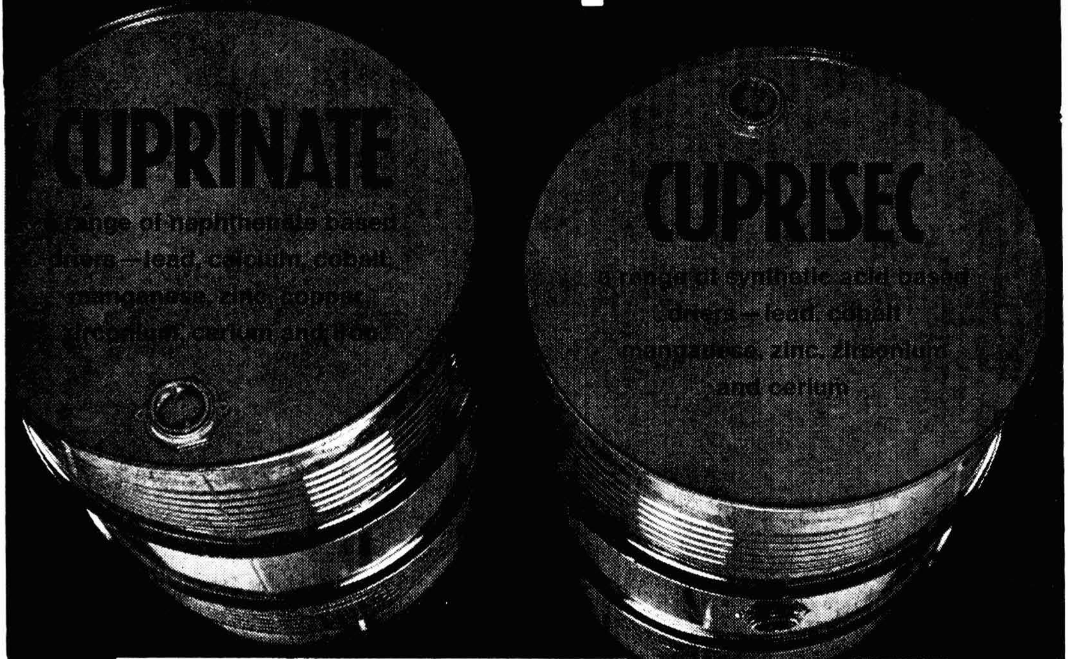

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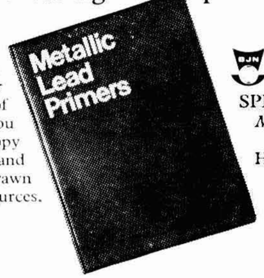
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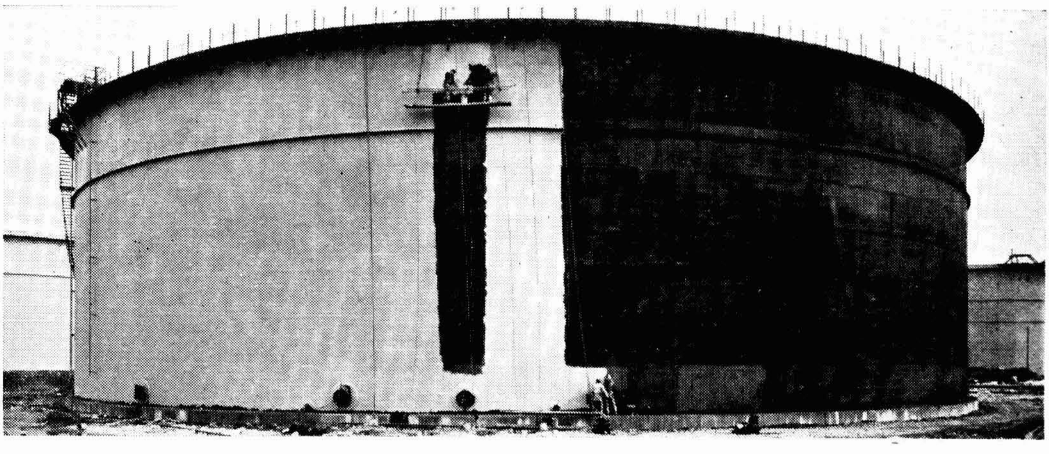

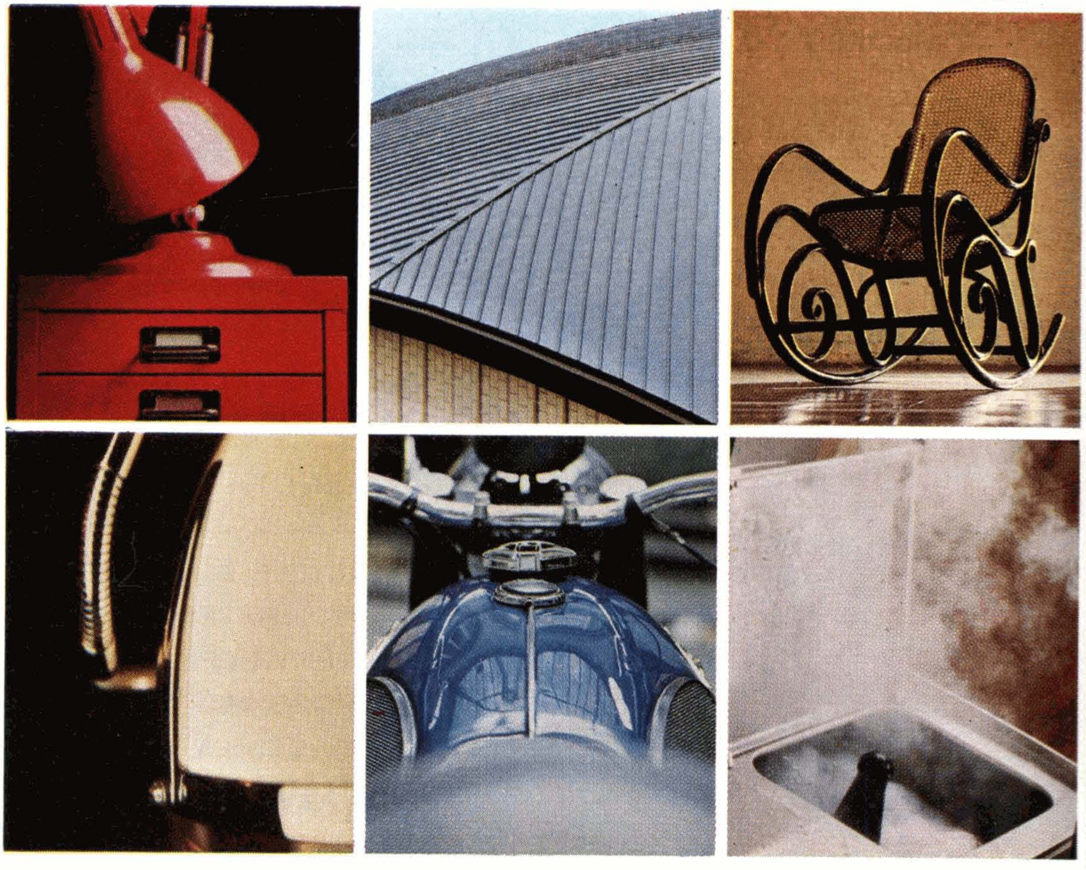

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Transactions and Communications

Effect of pigment dispersion on the appearance and properties of paint films*

By W. Carr

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Summary

Having established a technique for measuring the pigment particle size distribution of non-bleeding organic pigments in an alkyd resin system, paint stainers were made from six well known types of paint pigments by ball milling and sand grinding for various times. The pigments used were commercial brands of a β-form phthalocyanine blue, a phthalocyanine green, a carbazole violet, a dioxazine violet, a pigment green B and a diarylide yellow. Paint stainers that differed in degree of pigment dispersion were obtained from each pigment. The particle size distribution of each of the stainers was determined on a disc centrifuge.

The stainers were also complete paints in themselves. Films were made from the stainers and from reductions of them with a white base paint made from the same resin. The resultant films were critically examined for the following properties:

> colour strength, changes in shade, brightness, flocculation, flotation and flooding, gloss—using a Zeiss goniophotometer, light fastness, weathering, bronzing, opacity and transparency.

The relationship between these properties and pigment dispersion in the stainer was examined for the alkyd resin system used.

In many of these properties, but not all, the degree of dispersion of the pigment, as expected, plays an important part. The present work has shown that its role becomes more and more important in the region of high levels of dispersion, i.e. at very small particle sizes. At lower levels of dispersion, small changes are much less significant.

The relationships between colour strength, flocculation and stainer particle size are particularly interesting in that they open up a completely new approach to the phenomenon of flocculation of phthalocyanine blues.

Keywords

Properties, characteristics and conditions primarily associated with:

dried or cured films
- brightness
- dispersion
- flocculation
- flotation
- flooding
- gloss
- light fastness
- opacity
- weathering resistance

materials in general
- particle size

prime pigments, dyes, etc.
- carbazole violet
- diarylide yellow
- dioxazine violet
- phthalocyanine green
- phthalocyanine blue
- pigment green B

L'effet de l'état de dispersion pigmentaire sur l'apparence et les caractéristiques de feuils de peintures

Résumé

Après avoir établi une technique pour mesurer la répartition granulomètrique des pigments organiques du type non-saignant, dispersés dans une résine alkyde, on a préparés des pâtes

---

*Presented to the Torquay Conference on 6 May 1971

pour la mise à la teinte, à partir de six types de pigments pour peintures bien connus, par broyage à billes et à sable pour de diverses durées. Les pigments utilisés étaient des marques commerciales d'un bleu de phtalocyanine de forme β, d'un vert de phtalocyanine, d'un violet de carbazol, d'un violet de dioxazine, d'un pigment Green B, et d'un jaune diarylide. A partir de chaque pigment on a preparé des pâtes qui se differaient du degré de leur dispersion. La répartition granulomètrique de chaque pâte a été déterminée au moyens du centrifugeur à disque. Les pâtes étaient d'ailleurs de vraies peintures en elles-mêmes. Des feuils ont été préparés à partir des pâtes ainsi qu'à partir de leurs teintes pastelles avec une pâte blanche basée sur la même résine. Les feuils ont été examinés critiquement au point de vue des propriétés suivantes: pouvoir colorant, changement de nuance, floculation, flottation, brillant au moyens d'un goniophotomètre de Zeiss, solidité à la lumière, résistance aux intempéries, bronzage, opacité et clarté.

On a examiné le rapport entre ces propriétés et l'état de dispersion pigmentaire dans la pâte pour la mise à la teinte.

Pour beaucoup de ces propriétés, mais non pas pour toutes, le degré de dispersion, comme on doit s'y attendre, joue un rôle important. L'étude actuelle a démontré que son rôle devient plus et plus important dans la région où se trouvent les niveaux de dispersion élevés, c'est-à-dire, où il s'agit des dimensions particulaires très petites. Aux niveaux de dispersion plus bas, de petits changements ont un effet beaucoup moins important.

Les rapports entre pouvoir colorant, floculation et grandeur particulaire sont particulièrement intéressants puisqu'ils mettent en évidence un nouvel abordement au phenomène de la floculation des bleus de phtalocyanine.

Auswirkung des Dispersionsgrades von Pigmenten auf das Aussehen und die Eigenschaften von Lackfilmen

Zusammenfassung

Nachdem sich eine verlässliche Messmethode zur Bestimmung des Verhältnisses der verschiedenen Grössen von Teilchen nicht ausblutender organischer Pigmente in einem Alkydharzsystem bewährt hatte, wurden Farbabmusterungspasten aus sechs bekannten Lackfarbenpigmenten auf Kugel- und Sandmühlen mit verschiedener Mahldauer hergestellt. Bei den verwandten Pigmenten handelte es sich um handelsübliche Marken eines Phthalozyaninblaus in der β Form, Phthalozyaningrüns, Carbazolvioletts, Dioxazinvioletts, Pigmentgrüns B und Diarylidgelbs. Von jedem dieser Pigmente wurden Farbabmusterungspasten hergestellt, welche sich durch den Grad der Pigmentdispergierung unterschieden. Mit Hilfe einer Scheibenzentrifuge wurde die Teilchengrössenverteilung jeder der Farbabmusterungen bestimmt.

Die Farbabmusterungen als solche waren gleichzeitig vollkommene Lackfarben. Von diesen Pasten und von Verschnitten derselben mit einer das gleiche Harz enthaltenden weissen Lackfarbe wurden Filme hergestellt. Diese wurden kritisch auf folgende Eigenschaften hin geprüft: Farbstärke, Farbton, Brillianz, Flockung, Ausschwimmen, Glanz—gemessen mit dem Zeiss–Goniophotometer—, Lichtbeständigkeit, Wetterfestigkeit, Bronzieren, Opazität und Transparenz.

Die Beziehungen zwischen diesen Eigenschaften und der Pigementdispersion in der Abmusterungspaste wurden für das benutzte Alkydharzsystem untersucht.

In vielen, aber nicht allen, dieser Eigenschaften ist wie zu erwarten war der Dispersionsgrad des Pigmentes wichtig. Die vorliegende Arbeit ergab, dass diese Rolle sich im Bereiche hoher Dispergierungsniveaux immer mehr vergrössert, d.h. bei sehr geringen Teilchengrössen. Bei niedrigerem Dispersionsniveau sind geringe Änderungen viel weniger bedeutsam.

Die Beziehungen zwischen Farbstärke, Flockung und Teilchengrösse in der Abmusterungsfarbe sind insofern interessant, als sie einen völlig neuen Weg zur Erkennung des Flockungsphänomens von Phthalozyaninblau eröffnen.

Влияние пигментной дисперсии на наружный вид и свойства красочных пленок

Резюме

После оформления технологии измерения распределения величины пигментных частиц невытекающих органических пигментов в алкидносмольной системе, были приготовлены красители из шести хорошо известных типов красочных пигментов путем размола в шаровой мельнице и песочным размельчением в течение различных периодов времени. Применялись пигменты промышленной марки фталоцианиновой сини формы β, фталоцианиновой зелени, фиолетового карбазола, фиолетового диоксазина, пигментной зелени В и диарилидовой желчи. Из каждого пигмента были получены красители которые отличались в степени пигментной дисперсии. Распределение величины частиц каждого красителя определялось на дисковой центрифуге.

Красители представляли собой в то же время и полную краску. Пленки приготовлялись из красителей и из их редукций на основе белой краски, приготовленной из той-же смолы. Полученные пленки подвергались критическому анализу следующих свойств: прочности краски, изменения оттенка, яркости, флоккуляции, флотации и неравномерного окрашивания, лоска с применением гониофотометра Цейсса, светостойкости, выветривания, бронзировки, прозрачности и непрозрачности.

Рассматривалось соотношение между этими свойствами и пигментной дисперсией в красителе применяемой алкидно-смольной системы. Во многих из этих свойств, но не во всех, степень дисперсии пигмента играет, как и следовало ожидать, важную роль. Настоящая статья показала что дисперсия играет более значительную роль при высоких ее уровнях т. е. при очень малой величине частиц. При более низких уровнях дисперсии незначительные изменения не играют большой роли.

Соотношения между прочностью краски, флоккуляцией и величиной частиц красителя особенно интересны, т. к. они иллюстрируют совершенно новый подход к вопросу флоккуляции фталоцианиновой сини.

Introduction

Paint films usually have a dual function to serve—decoration and protection. Protection is determined mainly by the resin binder in the film and decoration by the pigments present in it. The latter can be wholly inorganic, as in white paints, or wholly organic, as in post office red shades, or more usually, mixtures of the two.

The two functions are not completely independent. The degree to which the pigments are dispersed is believed to affect the gloss, the opacity and the weathering properties of the film, i.e. its protective properties. The type of vehicle or resin binder used is believed to control the degree of dispersion of the pigments for a given type of mill and hence to affect the colour value and brightness of the film i.e. its decorative properties.

The degree of dispersion of the pigments is seen, from these arguments, to affect some of the decorative and protective properties of paint films and is, therefore, an important parameter in paints. The exact way in which it affects the appearance and properties of paint films has never been precisely determined because it has not been possible to measure the degree of dispersion in the past, but the position is slowly changing.

In the 1969-1970 session, the author described, in a lecture given to both the Manchester and London Sections of OCCA which has since been published[1], a technique for measuring the particle size distribution of certain organic pigments in paint stainers based on an alkyd resin, Beckosol P.470. In that lecture the preparation of a large number of paint stainers by ball milling and sand grinding was described, using three organic pigments, a phthalocyanine blue, a carbazole violet and a pigment green B. By varying the milling times, a large number of stainers was obtained for each pigment, the only difference being in degree of dispersion. The particle size distributions of the stainers were measured accurately using a Joyce Loebl disc centrifuge, and a comparison was made between ball milling and sand grinding in terms of particle size reduction.

This work has been extended to include three more organic pigments, a phthalocyanine green, a dioxazine violet and a diarylide yellow. Films were made from the stainers themselves and from reductions with a standard white in the same resin. These films have been examined as critically as possible for a wide range of properties. These include colour strength, changes in shade and brightness, flocculation defects, flotation and flooding, gloss, light fastness, weathering, bronzing, opacity and transparency.

In this way, a picture has been obtained of precisely how these properties are affected by the degree of dispersion of the pigment for the six pigments concerned. The results of this work are described in this paper.

Experimental

The pigments used in the stainers were the following:

a β form phthalocyanine blue, Irgalite Blue GLSM (CI Pigment Blue 15)
a pigment green B, Irgalite Green DBN (CI Pigment Green 8)
a carbazole violet, Irgazin Violet 6RLT (CI Pigment Violet 34)
a phthalocyanine green, Irgalite Green GLN (CI Pigment Green 7)
a dioxazine violet, (CI Pigment Violet 23)
a diarylide yellow, Irgalite Yellow 2GP (CI Pigment Yellow 17)

It will be noted that all these pigments are non-bleeding in most solvents. This is a requisite of the present technique for measuring size distribution.

The resin used was a long oil soya penta-alkyd resin (Beckosol P470) which is thinnable with white spirit. This is important to the particle size measuring technique, as the stainer has to be diluted with a thinner or solvent that does not cause flocculation of the pigment or precipitation of the resin and does not attack the perspex disc in which the centrifugal sedimentation is carried out.

Except in the case of the yellow, the pigment:binder ratio was 1:6 and the pigmentation level was 8 per cent. For the yellow, these were reduced to 1:20 and 2.5 per cent respectively, to keep the viscosity down to an acceptable level. Each stainer contained adequate driers so that it was a complete paint in itself. The ball milling times ranged from ½ hour to 72 hours and the sand grinding times from ¼ hour to 8 hours, so that a wide range of degrees of dispersion was obtained. For the particle size determinations on the Joyce Loebl disc centrifuge, a buffered layer line start technique was used. The spin fluid through which the pigment particles sedimented was a mixture of white spirit and carbon tetrachloride (70/30 v/v).

The buffer layer was 1ml of white spirit.

The stainers were reduced to a pigment level of 0.5 per cent by the addition of white spirit with stirring.

After centrifuging for the appropriate time at an appropriate speed, samples were drawn from a fixed depth and these contained the undersize particles. All the various size fractions were then analysed for their pigment content.

In this way size distribution curves were obtained for each of the stainers. Typical size distribution curves obtained by this technique are shown in Fig. 1. The stainers were then examined by themselves or as reductions with a standard TiO_2 paint, also based on Beckosol P470, for a variety of properties.

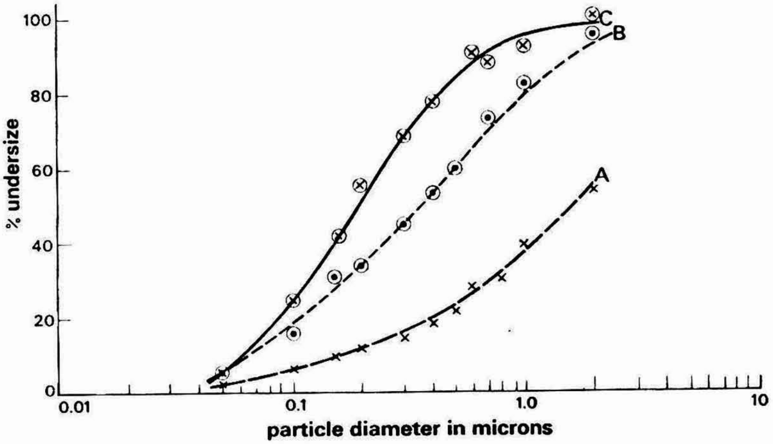


Fig. 1. Irgazin Violet 6RLT ball milled paint stainers, particle size distribution after milling for A 2 hours, B 12 hours, C 72 hours

Colour strength

Experimental

The colour strengths of the stainers of each pigment were compared with each other by making known reductions with a standard white paint, applying films of the reductions with a bar coater to a suitable glossy card, drying, and examining on a G. E. Hardy spectrophotometer. The k/s values were measured for each reduction; these values are directly proportional to the colour strengths of the stainers. In order to plot colour strength against dispersion, the k/s values were plotted against the 50 per cent diameter of the stainer.

In the case of the blue and the pigment green B, the reductions were 1:12.5 pigment to titanium oxide. In the case of the other four pigments, the reductions were 1:75 pigment to titanium oxide.

Results

The curves for the phthalocyanine blue and the pigment green B are shown in Fig. 2, the curves for the carbazole violet and the dioxazine violet in Figs. 3 and 4 and the phthalocyanine green and diarylide yellow in Fig. 5.

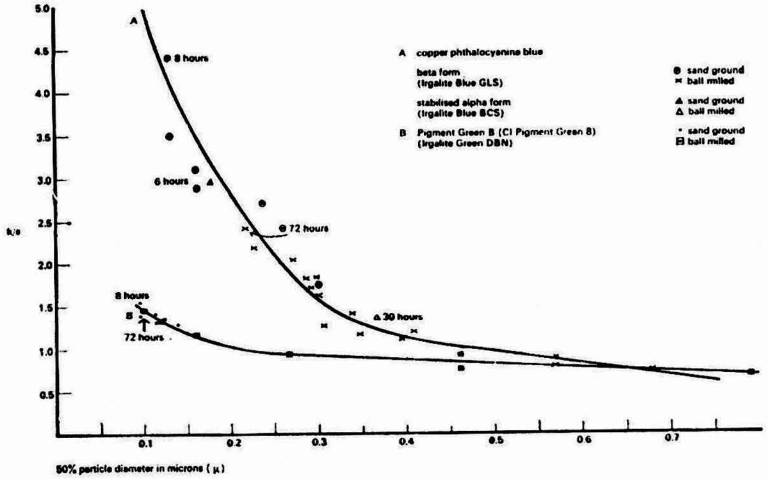


Fig. 2. Particle size of paint stainers/colour strength of titanium dioxide reductions (1:12.5)

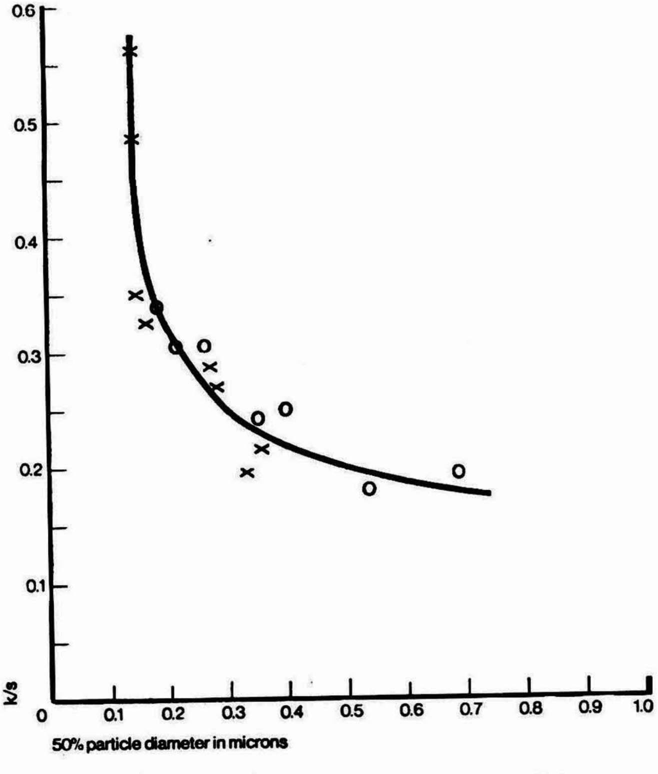


Fig. 3. Carbazole violet (CI Pigment Violet 34) paint stainers 1:75 reductions with titanium dioxide

o ball milled × sand ground

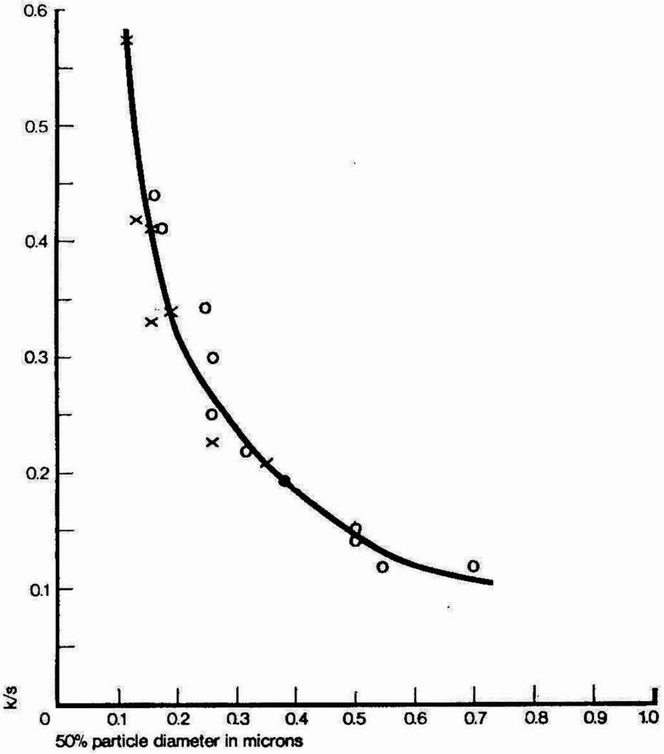


Fig. 4. Dioxazine violet (CI Pigment violet 23) paint stainers in 1:75 reductions with titanium dioxide

o ball milled × sand ground

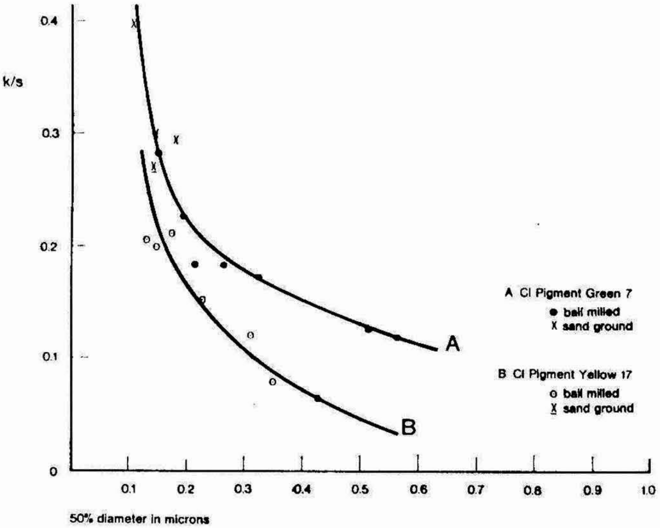


Fig. 5. Phthalocyanine green and diarylide yellow paint stainers in 1:75 reductions with titanium dioxide

Discussion

It will be seen from Fig. 2 that the shape of the colour strength/particle size curve obtained for the green pigment is very different from the shape of the corresponding curve for the phthalocyanine blue pigment.

In the case of the green, the colour strength increases only slowly with decreasing particle size, down to very small sizes. This slow increase, coupled with the low price of the pigment, means that prolonged grinding of this pigment will never be economical in terms of colour strength. With the blue the picture is completely different. The colour value only increases slowly at first as the particle size is reduced. The graph then starts to slope upward very much more sharply and the colour strength becomes very dependent on the particle size. This rapid increase in colour strength continues until the 50 per cent diameter is down to 0.125μ, which is as low as was possible in these experiments. From the curve, it is seen that the colour strength is very sensitive to changes in particle sizes in the regions below 0.4μ. This is illustrated from the corresponding k/s figures for various particle sizes taken from Fig. 2, e.g.

Phthalocyanine blue

$$\left.\begin{array}{ll} k/s \text{ for } 0.125\mu \text{ size} & = 4.13 \\ k/s \text{ for } 0.2\mu \text{ size} & = 2.66 \end{array}\right\} \text{Increase of 55 per cent}$$

$$\left.\begin{array}{ll} k/s \text{ for } 0.2\mu \text{ size} & = 2.66 \\ k/s \text{ for } 0.4\mu \text{ size} & = 1.13 \end{array}\right\} \text{Increase of 140 per cent}$$

Pigment green B

$$\left.\begin{array}{ll} k/s \text{ for } 0.125\mu \text{ size} & = 1.22 \\ k/s \text{ for } 0.2\mu \text{ size} & = 1.03 \end{array}\right\} \text{Increase of 18 per cent}$$

$$\left.\begin{array}{ll} k/s \text{ for } 0.2\mu \text{ size} & = 1.03 \\ k/s \text{ for } 0.4\mu \text{ size} & = 0.77 \end{array}\right\} \text{Increase of 32 per cent}$$

These figures demonstrate the difference between the two pigments.

The tremendous sensitivity of the colour strength of phthalocyanine blue to small changes in particle size below 0.4μ is almost certainly the cause of many of the troubles associated with the testing of this pigment. When comparing batches of this pigment or stainer batches made from the same delivery of blue, unless the comparisons are made at exactly the same degree of dispersion there will be significant changes in colour strength. When different makes of this pigment are compared, unless the comparisons are at the same degree of dispersion, they will be invalid.

The curves for the two violets, the phthalocyanine green, and the diarylide yellow, shown in Figs. 3, 4 and 5, are similar to that of the blue in that they show a very steeply rising graph when the particle size is reduced below 0.4μ.

The case of the two violets is particularly interesting in view of the very high price of these pigments. The results show that, by prolonged grinding of these two pigments, very substantial savings in raw material cost can be made.

Effect of pigment dispersion on shade

It has long been claimed that many pigments alter in shade as their dispersion increases and it was decided to check if this is in fact true, and if so to get some idea of the direction and the extent of the change.

The first step was to reduce the various stainers of the five pigments with a standard white paint so that the reduced paints were approximately equal in colour strength. The extent of the reductions required to do this was obtained from the colour strength/particle size curves previously determined. With the yellow, the phthalocyanine green, and the two violets, the level of reduction used was different from that for the blue and the pigment green B.

The reductions were applied to panels by a bar coater and, after drying, the films were examined on a spectrophotometer (GE). The *XYZ* values were measured and the chromaticity co-ordinates calculated and plotted on enlarged chromaticity charts. Calculations were made of the spread in chromaticity co-ordinates if the colour was changed by 1 NBS unit, and this limit shown as a parallelogram on the charts. The charts for the dioxazine violet and the phthalocyanine blue are shown in Figs. 6 and 7 respectively.

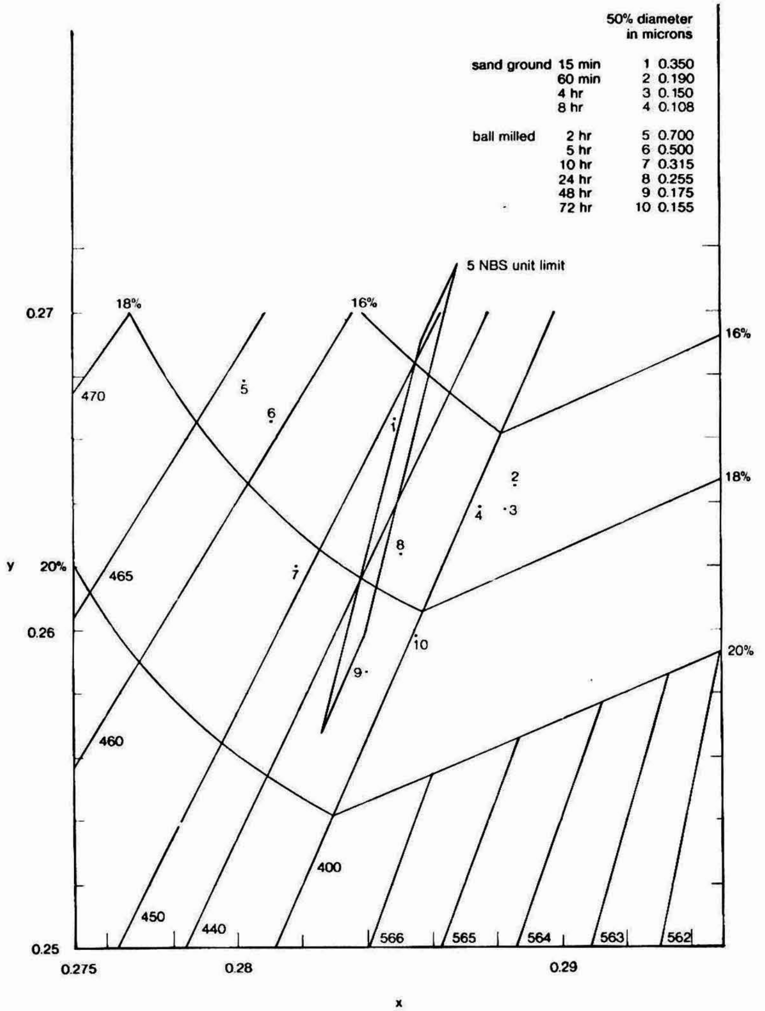


Fig. 6. Dioxazine violet stainers chromaticity chart (enlarged)

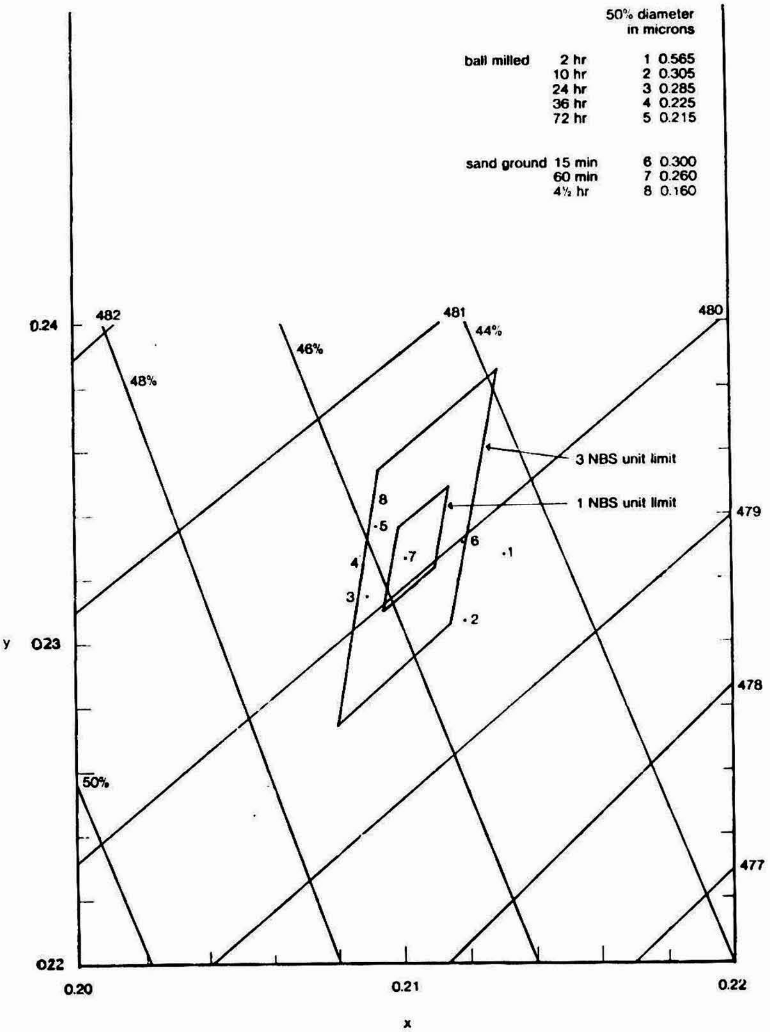


Fig. 7. Irgalite Blue GLS stainers chromaticity chart (enlarged)

In Fig. 6, it will be seen that the points move regularly from left to right as the 50 per cent diameter decreases. This means that the shade reddens with improved dispersion and the change overall is much greater than 1 NBS unit and should therefore be clearly visible.

In Fig. 7, it will be seen that the points go from right to left with reduced particle size. This means that the shade of the blue becomes greener. The extent of this change is not nearly as great as with the violet, but should be just visible.

The carbazole violet was also found to redden with improved dispersion but to a much smaller extent than the dioxazine violet.

With the phthalocyanine green and the pigment green B, the charts showed no discernible change in shade.

With the diarylide yellow, the chart showed a definite greening in shade.

In another approach, lines were drawn joining the individual points to the white point and the angles subtended by these lines were measured. These angles were plotted against particle size for each of the six pigments. Changes in the angles indicate changes in the dominant wave lengths of the reductions.

The plots for two of the pigments are shown in Figs 8 and 9, for dioxazine violet and phthalocyanine blue respectively.

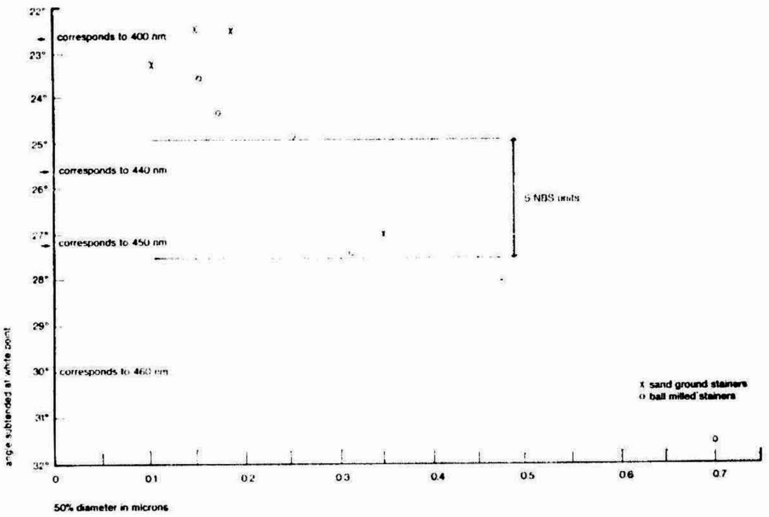


Fig. 8. Change in shade/50 per cent diameter dioxazine violet

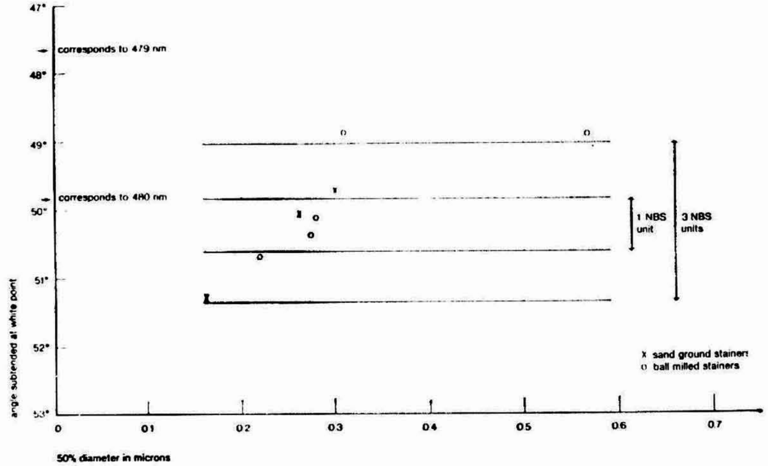


Fig. 9. Change in shade/50 per cent diameter β phthalocyanine blue

In Fig 8, the points lie on a curve, rising from right to left as the 50 per cent diameter of the violet in the paint stainer decreases. This indicates a reddening in shade on reduction of particle size. The extent of this reddening is considerable, as the scale of the curve shows.

In Fig. 9 the points also lie on a curve, sloping the opposite way. This indicates a slight greening in shade of the blue on reduction of particle size. From the scale of the curve, this greening should be just detectable by the eye.

The carbazole violet points also lay on a curve, although not so well defined, indicating reddening of shade, but the extent was much smaller than with the dioxazine violet.

With the two green pigments, the points did not lie on a curve. This indicates no significant change of shade.

With the diarylide yellow, the points lie on a curve sloping from left to right, the overall change being approximately 1 NBS unit. This indicates a small but definite greening in shade with increasing dispersion.

Visual examination of the panels supported the above deductions, as shown below.

Dioxazine violet panels—marked visual reddening of shade with increased dispersion.

Carbazole violet panels—definite visual reddening in shade but less marked.

Phthalocyanine blue panels—possibly very slight greening in shade but barely detectable.

Phthalocyanine green panels—no visual change in shade.

Pigment green B panels—no visual change in shade.

Diarylide yellow panels—slight but visually detectable greening of shade.

From these results it would appear that improved dispersion can give significant changes of shade with some pigments, but not with all.

Brightness

The effect of pigment dispersion on brightness was examined.

The reductions of equal colour strength used to observe changes in shade were again used to follow changes in brightness. The Y value of the tristimulus XYZ values was taken as a measure of brightness and the values of Y plotted against particle size for each of the six pigments.

The results for the phthalocyanine blue and green are given in Fig. 10. In both cases the points lie on a definite curve, indicating that the brightness is a function of particle size. The brightness increases with dispersion once the particle size is reduced below a certain value. With the blue this value appears to be about 0.4μ, with green about 0.3μ. The subsequent increases in brightness are of the order of 6-12 per cent.

With the pigment green B, a similar curve was obtained, the increase in brightness being of the order of 7 per cent.

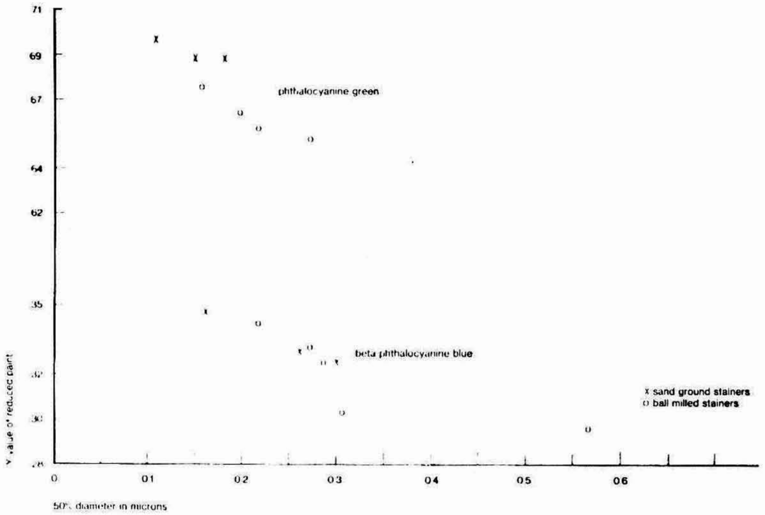


Fig. 10. Brightness of shade/50 per cent diameter

With the two violets, curves were obtained similar to those for the other pigments. Marked increases in brightness occur only when the 50 per cent diameter is reduced below 0.4μ. From then on the increase in brightness is of the order of 8 per cent.

With the yellow, the brightness increased by only 3-4 per cent as the mean particle size was reduced from 0.4 to 0.1μ.

It can be stated that, with all the six pigments, as the dispersion improves, the brightness increases very slowly until a mean diameter of about 0.4μ is reached. Further dispersion gives a more rapid increase in brightness, of the order of 8-10 per cent, except with the yellow, where the increase is only between 3 and 4 per cent. These increases in brightness are all discernible to the eye.

Effect of dispersion on flocculation

The stainers of the six pigments were reduced with the standard white paint, and the resulting paints were assessed for flocculation defects. The paints were brushed out on a card in the normal way; after a measured short time interval, portions of the film were vigorously rubbed with a finger. A 1ml portion of the paint was also allowed to flow down part of the card. This is equivalent to applying the paint at three different rates of shear. Where the colour strengths of the three regions are markedly different the pigment is described as flocculating. Where there is no change in colour strength, the pigment is described as non-flocculating.

The results obtained were very surprising. The pigment green B alone behaved in the way expected. Once a reasonable level of dispersion had been achieved, i.e. after four hours ball milling, when the mean particle size was down to about 0.28μ, there was no evidence of flocculation or of variation in colour strength with applied shear rate. This is in agreement with long practical experience with this pigment.

As the particle size of the phthalocyanine blue pigment in the stainers was reduced below 0.4μ, the degree of flocculation, or shear/strength variation, in the reduced paints increased and became very considerable. However, when the particle size of the pigment in the stainer was reduced below 0.2μ the degree of flocculation or shear/strength variation decreased and the defect eventually disappeared altogether. The only difference in the stainers was in the degree of dispersion of the pigment and this degree of dispersion appeared to control the incidence and extent of the flocculation defect.

These results are summarised in Tables 1 and 2, which contain representative data.

Table 1

Effect of particle size on flocculation of phthalocyanine blue ball milled stainers

Time of grind (hours)	50% diameter μ	*k/s* values (1:12.5 reductions)	Degree of flocculation
2	0.565	0.84	Moderate
8	0.405	1.19	Severe
12	0.335	1.38	Severe
24	0.285	1.82	Severe
36	0.270	2.04	Severe
72	0.215	2.41	Moderate

Table 2

Effect of particle size on flocculation of phthalocyanine blue sand-ground stainers

Time of grind (hours)	50% diameter (μ)	*k/s* values (1:12.5 reductions)	Degree of flocculation
¼	0.3	1.45	Severe
1	0.26	2.41	Severe
2	0.235	2.69	Moderate
4½	0.160	2.90	None
5	0.160	3.00	None
5½	0.175	2.60	None
6	0.140	3.52	None
8	0.130	4.40	None

The same phenomenon was found with the reduced paints made from the stainers of the two violets, the phthalocyanine green and the yellow.

In other words, these results show that whether or not the flocculation defect occur in paints tinted with the stainers depends solely on the particle size of the pigment. Thus, the Irgalite Blue GLSM, which is not normally regarded as a non-flocculating blue, can be made to give paints completely free from flocculation defects, if it is dispersed well enough. There is no need to adjust the pigment or the stainer formulation in any other way.

The author's views on the causes of these phenomena have been given in detail elsewhere[2] but can be summarised here.

First, the so called flocculation defect for so long associated with phthalocyanine blues is not necessarily due to massive flocculation of this pigment, but is due to the shape of its colour strength/particle size curve. The outward sign of this defect is the difference in colour strength when the paint is applied at different rates of shear. Only very slight reversible flocculation of the pigment particles would be required to give significant strength variations. Most paints are traditionally assumed to flocculate slightly on standing, developing sufficient false body to enable them to store satisfactorily. This slight flocculation, which is traditionally a desirable property in paint, is reversible and easily broken down.

Such slight reversible flocculation would produce no noticeable strength differences in the pigment green B/titanium oxide paints, because the colour strength of this pigment is not very sensitive to particle size.

Slight reversible flocculations of the same extent would give rise to the flocculation defect with the blue, but not with the green.

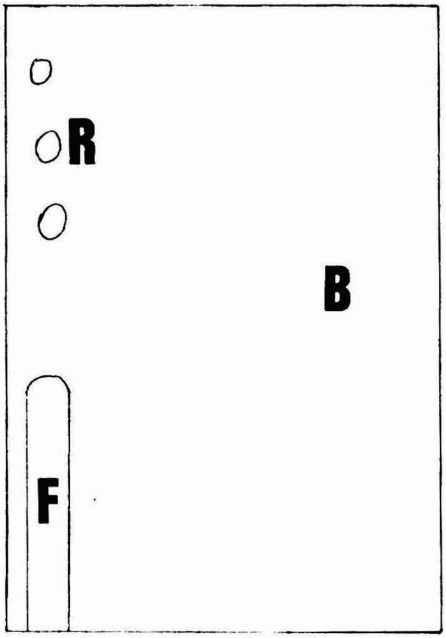
Secondly, the question of why this flocculation defect should disappear when the particle size of the blue is reduced below 0.2μ arises. From Fig. 2, it can be seen that the slope of the curve is very steep at this region and hence slight flocculation of the pigment should still give significant strength/shear variations.

Two explanations for this disappearance of the defect are suggested.

1. It is widely believed at the present time that the stability of pigment particles in non-aqueous suspensions is brought about by a steric hindrance effect. This means that long chain molecules of polymers, resins, or surfactants are adsorbed on the surface of the pigment particles and their presence hinders the particles from coming close enough together to allow the forces of attraction to come into play and cause flocculation. It is also believed that the efficiency of steric hindrance forces as a stabilising mechanism for pigment dispersions is increased as the pigment particle size is reduced. On this argument, it is reasonable to expect that when a pigmented resin stainer is ground finely enough, a state will eventually be reached where the steric hindrance effect of the resin molecules adsorbed on the pigment particles will be sufficient to ensure complete dispersion stability and freedom from any flocculation whatsoever. It would appear from the experimental results that, in the cases of the phthalocyanine blue and green, the carbazole and dioxazine violets, and the diarylide yellow the critical mean particle size in this respect is about 0.18μ.

2. The "flocculation" of paints is generally assessed in the following manner. The paint is brushed out on a panel, giving a region "B" where it has been applied by brushing. A quantity of paint, usually 1 ml, is allowed to flow down the panel under gravity, giving a region "F" where the paint has been applied by flowing under its own weight.

After the brushed out film has been allowed to stand for three minutes, areas of the film are rubbed with a finger after 3, 4 and 5 minutes, giving a region "R" on the panel where the shear applied to the paint film has been very high. The test panel illustrates, therefore, three areas, B, F and R, where the paint has been subjected to three widely differing rates of shear. If the colour strengths in all three regions are equal after drying, then the pigment is judged to be "non-flocculating." If the colour strengths in the three regions are different, then the pigment is judged to be flocculating.



In fact, this is only a demonstration of the variation of colour strength with shear rate for the pigment.

Why then should the flocculation disappear on prolonged grinding?

If a blue stainer has only been lightly milled, i.e. only submitted to a low shear, then on brushing out the blue/white paint, the pigment will be submitted to a much greater shear. When the film has partly dried and its viscosity increased, the finger rubbing will apply a still greater shear to the still liquid paint. The flow down under gravity will not submit the blue to any greater shear than it already has had in the mill.

The particle size of the blue pigment in the regions B, F, and R will therefore be different, because it has been submitted to differing shear rates.

Because the particle sizes are different, and because of the shape of the colour strength/size curve, these size differences will produce widely differing colour strengths in the three areas, in the order F, B, R.

On the other hand, if the blue stainer had been milled longer, the shear applied in brushing would not be greater than in the original milling, so the particle sizes in regions B and F should be similar and hence there should be no strength differences in these regions.

The rubbing will still give an increased shear rate and hence the strength in R will still be greater than in B and F.

If the blue stainer had been given severe and prolonged milling, i.e. it was submitted to considerable shear, then no greater shear will be applied in any of the areas F, B and R than that which the pigment had already been subjected to during grinding. The particle sizes of the blue in these regions will be the same, and equal to that in the original paint, hence the colour strengths at F, B and R will all be equal and the pigment will be classed as non-flocculating. In fact, it has had such a powerful grind that the application techniques have not altered its size distribution.

If the same argument is applied to pigment green B, it will be seen from the shape of its colour strength/particle size curve that even where F, B and R represent regions of different shear and different particle sizes, their differences in colour strength will be small.

The curves for the two violets and the phthalocyanine green and the yellow are similar to that of the blue and these stainers exhibit the same phenomena as the blue.

It is difficult to decide between the two explanations outlined above. It will be appreciated that, in either explanation, there is no supposition that the phthalocyanine blue, either in the stainer or reduced strength form, behaves any differently from the pigment green B in terms of the classical view of flocculation, namely the coming together of two or more small particles to form a larger one. The differences between them in terms of the so called flocculation defect can be attributed to the differences in the way that their colour strengths vary with particle size and these differences are due to their different optical properties.

Whether either of the above explanations is correct or not, the experimental findings are that the degree of dispersion is the important factor in controlling the so called flocculation defect in phthalocyanine blue and green, carbazole and dioxazine violets, and diarylide yellow.

Commercial non-flocculating brands of these pigments have been examined and it was found that they are reduced to the safe size region within normal milling times. They differ from ordinary grades of the same pigments in that they disperse more quickly.

Flotation and flooding

Three methods of assessing the extent of flotation and flooding were considered. First, drawdowns of equal strength reductions of the stainers were made on glass panels. The films were to be examined on the GE spectrophotometer to measure any difference in strength between their upper and lower surfaces. Unfortunately, this approach failed, as the glass panels had a slight greenish cast and this made accurate strength comparisons of the upper and lower surfaces impossible. Secondly, whilst brushed out panels of equal strength reductions were drying, crosses were lightly drawn on the wet films. This shows up the presence of any flooding by producing either a lighter or darker cross on the brushed out background. Thirdly, the equal colour strength panels that had been used to detect flocculation were examined. The boundary between the flowdown and brushed out films were examined using a magnifying glass. Variations in colour strength at this boundary are usually attributed to flotation.

An experienced observer assessed the panels for flotation and flooding using the second and third methods. His findings are given below.

The phthalocyanine green and the diarylide yellow gave virtually no flotation or flooding at all particle sizes.

The carbazole violet and the pigment green B gave no flooding and only slight or very slight flotation, the extent being largely independent of particle size.

With the dioxazine violet, flotation increased with decreasing 50 per cent diameter, and white flooding was present at larger particle sizes.

With the β phthalocyanine blue, flotation tended to decrease at very small diameters, as also did the white flooding.

It is apparent from these findings that the effect of particle size of the organic pigment on flotation and flooding in this resin system is not clear cut.

Gloss

To study the variation of gloss with dispersion, an accurate method of measuring gloss must be available.

In the author's experience, the most accurate instrument for this purpose is the Zeiss GP2 goniophotometer and this was used for the following experiments. The GP2 instrument has several apertures for incident and reflected light, and both angles of incidence and reflection can be varied. In this work the apertures in both the illuminating and measuring collimators were 1° and the angle of incidence was 45°. The intensity at different angles of reflection was measured. For each of the six pigments a series of stainers in Beckosol P470 at 8 per cent w/w with a known variation in dispersion was used (with the diarylide yellow, the pigmentation was 2.5 per cent w/w).

The stainers were drawn down on glass plates to a wet film thickness of 0.004in using an applicator. The films were all dried under the same conditions, namely at 20°C and a relative humidity of 50 per cent.

The plates were examined on the goniophotometer, and the intensity of the reflected light measured at different angles of reflection between 36° and 54°.

Fig. 11 shows a set of curves which are typical of the results obtained. These curves are for ball milled stainers of the β-phthalocyanine blue.

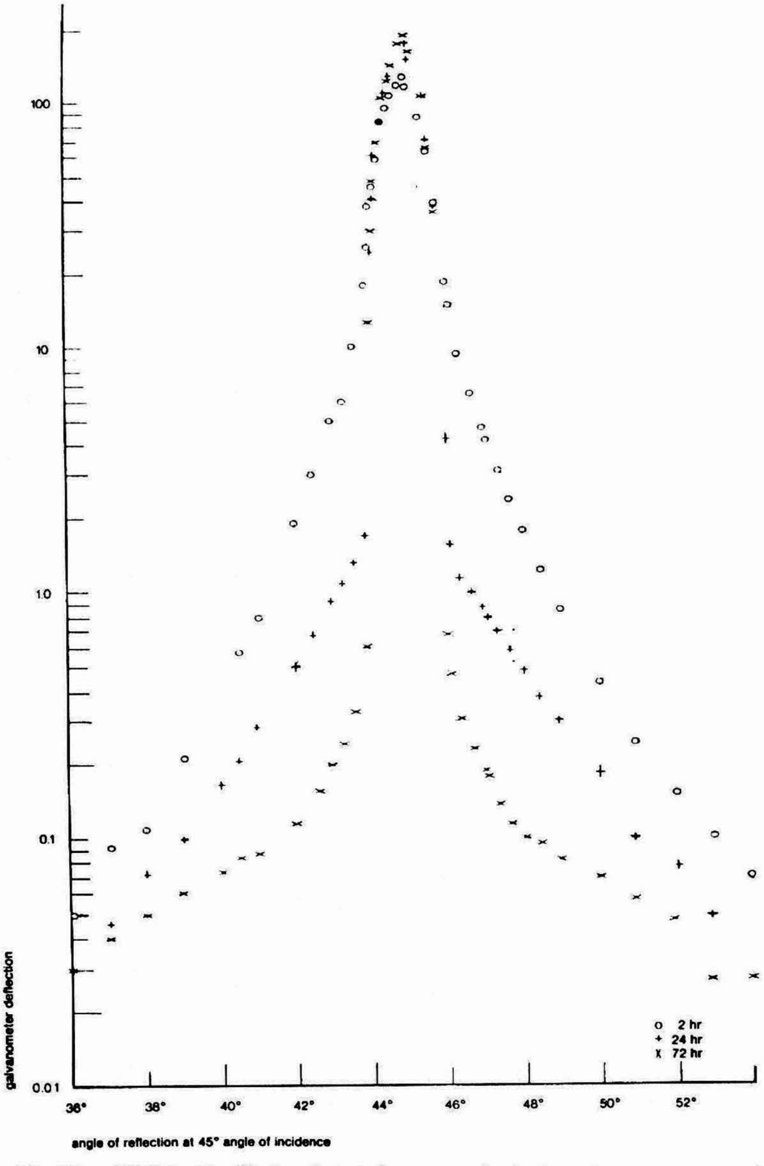


Fig. 11. Irgalite Blue GLS ball milled paint stainers: goniophotometer measurements on films on glass

Discussion

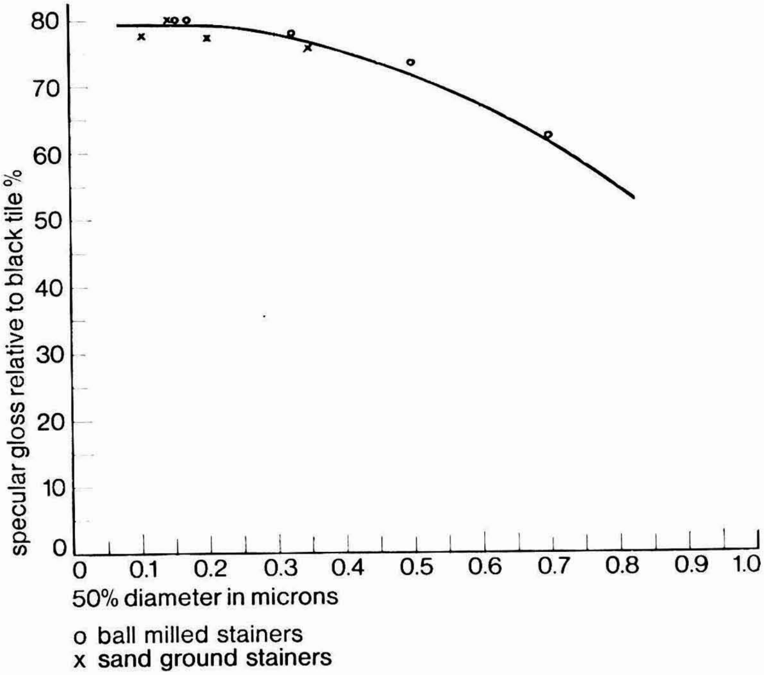
The peak shown in all the curves is a measure of the specular reflection of the paint films. The shape and sharpness of the peaks is a function of the aperture width and the intensity of the light source, as well as of the actual film surface.

The variations in the width of the curves at angles well removed from the specular angle are due to differences in the haze of the films, where the term haze is used to mean the sharpness or diffuseness of the edges of the image[3]. The wider the curves, the more hazy is the film.

The gloss of the films, in the conventional meaning of the word, is a function of both the specular reflection and the haze.

If the maximum height (*h*) of the goniophotometer curves is divided by the width ε at half the maximum height and compared with the results for a black tile, then a figure is obtained which has been found to correlate well with visual assessments of gloss (over small haze differences). The influence of haze differences on this figure is negligible, as these differences represent only 0.1 per cent of the total light reflected.

This specular gloss figure has been calculated from the curves for the stainers of each pigment and has been plotted against particle size for each pigment. In each case, it was found that the specular gloss increased as the particle size was reduced until a mean diameter of about 0.3μ was reached. After that, further increase in dispersion did not alter the specular gloss. The graph for the dioxazine violet is shown in Fig 12.



$$\text{specular gloss} = \frac{\left(\frac{h}{\varepsilon}\right)\text{for stainer}}{\left(\frac{h}{\varepsilon}\right)\text{for black tile}} \times 100\%$$

Fig. 12. Gloss of dioxazine violet stainers (CI Pigment Violet 23) specular gloss vs. 50 per cent diameter

It is difficult to know how to express haze in numbers. In a qualitative way, it can be seen from curves such as those illustrated in Fig. 11 that the width of the curve decreases quite sharply as the dispersion is increased.

The haze continues to decrease markedly as the pigment particle sizes are reduced, at least until the mean size is down to 0.12μ, which is the smallest size obtainable in this investigation. If panels of a given pigment are compared at the point where the specular reflection is at a maximum, and where the mean diameter is 0.3μ or less, then differences in haze, as shown on the goniophotometer, correspond to significant visual differences in observed gloss. The results can be summarised as follows:

as pigment particle size is reduced, the main visual effect is the increase in specular reflection, which continues until the mean particle size is about 0.3μ;

as the particle size is reduced still further, the haze or image boundary diffuseness decreases and this too is clearly visible to the eye.

Transparency

It has long been accepted from both theory and practice that the transparency of organic pigments increases with increased dispersion. The various stainers of the six pigments were examined to check this belief and to see if they all behaved similarly.

In the first instance, the stainers were drawn down on Morest Charts to compare their opacity and transparencies. Accurate comparisons were found to be impossible. First, the gloss differences between stainers of the same pigment made assessment difficult and secondly, strength differences between stainers added to the difficulty. The gloss and strength variations are, of course, themselves due to differences in dispersion.

A number of experienced observers tried to compare the drawdowns using, as a sole criterion, the contrast between black and white sections on the chart. No overall pattern of increasing transparency with increasing dispersion was found.

The stainers were then drawn down on glass using a block applicator. A light source was viewed through the panels by a number of observers. Using the distinctness of the image as a measure of transparency, all the viewers found that transparency increased as the particle size was reduced, for each of the six pigments.

No quantitative measurements have been made so that there is only a qualitative finding that transparency increases with dispersion for each of the six pigments.

Opacity

Opacity determinations were carried out on the various stainers of the six pigments.

The method used was similar to that described in DEF—1053, Method No. 12 Opacity (contrast ratio).

A film of each stainer was drawn down on cellulose film, backed by glass, with a bar coater (015 gauge $\equiv$ 0.0017in wet film thickness). The cellulose sheet was removed from the glass support and allowed to dry for 24 hours in a dust free atmosphere. It was then placed over a black test plate, using white spirit to ensure good optical contact, with the paint film uppermost. The Y value of the film was measured on a GE recording spectrophotometer at three different positions on the film, the mean being taken. The film was then placed over a white test plate and the *Y* value measured again, the mean of three readings being taken. The ratio of the *Y* reading over the black panel to the *Y* reading over the white panel, expressed as a percentage, was taken as the opacity of the stainer film.

This procedure was carried out with a large number of stainers of each of the six pigments, covering a range of particle sizes. The results obtained for a selection of the ball milled stainers are given in Table 3. The results for the sand ground stainers are similar.

Table 3
Opacities of ball milled stainers

Pigment	Milling time (hours)	50% Diameter (μ)	Opacity
Carbazole Violet	2	1.60	77.8
(CI Pigment Violet 34)	6	0.54	89.7
	12	0.345	97.2
	48	0.215	96.6
	72	0.19	83.3
Dioxazine Violet	3	0.54	79.7
(CI Pigment Violet 23)	8	0.375	97.5
	12	0.260	85.5
	24	0.255	85.2
	48	0.175	97.4
	72	0.155	90.6
Phthalocyanine Green	1	0.57	7.2
(CI Pigment Green 7)	3	0.335	8.6
	4	0.270	9.7
	8	0.215	9.6
	24	0.195	9.6
	72	0.155	9.5
Pigment Green B	1.5	0.835	49.8
(CI Pigment Green 8)	3	0.465	25.3
	4	0.265	46.4
	8	0.160	41.8
	72	0.10	50.4
Phthalocyanine Blue	0.5	0.675	33.9
(CI Pigment Blue 15)	1	0.565	26.8
	4.5	0.415	26.8
	8	0.405	22.9
	12	0.335	22.8
	16	0.30	22.7
	24	0.285	25.3
	30	0.30	22.9
	48	0.225	22.9
	72	0.215	23.6
Diarylide Yellow	0.17	0.425	2.7
(CI Pigment Yellow 17)	0.5	0.35	2.1
(032 gauge ≡ 0.0034in wet film thickness)	6	0.22	2.2
	12	0.15	2.8
	24	0.175	2.6
	72	0.13	2.5

These results do not confirm the commonly held view that opacity decreases as particle size decreases. Instead they show that once the mean diameter has reached about 0.35μ, there is no reduction in opacity with further reduction in particle size.

Although these results are unexpected, it would probably be wiser to delay speculation until many more pigments have been examined, particularly those commonly used at full strengths.

Bronzing

The stainers were all assessed for bronzing using the panels prepared for goniophotometric measurement. These covered a wide range of 50 per cent diameters of the six pigments and were originally drawn down on glass with an applicator to 0.004in wet film thickness. An experienced observer examined these and found that pigment green B, phthalocyanine green and the diarylide yellow showed no bronzing at all over the whole size range. The phthalocyanine blue showed moderate bronzing at the very largest particle size, i.e. lowest milling time. The dioxazine and carbazole violets showed bronzing, as shown below.

	Dioxazine Violet			Carbazole Violet	
	50% Diameter μ			50% Diameter μ	
Ball milled	0.700	Moderate bronzing	Ball milled	1.60	Slight to mod. bronzing
	0.260	no ”		0.255	no ”
	0.175	no ”		0.215	no ”
Sand ground	0.350	Slight bronzing	Sand ground	0.320	Slight bronzing
	0.150	no bronzing		0.187	v. slight bronzing
	0.108	no bronzing		0.143	no bronzing

Light fastness

For each pigment, equal colour strength films were examined side by side for light fastness to see if it varied with the pigment dispersion.

The light fastness comparisons were carried out in several ways.

Lamp exposures

Patterns were exposed on the Xenotest unit together with a set of BS 1006 Blue Wool Scale patterns. The degree of fading was assessed visually. The films of the diarylide yellow and pigment green B faded at approximately 4 on the Wool Scale. The films with the poorer dispersion were slightly more light fast than those in which the dispersion was much finer. The differences could be observed but were not marked, and it was not possible to give the films different ratings on the Wool Scale.

With the other four pigments, no difference in light fastness was caused by differences in pigment dispersion after an exposure period in which the Blue Wool Standard 7 had faded appreciably.

Daylight exposures under glass

These were carried out in south Manchester, the amount of colour loss being measured instrumentally. Again the diarylide yellow and the pigment green B films showed more fade as the pigment dispersion increased. The difference in amount of fade increased once the mean diameter was reduced below 0.15μ. With the other four pigments, there was no variation in light fastness with dispersion over a six month period, (April—September).

Compared with the other four pigments, the light fastness of the yellow and the pigment green B is only moderate and is known to vary appreciably with the ratio of organic pigment to titanium dioxide in the film.

Weathering

Reductions of the Blue GLS stainers on 23 panels, 12in × 4in, have now had 12 months exposure at Cascais in Portugal. The films exposed contained 1:12.5 reductions of the blue with Tioxide R-CR grade of titanium oxide. The reductions were made from a standard white paint based on Beckosol P470 and the blue stainers varied only in their degrees of dispersion.

The panels were exposed at 45° facing south with the top 4in portion of the panel covered. Half of each panel (vertically divided) was washed at monthly intervals. The washed portion was then examined for general properties, including visual colour change and gloss change, by means of a 60° photo-electric gloss meter to ASTM specification.

These examinations and assessments were carried out in Portugal by independent, experienced personnel.

The effect of particle size of the blue on the colour fade, and the gloss retention is shown in Tables 4, 5, 6 and 7 and graphically in Figs. 13, 14, 15 and 16. In order to keep the tables compact and enable the graphs to be followed easily, only the results for four ball milled and four sand ground stainers are given, but these are fully representative of all the results.

Table 4

Ballmilled stainers—Colour fade on exposure—phthalocyanine blue

Time of grind (hours)	50% diameter	Fade figures										
	months	1	2	3	4	5	6	8	9	10	11	12
16	0.300μ	1	2	2	3	3	4	6	6	6	7	8
24	0.285μ	1	2	3	3	3	3	5	6	7	7	8
48	0.225μ	0	0	1	2	2	3	4	5	6	6	6
72	0.215μ	0	0	0	0	0	1	3	4	5	5	6

KEY: 0—no fade, 1—suspected fade, 2—3—slight fade, 4—5—definite fade, 6—7—bad fade, 8—9—very bad fade, 10—complete fade.

Table 5

Ballmilled stainers—gloss retention on exposure—phthalocyanine blue

Time of grind (hours)	50% diameter	Gloss figures (%)											
	months	0	1	2	3	4	5	6	8	9	10	11	12
16	0.300μ	92	86	80	81	81	82	67	63	50	47	43	21
24	0.285μ	92	90	86	82	84	84	66	60	52	53	43	22
48	0.225μ	92	82	87	80	78	80	74	62	52	55	48	41
72	0.215μ	94	84	87	85	88	85	75	63	57	60	55	43

Table 6

Sand ground stainers—Colour fade on exposure—phthalocyanine blue

Time of grind (hours)	50% diameter	Fade figures										
	months	1	2	3	4	5	6	8	9	10	11	12
¼	0.300μ	0	0	1	2	2	3	4	5	6	6	6
1	0.260μ	0	0	0	2	2	3	4	5	6	7	8
5½	0.175μ	0	0	0	0	0	1	3	4	5	6	7
8	0.130μ	1	2	3	4	4	5	7	7	7	7	8

KEY: as for Table 4.

Table 7

Sand ground stainers—gloss retention on exposure—phthalocyanine blue

Time of grind (hours)	50% diameter	Gloss figures (%)											
	months	0	1	2	3	4	5	6	8	9	10	11	12
¼	0.300μ	93	89	91	91	89	89	76	67	62	59	52	40
1	0.260μ	92	84	87	87	88	90	74	67	58	57	50	40
5½	0.175μ	91	90	87	85	87	87	78	77	73	72	65	55
8	0.130μ	88	90	91	85	87	85	72	60	60	58	54	44

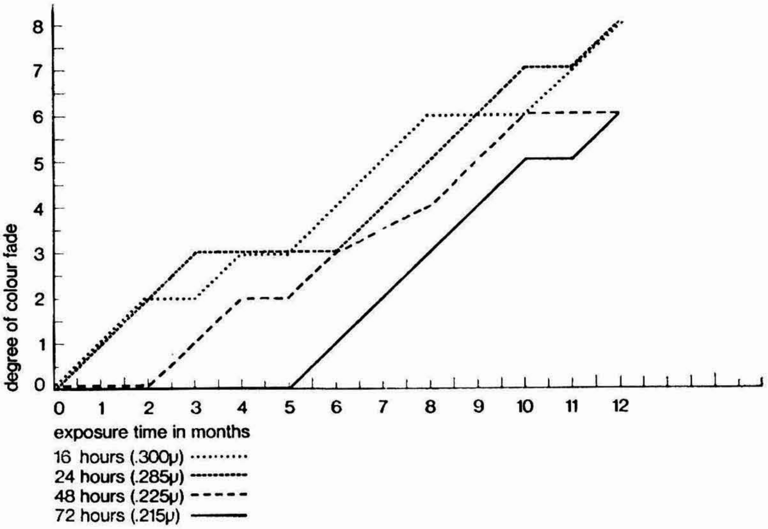


Fig. 13. Phthalocyanine blue (beta form) ball milled stainers. Colour fade: exposed in Portugal

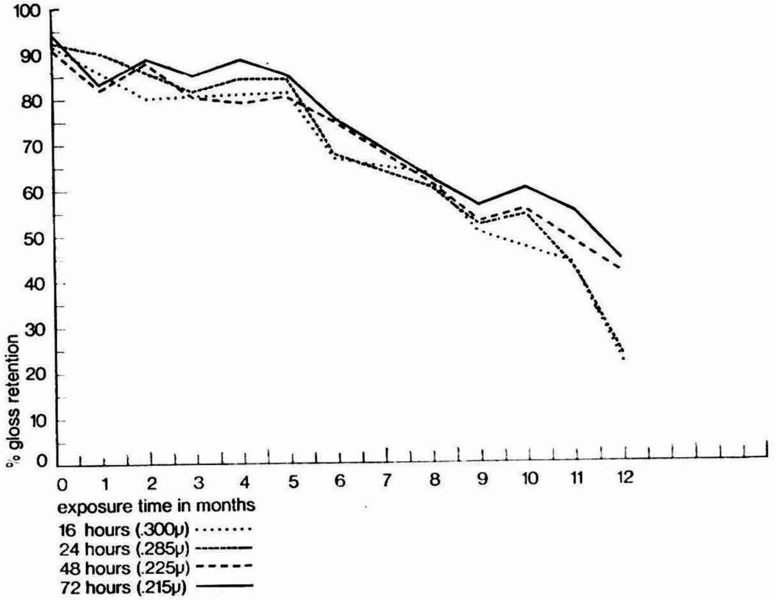


Fig. 14. Phthalocyanine blue (beta form) ball milled stainers
Gloss retention: exposed in Portugal

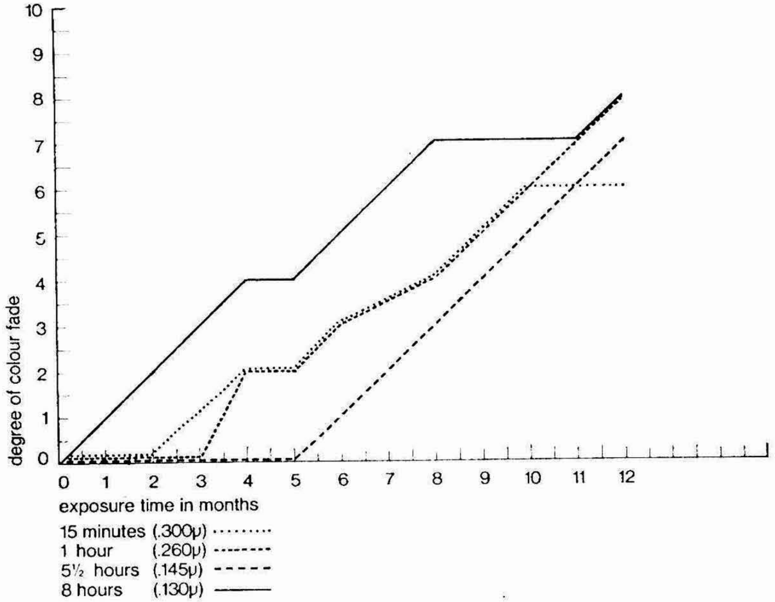


Fig. 15. Phthalocyanine blue (beta form) sand ground stainers
Colour fade: exposed in Portugal

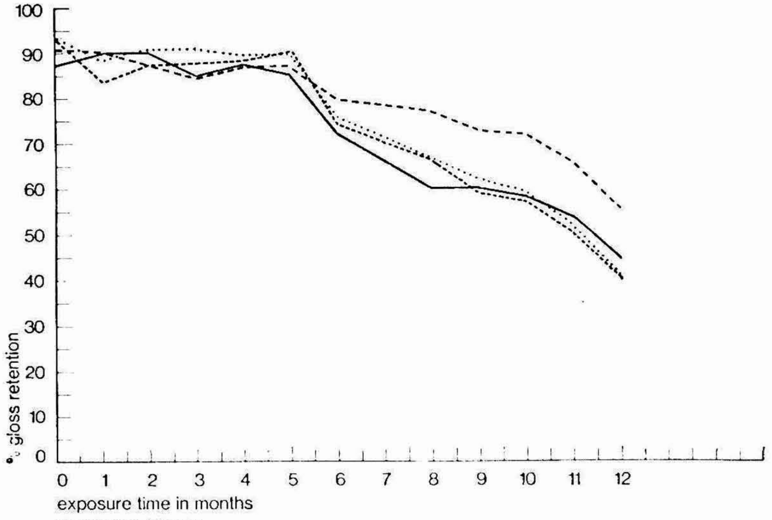


Fig. 16. Phthalocyanine blue (beta form) sand ground stainers
Gloss retention: exposed in Portugal

In the ball milled series, increased milling time gives an improvement in both colour and gloss retention, as can be seen from the samples ball milled for 24, 48 and 72 hour periods. The 16 and 24 hour periods behave similarly to one another and are inferior to the 48 and 72 hour periods.

Films from the sand ground stainers behave differently. An optimum performance is reached at the 5½ hour grind in both gloss and colour retention. The 8 hour sand grind shows gloss retention similar to the 15 minute and 1 hour grind and inferior to the 5½ hour grind, and a colour fade much greater than that of the other test panels, particularly in the first nine months of exposure.

The 5½ hour sand ground stainer behaves similarly to the 72 hour ball milled stainer in terms of colour retention, although the mean size of the latter is the greater. This may be because the 5½ hour sand ground stainer has passed the optimum particle size figure for colour retention whilst the 72 hour ball milled stainer may be approaching it.

More work needs to be done with other pigments before a firm and definite picture can be obtained of the effect of dispersion on weathering. Experience with the blue does seem to show that it can have a significant effect and that it is possible, in the laboratory at least, to overgrind a pigment.

Other resins

A small number of experiments has been carried out with the phthalocyanine blue and the pigment green B dispersed in other air-drying resins. These were:

an oil modified urethane, Beckurane 76-60 and,

a vinyl toluenated alkyd resin, Scopol 41 HM/75.

The various stainers of each pigment were reduced with titanium oxide, 1:12.5, their strengths measured, and their flocculation tendency assessed. The white paint was based on Beckosol P470, as in all the other work.

Although the oil modified urethane resin gives finer dispersions of the blue than the Beckosol P470, for the same grinding times, and the vinyl toluenated alkyd gives much poorer dispersions of the blue, for the same grinding times, there is no fundamental difference in the behaviour of the pigment in the three resin systems. The k/s values for the reduced stainers based on Beckurane 76-60 and Scopol 41 HM/75, when plotted against their 50 per cent diameter, lie on the same curve, illustrated in Fig. 2, that was obtained for the stainers based on Beckosol P470. Stainers with a 50 per cent diameter below 0.2μ gave little or no flocculation, those above did.

Similarly, with the pigment green B, the k/s values plotted against 50 per cent diameters for the stainers based on the other two resins fell within experimental error on the curve obtained for the Beckosol P470 stainers.

Apart from differences in the rate of dispersion, there was no indication that the effect of dispersion on the properties of paint films based on these two pigments differed markedly with the resin used.

Conclusions

The results described above relate to 1 resin system, 6 pigments and 12 application properties over a wide range of pigment dispersion.

How can the effect of dispersion be summarised or classified? The author has tried to do this using the application properties as a yardstick.

Colour strength

The relationship between colour strength and particle size is different for each pigment. For five of them, there is a very considerable rate of increase in strength once the 50 per cent diameter is reduced below 0.4μ.

Change of shade

The two violets go markedly redder, the blue and the yellow go slightly greener, the two greens are unaltered in shade as the dispersion of the pigment increases. The changes in shade are more pronounced as the mean diameter falls below 0.4μ.

Brightness or cleanliness of shade

With all the six pigments, brightness increases once the mean diameter is reduced below 0.4μ. The subsequent increase is only of the order of 10 per cent or less but is visible to the eye.

Flocculation

The so called flocculation defect can occur with all these pigments, except pigment green B. It becomes very marked when the 50 per cent mean diameter is reduced to 0.4μ and less. It begins to decrease once the 50 per cent mean diameter reaches 0.2μ and finally disappears.

Flotation and flooding are very little dependent on the dispersion of the organic pigment.

Gloss

Specular reflection increases with dispersion until a 50 per cent diameter of 0.3μ is reached. On further dispersion the specular reflection is unaltered but the haze is reduced.

Transparency increases as the dispersion increases.

Opacity, as measured by the contrast ratio, is virtually independent of dispersion.

Bronzing

Only slight or moderate bronzing was observed with any of the stainers. Where it does occur, it is associated with coarser dispersion.

Light fastness worsens slightly with increasing dispersion for those pigments which only have moderate light fastness.

Weathering

Weathering tests on the reduced blue stainers in Portugal for one year show that increased dispersion can significantly improve colour and gloss retention. Excessive dispersion will give a reduction in weathering properties.

It will be seen from this that, where pigment dispersion does affect the appearance of a paint film, its effect is most marked when the mean diameter is reduced to 0.4μ or less. It is in this size region that small improvements in dispersion give significant improvements in film properties.

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2. Carr, W., *J. Pt. Tech.* 1970, **42,** 696.
3. Amberg, R., *JOCCA* 1971, **54.**

Discussion at the Torquay Conference

DR V. T. CROWL said that he had experience of the use of the disc centrifuge, and congratulated Dr Carr on the vast amount of work carried out to produce the experimental results in the paper.

Referring to Tables 1 and 2 of the paper it seemed that about 0.2 microns was a critical limit of size for flocculation or shear/colour strength variation to occur; phthalocyanine blue pigment ground to less than this size showed no flocculation. This agreed with work he himself had done, which was reported in his paper at the Scarborough Conference in 1967 (*JOCCA* 1967, **50**, 1023). The inference from this work was that particles smaller than 0.2 microns could be stabilised by an absorbed layer mechanism, whereas larger particles could not.

Another point which had emerged from his own work was that there was a relationship between particle size and tendency to flotation. In general, paints containing smaller particles of coloured pigments showed more tendency to flotation, but this did not apply in all cases. It had been concluded that co-flocculation was of importance; this had also been suggested by Daniel's work (VII FATIPEC, 1964 p. 280). Had Dr Carr considered the question of co-flocculation of the coloured pigment with the white in his formulations?

DR W. CARR said that he did not think that the absence of flocculation at small pigment sizes was due to an absorbed layer mechanism. He did not think that flocculation as such ever occurred in the paint. It was obvious that the pigment powder consisted of large agglomerates, and these were broken down on dispersion. It was his belief that the variation in applied shear during dispersion reduced the pigment particles more than the original milling of the stainer. There was no evidence that, once small particle sizes had been achieved, there was flocculation back to larger sizes; rather, it seemed that grinding was a slow steady process, and that it was difficult to achieve small particle sizes.

With regard to flotation, he had not investigated the dispersions of the white in the paint formulations, but agreed that such a study, although difficult, would throw light on flotation and flooding.

DR CROWL asked if Dr Carr could suggest why Pigment Green B behaved differently from the other pigments.

DR CARR replied that it behaved differently because it had different optical constants from the other pigments; it had low tinctorial strength.

DR CROWL observed that the inorganic pigments would therefore be expected to tend to resemble Pigment Green B, since they generally had lower absorptions than the organics.

DR CARR agreed, but said that he had no experimental evidence to support the theory.

Mr J. Groom said that he had been involved in work into pigment dispersion on a roller mill, and the results had supported those of Dr Carr: colour strength increased with reduced particle size, but overgrinding produced unusual effects. Part of this work had involved examinations at high temperatures and pressures, and under these conditions changes in the crystal structure of some pigments had been noticed. Would Dr Carr comment on the effects of temperature and pressure in ball or roll milling?

Dr Carr replied that he had no practical evidence that pressure or temperature affected dispersion, but he would expect that they would: pressure would affect the grinding action and temperature would affect the viscosity of the mill charge, and thus in turn the shear being applied. However, he would not expect any change to occur in the crystal structure of the pigment.

Mr K. McLaren remarked that Dr Carr had stated that, in the light fastness tests, the amount of colour loss had been measured instrumentally. Would Dr Carr describe the method used?

Dr Carr said that reflectance curves had been obtained before and after exposure using a G. E. Hardy spectrophotometer. The colour value of each curve had been calculated, and the difference in NBS units between the two measured. He was aware of Mr McLaren's earlier remarks about the use of NBS units, but was not sufficiently versed in colour physics to discuss their use in this method.

Mr J. Boroky asked if it was possible that the deterioration of properties of the pigment on overgrinding might be due to rounding off the edges and corners of the micro crystallites.

Also, Dr Carr had tended to favour the theory that high shearing actions to produce small particle sizes reduced flocculation. Could it not be that high shear over a long period replaced more of the gaseous phase with liquid, thus producing high adsorption of binder? Thus, a pigment with a different surface area and distribution of radical groups on the surface, such as Pigment Green B, would require less grinding time.

Dr Carr said that Mr Boroky's mechanism for the overgrinding effect was plausible, but it was not possible to prove or disprove it on the evidence available. Although overgrinding had been shown to be a theoretical possibility, it was unlikely to be a practical danger in view of the long grinding times involved. As with Mr Boroky's theory about resin adsorption causing lack of flocculation, no proof could be produced until it was possible to measure adsorption on different edges and faces of the particle.

There were several reasons why the theory that flocculation did not occur at low particle sizes was favoured. For instance, flocculation was very rarely found in phthalocyanine blues in aqueous emulsion paints, and this was believed to be because the stainers used for such paints were ground to small particle sizes, below 0.2 microns. Also, if two Permanent Violet stainers were examined, one with a mean particle size of 0.17 microns and one with a mean particle size of 0.25 microns, the latter was found to exhibit marked flocculation defects. However, on microscopic examination of cross-sections, the dispersion of the 0.25 micron particle size stainer was not markedly poorer than that of the 0.17 micron particle size. Both these phenomena tended to support the proposed mechanism.

Mr J. A. L. Hawkey said that, among the properties affected by dispersion, no mention had been made of viscosity. It would seem that reduction of the particle size would increase the surface area, and thus the amount of material adsorbed—it was unlikely in this case to be confined to a monolayer—and hence the effective volume of the pigment in the stainer would increase. This might be expected to have an effect on the viscosity.

A thought that came to mind was that some misunderstanding of flocculation was caused by difficulties in terminology. Small particles would tend to exert stronger repulsive forces against other particles, because of their higher proportion of absorbed layers, than would larger particles, and when the repulsion between larger particles was not sufficient, what was termed flocculation occurred. One thing that had emerged from Dr Carr's paper was that the particle size necessary for full development of colour strength could not be measured by a fineness of grind gauge, and if the demise of this gauge was thus hastened, it would be of great value to both the paint and printing ink industries.

Dr Carr said that the viscosity of the stainers had, in fact, been measured, and, surprisingly, no variation in viscosity had been found in stainers of different particle size. However, the pigmentation level had only been of the order of 8 per cent, and subsequent tests on other stainers had shown that dispersion did affect viscosity, but only at higher levels of pigmentation.

With reference to Mr Hawkey's second point, there was no doubt that smaller particles were more easily stabilised by steric hindrance than larger ones. He had assumed flocculation to mean association of small particle sizes to form an aggregate, and in his opinion the major problem for the paint and ink manufacturer was the initial breakdown of aggregates, rather than re-aggregation, or flocculation, of the smaller particles.

Dr K. Hamann said that Dr Carr's work had been based on the use of the Joyce Loebl disc centrifuge. From his own experience with this instrument, he would say that it was necessary to use dispersions of less than 2 per cent PVC, hence the dispersions must have been diluted. Surely all the pigments would behave in the same way in diluted dispersions?

Dr Carr replied that they did not all behave in the same way after dilution. However, the need to dilute the stainers was the major weakness of this technique, or any sedimentation technique. Great care had to be taken in the dilution, and some pigments were affected more than others. However, if suitable care was taken, valid results could be obtained.

Dr H. R. Hamburg asked if Dr Carr could suggest how the paint manufacturer might benefit from his work, since the ball milling and sand grinding times quoted in the paper were outside any practical range.

Dr Carr said that the work had set out to show the dependency of important properties on the degree of dispersion of the pigment. Once this had been shown, improved dispersion in practice could be achieved by improvements being made by raw material and machinery manufacturers, and by paint formulators.

Mr A. B. Lock agreed that the paint industry should examine dispersion very closely. However, in Figs. 13 and 15 of the paper, 15 minutes' sand milling and 16 hours' ball milling produced the same degree of dispersion of a pigment, and yet the performance of the formulations produced by the different methods was not the same. Could Dr Carr explain why the dispersion of a pigment to the same degree by different means should result in a difference in performance?

Dr Carr said that this anomaly illustrated a difficulty encountered when using the Joyce Loebl disc centrifuge. The system under examination was not monodisperse and a particle size distribution was obtained. However, a distribution curve could not be related easily to a property of the final paint, and some single figure had to be obtained. In this paper, the mean particle size, or 50 per cent diameter, had been used as an index of the dispersion. In the case Mr Lock had mentioned, although the 50 per cent diameters of the dispersions were the same, their size distribution curves were not identical, and hence their performances differed. This was a danger which had been recognised, but it was difficult to see how it could be avoided.

Professor G. D. Parfitt remarked that it would be valuable if Dr Carr examined the work in terms of known theoretical concepts. There was a problem in terminology. The term "dispersion" described an operation that included several processes. The first of these concerned dispersibility, or the act of incorporating the pigment in the medium. This was what Dr Carr was really discussing, rather than the overall concept of dispersion; the aspect of dispersion stability—flocculation, flooding etc—was not included. It was important not to confuse dispersibility and dispersion stability in this context, and he felt that Dr Carr's paper was concerned almost exclusively with the former.

With regard to the weathering tests, it would be of interest to know the weathering resistance of the base white paints to which stainers were added. Had Dr Carr any such information?

Dr Carr said that he agreed that dispersion was a complex phenomenon. However, he was of the opinion that the major factor in dispersion was the dispersibility, and that dispersion stability was only a minor problem. This could be illustrated by reference to the phthalocyanine blue used in the work, which was typical of the other pigments. This pigment had a surface area of about 50 $m^2 g^{-1}$ and a specific gravity of about 1.5. Hence its basic particle size could be calculated to be 0.08μ. After sand grinding the pigment for eight hours, the mean particle size was 0.135μ. Thus, it was not possible using current technology to achieve complete dispersion of the pigment to its primary particle size, and he felt that the achievement of this was the important factor.

With regard to the performance or weathering of the base white paints, he had no information.

Mr H. Meyer (Chairman) pointed out that the phthalocyanine blue pigmented formulations showed a colour fade after exposure for four months, and a very strong fade in less than 12 months. This was poorer performance than would normally be expected for this pigment.

Dr Carr said that he suspected that the medium used was not the best choice for Portugal, where the exposure tests were carried out, and that the colour fade was due to chalking or film breakdown rather than fading of the pigment. However, he had no evidence to support this.

Mr S. L. Davidson referred to a paper on dispersion published by Mr F. K. Daniel (*J. Pt. Tech.* 1966, **38,** 534), which he thought would be of interest to the author and other speakers.

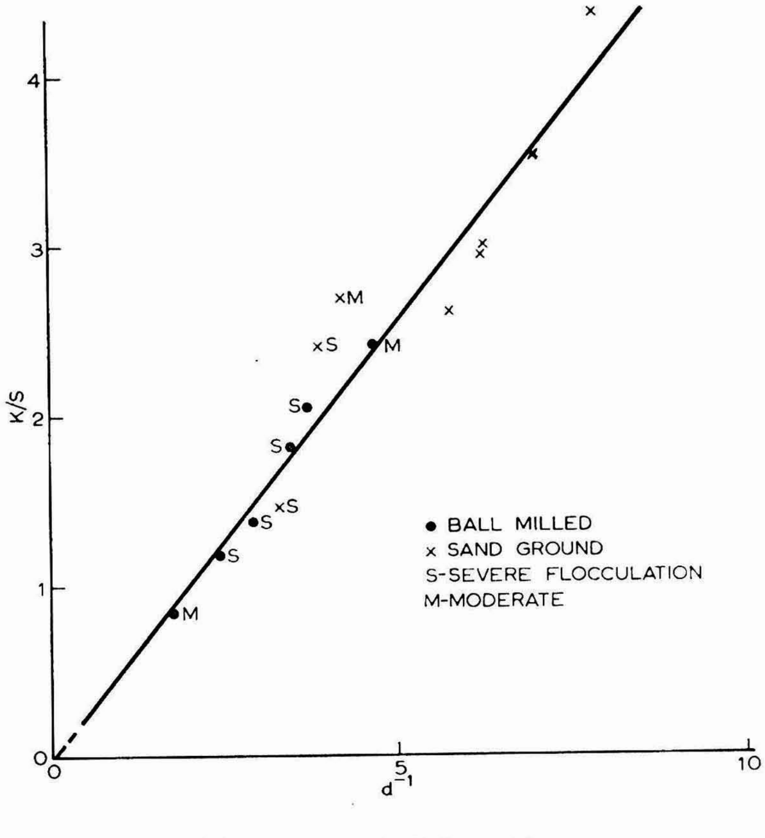
Mr H. Foster said that it was somewhat surprising that opacity had been shown to be independent of particle size below about 0.35μ. Did this not suggest that a further change in particle size, such as flocculation, had occurred on drying, so that this size of 0.35μ, which might be the critical size, was attained?

Dr Carr replied that, since the paper had been written, an explanation of this effect had been suggested.

The opacity of a coating based on an organic pigment depended on a combination of the scattering and the absorption of the pigment. If graphs of scattering and absorption against particle size were drawn and superimposed to give a graph of particle size vs opacity, the portion of the combined curve between 0.1 microns and 0.6 microns would be a straight line perpendicular to the opacity axis. Thus, the opacity would be independent of the particle size in this region.

Mr T. R. Bullett said that he did not entirely follow the explanation given. The opacity of coloured paints varied greatly with wavelength throughout the spectrum so that one could not generalise from graphs drawn at one wavelength. Turning to colour strength development, if one considered the optics for a wavelength corresponding to high absorption by the pigment, then to a first approximation the summed absorption for a given weight of pigment in a thin layer would be inversely proportional to particle diameter *d*. This was because the number of particles was proportional to $1/d^3$ and the absorption cross section per particle was proportional to d^2. For this case colour strength would also, to a first approximation, be inversely proportional to *d* giving the hyperbolic curves shown in Figs. 3, 4 and 5. Subsequently he checked that the data illustrated in Figs. 2, 3, 4 and 5 when replotted as k/S against $1/d$ curves gave reasonably linear plots for all pigments except the Pigment Green B. Moreover, the lines all passed close to the origin. In view of the crudeness of the theory and the fact that the values taken for *d* were simply means for a wide dispersion in size, this agreement was surprising. It could only be supposed that, except for the Pigment Green B, there were several compensating errors in the application of the crude theory.

The figure shows k/S against $1/d$ for the data in Tables 1 and 2 from page 1106. The fit was particularly good for the ball-milled stainer data. However, there is no evidence that the "flocculation" free stainers had behaved very differently from the 'flocculating" stainers.



Mr H. J. Griffiths said that the use of cellulose chips tended to support Dr Carr's theories. Such chips were popular because of the high degree of dispersion of the pigment. If pigments were dispersed direct into the medium flocculation could occur, but by dissolving the chips at very high concentrations in neat solvent, there was little tendency to flocculate.

Dr Carr agreed that this was practical evidence in support of his experimental findings; it was unfortunate that, at present, measurement of dispersion was possible only in limited circumstances.

Mr Hawkey pointed out that although much of the discussion had been involved with opacity in relation to colour strength, with printing inks high colour strength and transparency were required.

Dr Carr agreed that this aspect should be investigated. The difficulty was in determining the degree of dispersion in inks, and he had no experimental results on which to base a comment.

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Financial evaluation of research projects*

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Summary

While research projects should never be justified or rejected solely on financial terms, it is always advisable in major projects to carry out financial analysis. A research investigation is no different from any other financial investment in that one expends money in the hope of future profit, and judges whether the return is sufficient. Financial evaluation of investments has been studied in the past by the traditional method of calculating payback time, and then judging subsequent profitability on the basis of criteria such as percentage of sales, or return on investment. Such methods may still be applicable in the case of relatively short term projects, but for any major project, one must take into account the time scale of the investment and return. This has led to the almost universal use of the method known as discounted cash flow (DCF) which compensates for the time element. Essentially this method is one in which one calculates the cash flow at yearly intervals for the life of the project and then discounts these to arrive at zero present value.

The big difference between a research project and many other investments is that one must accept that research projects incorporate a major risk, that objectives will not be achieved, or that external influences, such as change in potential requirements or the issuance of a competitive patent, may invalidate the whole operation. The risk element is best included by endeavouring to assign probabilities to the various outcomes based on both decisions and chance results. The use of such a decision tree can then be combined with DCF calculations to arrive at an expected average return for the project.

When one is dealing with research projects where the chance of success is low but the ultimate rewards in the case of success are high, one must also be concerned with both the magnitude of the investment and the effect of failure on other events within the company. Attitude to risk varies both with the individual and the company, and must depend in both cases on the financial situation at the time the decision is made. These attitudes are best examined by utility theory which can be combined with DCF and decision tree analysis to present a final answer.

These methods will be used to investigate the potentiality of a project for investigation of electron beam curing.

Keywords

Miscellaneous

discounted cash flow
financial analysis
management

L'évaluation financière des projets de recherche

Résumé

Bien que les projets de recherche ne doivent jamais être justifié ou rejeté pour des considérations financières, c'est toujours prudent dans le cas des projets importants d'entreprendre une analyse financière. Il n'y a pas de différence entre un programme de recherche et autre investissement quelconque où on dépense des fonds dans l'espoir de toucher des bénéfices à l'avenir, et où on juge si le rendement soit suffisant. Dans le passé on a étudié l'appréciation financière au moyens de la méthode classique où il s'agit de calculer le temps nécessaire pour accomplir le remboursement (pay-back time), et ainsi de juger la rentabilité subséquente à base des critères tels que le pourcentage de ventes, ou le rendement des investissements. Telles méthodes peuvent être valables encore dans le cas des projets à terme assez courte, mais

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*Presented at the Torquay Conference on 5 May 1971.

pour aucun projet important on doit tenir compte de l'échelle de temps pour l'investissemnt et également pour le rendement. Cette considération a produit l'emploi presque universelle de la méthode appelée flux monétaire escompté (discounted cash flow), qui offre la possibilité de compenser l'échelle de temps. Essentiellement dans cette méthode on calcule le flux monétaire pour les intervalles annuels pendant la durée du projet, et puis on les escompte pour arriver à une valeur actuelle de zéro.

La grande différence entre un projet de recherche et plusieurs autres investissements c'est que l'on doit agréer que les projets de recherche renferment un risque majeur, que les buts ne soient par achevés, ou que les influences externes, telles qu'un changement dans la consommation potentielle, ou l'émission d'un brevet concurrent, peuvent rendre sans valeur l'opération entière. Il est mieux d'inclure l'élément de risque en essayant d'accorder les probabilités aux diverses conséquences basées sur les décisions et les résultats aléatoires. L'utilisation d'un arbre de décisions peut être combinée ensuite avec des calculs du flux monétaire escompté afin d'arriver à un rendement moyen pour le projet.

Lorsqu'il s'agit des projets de recherche où les aléas de succès sont faibles, mais également où le rapport ultime est élevé, on doit tenir compte aussi de la grandeur de l'investissement et à la fois de l'effet d'un insuccès sur d'autres évenements dans l'entreprise. L'attitude vers des risques se varie selon l'individu et également l'entreprise, et elle doit se dépendre dans tous les deux cas de la situation finacière à l'instant où l'on effectue la décision. Ces attitudes peuvent être examinées par la théorie d'utilité qui peut être combinée avec le flux monetaire escompté et d'ailleurs avec l'analyse des arbres de décisions afin de présenter une réponse finale.

On va utiliser ces méthodes pour faire une appréciation de l'efficacité potentielle d'un projet pour l'investigation du processus de durcissement par faisceaux d'électrons.

Finanzielle Bewertung von Forschungsprojekten

Zusammenfassung

Während Forschungsprojekte nie lediglich aus finanziellen Gründen gerechtfertigt oder abgelehnt werden sollten, so ist es doch stets ratsam für grössere Projekte eine finanzielle Analyse zu machen. Eine Untersuchung auf dem Gebiete der Forschung unterscheidet sich keineswegs von irgendiener anderen finanziellen Prüfung, denn man gibt Geld aus in der Hoffnung künftigen Gewinnes und beurteilt, ob der Ertrag ausreichend ist. Bisher wurde bei finanziellen Erhebungen hinsichtlich Investierung nach der althergebrachten Methode so vorgegangen, dass die Rückzahlungsperiode (pay-back time) berechnet, und darauf die sich anschliessende Profitabilität auf der Basis von Kriterien, wie z.B. als Prozent vom Umsatz oder Gewinn aus Investierung beurfeilt wurde. Solche Methoden dürften noch immer bei verhältnismässig kurzfristigen Problemen anwendbar sein, für irgend ein grösseres Projekt muss jedoch die Zeitskala von Investierung und Ertrag in Betracht gezogen werden. Dies führte zum beinahe universellen Gebrauch der Methode die unter dem Namen diskontierter Geldumlauf ("discounted cash flow") bekannt ist, welche für das Zeitelement kompensiert. Im wesentlichen berechnet man bei dieser Methode den Geldumlauf alljährlich für die Lebensdauer des Projektes und diskontiert diese daraufhin, um auf den gegenwärtigen Nullwert zu kommen.

Der grosse Unterschied zwischen einem Forschungsprojekt und vielerlei anderen Investierungen besteht darin, dass man sich damit abfinden muss, dass erstere ein erhebliches Risiko einschliessen, gesetzte Ziele vielleicht nicht erreicht werden oder äussere Einflüsse, wie z.B. Veränderungen in dem Nachfragepotential, oder das Herauskommen eines konkurrenzfähigen Patentes die ganze Arbeit zunichte machen können. Das Element des Risikos wird am besten mit einkalkuliert, und zwar indem man sich bemüht, den verschiedenen sowohl auf der Grundlage von Entscheidungen als auch Chanceresultaten erhaltenen Ergebnissen Wahrscheinlichkeitswerte zuzuschreiben. Die Verwendung eines derartigen "Baumes der Entscheidungen" ermglicht es, ihn mit DCF Kalkulationen zu kombinieren, sodass der für das Projekt zu erwartende Durchschnittsertrag berechnet werden kann.

Wenn es sich um ein Forschungsprojekt handelt, bei dem die Erfolgschancen gering sind, die Belohnung beim Gelingen in Endeffekt aber hoch ist, muss man ebenfalls sowohl hinsichtlich der Höhe der Investierung als auch der Auswirkung eines möglichen Misserfolgs auf andere Vorgänge innerhalb der Firma besorgt sein. Die Einstellung zu einem Risiko ist je nach Individuum und Gesellschaft verschieden, in beiden Fällen muss sie zum Zeitpunkt der Entscheidung von der derzeitigen finanziellen Lage abhängen.

Am besten werden diese Haltungen mit Hilfe der Nutztheorie (utility theory), die mit der DCF und "Baum der Entscheidungen"—Analyse kombiniert werden kann, geprüft, um eine endgültige Antwort ausfindig zu machen.

Diese Methoden werden verwandt werden, um die Möglichkeiten eines Projektes, das sich mit der Härtung durch Elektronenbündel befasst, zu untersuchen.

Финансовая оценка исследовательских проектов

Резюме

В то время как исследовательские проекты никогда не следует оправдывать или опровергать исключительно по финансовым соображениям, все же всегда является целесообразным, для более крупных проектов, провести финансовый анализ. Исследовательский проект ничем не отличается от любого другого финансового капиталовложения, посколько в обоих случаях производится затрата денег в надежде на будущую прибыль и делается оценка достаточности дохода. Финансовая оценка капиталовложений проводилась до сих пор традиционным методом вычисления срока возвратного дохода и затем оценкой последующей прибыли на основании таких критерий как процент продажи или принос дохода. Такие методы все еще применимы для сравнительно краткосрочных проектов, но для любого крупного проекта необходимо учесть временной фактор капитального вложения и приносимого дохода. Это привело к почти универсальному применению так называемого метода процентного дисконта денежного оборота, который учитывает фактор времени. В сущности этот метод сводится к вычислению денежного оборота ежегодно в течение существования проекта, с последующей скидкой этих значений до нулевого уровня.

Главная разница между исследовательскими проектами и многими другими капиталовложениями, заключается в том что исследовательские проекты предъявляют особый риск что цель не будет реализована или что внешние факторы, как например перемена в потенциальных требованиях или публикация конкурентного патента, могут обесценить всю операцию. Элемент риска лучше всего учитывается попыткой приписать степень вероятности различным реализациям, основанным как на решениях так и на случайных результатах. Применение такой таблицы решений можно тогда совместить с процентным вычетом денежного оборота, для того чтобы определить средний ожидаемый доход от проекта.

Когда мы имеем дело с исследовательскими проектами, где возможность успеха низка, а конечные вознаграждения в случае успеха велики, следует тоже учесть размер капитальных вложений и эффект неудачи на другие предприятия компании. Позиция по отношению к риску неодинакова для личностей и для компаний и должна зависить в обоих случаях от финансового положения в момент приема решений. Эти позиции лучше всего анализируются теорией полезности, которую можно совместить с процентным вычетом оборота и с таблицей решений, для формулировки конечного ответа.

Эти методы будут применяться в определении потенциальных возможностей проекта для анализа электронной лучевой сушки.

Introduction

By definition, a research project can have no certain outcome, nor can one predict the exact cost and time needed to produce the desired result. It has therefore been traditional to use only the most primitive forms of financial assessment of a project before starting. Indeed, many projects are started without any financial justification, and often for considerations such as prestige, or to compete with products which indirectly are replacing an existing business. The very structure of a research and development department can also lead to projects which are not financially viable, since there is a tendency to have constant staffing and funding in a situation where worthwhile projects may vary considerably in number and scope.

This is not to say that there are not also dangers in a rigid financial approach. Taken to extremes, this demands that no work can be started until a market survey is carried out to establish the potential. From this information, which is often very subjective, a market figure of dubious precision is produced and the value of this market is then compared with calculations of research costs. The ultimate folly in such an approach occurs when the allocated funds expire when the project is nearly completed and this is then either dropped or delayed at a critical time.

In work with any degree of originality, the availability of worthwhile information to assess the project is necessarily limited, so a flexible approach that avoids the extremes of rigid financial control or operation by intuition is needed. The advocates of the intuitive method will point out the impossibility of ascribing numbers to unknown events, but the mere exercise of separating the components of the project and endeavouring to ascribe times and costs to each phase will often be valuable even if no detailed treatment of the figures is then carried out. There are a number of situations where a quite simple calculation can demonstrate the impossibility of adequate return on the R and D work.

In considering a new project, the points that require judgment can be listed and these can sensibly be defined in terms of a series of actions.

(1) Try to establish the total cost of the project by defining time, manpower, materials, equipment and overheads.

(2) Consider carefully the rate of expenditure and the rate of the subsequent financial return.

(3) Consider alternative outcomes and try to ascribe probabilities to the alternatives.

(4) Consider the size of the project in relationship to total research funds.

(5) Consider the effect of failure in terms of reaction both within the company and outside.

(6) Keep detailed records of expenditure.

(7) Reconsider the project at regular intervals and do not be afraid to change objectives.

(8) Study the final result in terms of original plans. This will help to improve the accuracy of future project planning.

When the data from items 1-6 have been collected, sensible use can be made of modern methods of financial analysis to examine the merits of the project. Three such methods are discussed in this paper, and while these will not all be used on every occasion, an example is shown of their simultaneous use in assessment of a project.

The first method studied, known as discounted cash flow or DCF, looks at the return on the research investment, both in terms of the total profit and the time taken for this to be received. The second method, known as decision tree analysis, looks at the various alternative results of the project and decisions that need to be taken during its life, assigns probabilities to the alternative results and financial values to these. The third method considered, utility theory, deals with the important subject of risk in relation to gain as judged both for the company and for the individual.

Discounted cash flow

In a commercial undertaking, research should only be undertaken in expectation of a financial return greater than the expenditure. This, of course, is a generalisation since background studies, work to produce patents, and work to enable scientific articles to be published will usually be accepted in practice. In many cases, one can indirectly ascribe values to such work as superior profit margins if patent coverage is obtained or the value of advertising for published articles, but it is probably easier to allow consciously, say, 20 per cent of the R and D effort as being non-accountable.

For a short term development project, an uncomplicated pay back time approach to financial evaluation may be used. There are many published formulae for such calculations, but they are only commonsense and suitable alternatives can easily be invented.

The development of a product for a specific customer may be taken as an example; here the volume of the requirement and the selling price are known, and the manufacturing cost can be reasonably estimated. The pay back time in months is then:

$$\text{Pay back time} = \frac{\text{research cost per day} \times \text{no. of days required}}{\text{profit per unit} \times \text{monthly unit sales} \times \text{probability of success}}$$

In a simple example, if 30 man days at £10 per day are required for monthly sales of 12 tons at a profit of £8 per ton, then pay back time at a probability of 0.5 (a 50/50 chance) is 6¼ months. With such a short pay back time, the question of the value of money when expended and the value of money when received does not arise, but if a more common probability such as 0.1 is taken, then the pay back time becomes 32 months and the interest on the money spent considerably in advance of receipt of profits should be considered. Thus, with an average time of receipt of 16 months and a period of eight months between inception and the first payment, an additional two years' interest on £300, say £60, must be included which at the 0.1 probability requires another six months sales (without compounding) to achieve pay back. It might then be considered that the maximum sales value is being approached, since few products will sell for more than three years without either further development work being required or price erosion reducing the return.

With more complex projects involving long time periods and variable cash flow, the DCF method is to be preferred. In this method a list of all the outgoings and income over the life of the project is made for each year, either separately or as a nett positive or negative balance for each year. A typical example of a larger project might be as follows:

Year No.	Expenditure (£1,000)	Income (£1,000)	Nett Expenditure (£1,000)	Nett Income (£1,000)
1	20	—	20 (20.0)	
2	20	—	20 (16.2)	
3	10	10		0
4	5	15		10 (5.4)
5	5	20		15 (6.6)
6	5	20		15 (5.3)
7	5	25		20 (5.8)
8	5	25		20 (4.7)
9	5	30		25 (4.8)
10	5	35		30 (4.7)
			40 (36.2)	135 (37.3)

Figures in brackets show value discounted at 23 per cent per annum

A simple pay back calculation shows that the money will be recovered in six years, but this figure in isolation is of no assistance in deciding the value of the project. An alternative approach is to say that total income after deducting costs is £95,000 on an investment of around £40,000 before income exceeds expenditure, and so the return is 267 per cent or 30 per cent per year, but this figure has little real significance. For example, there might be an alternative project in which no income was produced until year ten when £135,000 gross was obtained and this would give the same 30 per cent notional return, but it would obviously be a less desirable project.

In the DCF method a little mathematical trickery is used to produce a more meaningful figure of financial return. What is done is to apply a trial discount or interest rate to the cash flows and calculate their present value. Suppose a 10 per cent rate, which is a common interest on bank loans, is applied to the £10,000 expense of year one. On a simple compounded basis with nine years interest at 10 per cent, it is going to require repayment of around £23,500 in year ten or, alternatively, the income of £20,000 in year ten is worth only around £8,500 at year one. A corollary of this is that income many years ahead has a low present value, so if it is poorly estimated, it will have little effect on the calculated return.

Tables are published of discount rates applied over various time intervals and by making use of these, it is found that the rate required to equalise present value of income and expenditure is 23.5 per cent. It could equally well be said that the rate of return on the project if the expected figures are achieved will be 23.5 per cent, and this figure can be directly used as a criterion of a project and compared with the cost of money from bank loans or as equity.

The simple example shown would be applicable where the R and D cost could be directly compared with profit and would apply, for example, to the development of a product currently purchased and made in a plant that already exists. In most practical situations where new plant is required and where promotional expenses are also necessary, it will be more convenient to assess the entire project rather than the R and D component. There are many books on the detailed methods of employing DCF, but a very concise statement is given in a booklet published by HMSO.[1]

Decision tree analysis

Any project may have a variety of possible outcomes ranging from simple success or failure through to a continuous spectrum of possible outcome. There are ways of dealing with an infinite range of outcomes between set limits, but for our purposes it is convenient to consider cases where there are a finite number of possibilities. The outcomes are linked to decisions made both at the beginning of the project and during its life. The normal terminology applied in producing decision trees is "acts" and "events." The former represents decisions and the latter corresponding results. It is also necessary to establish the "consequences" of the events in financial terms and the "criteria" of success. A simple example will illustrate the method used. Suppose there is a chance to buy 100 tons of phthalic anhydride for import at a saving of £10 per ton, but there is a 50 per cent chance of £25 anti-dumping duty being applied before the material arrives. On the other hand, if this occurs, the material can be diverted to a Continental port where there is a 70 per cent chance of £5 per ton

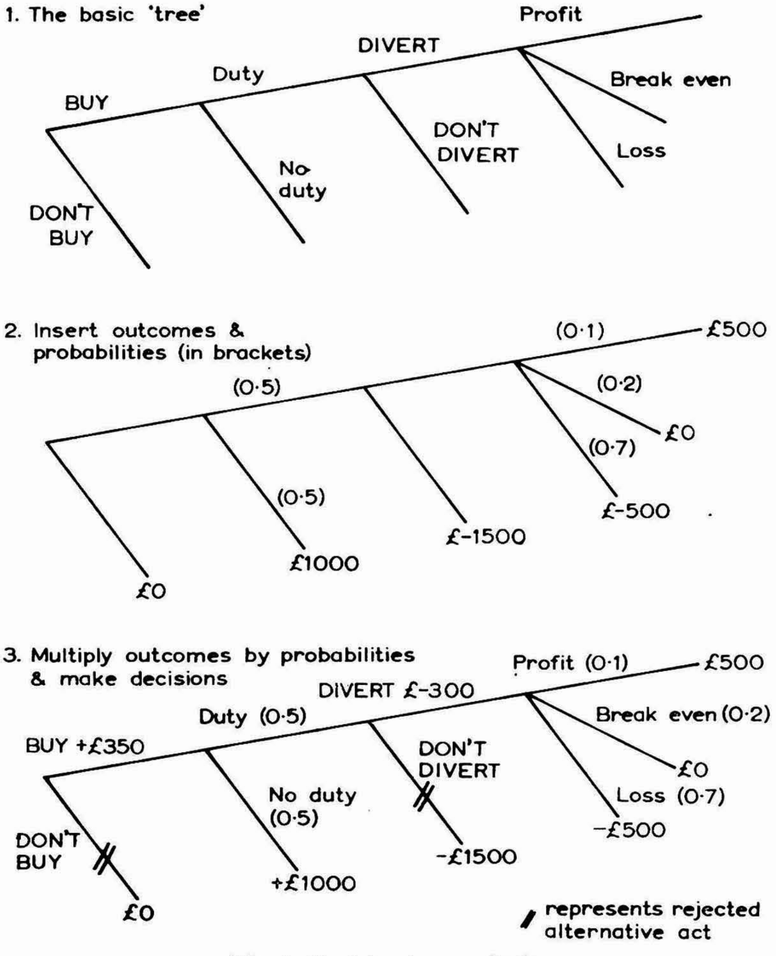


Fig. 1. Decision tree analysis

loss, 20 per cent chance of a break even and a 10 per cent chance of £5 per ton profit.

In Fig. 1 the three stages of constructing a decision tree are shown. In the first part the alternatives are drawn out, with acts in capitals and events in lower case. In the second part values are ascribed to the outcomes and their probabilities. The probabilities are then multiplied by outcomes and the sums show the expected value at each of the forks. The tree is traced backwards to decide on the two preferred acts. The first of these is the choice between —£300 if the materials are diverted and —£1,500 if they are not. The obvious choice is —£300 so the choice is to divert. Going back then to the buy—don't buy decision, there is an expected value for buying of +£350 versus a zero sum for not buying, so the decision is to buy. In the third part of Fig. 1, the complete decision tree is shown with the unacceptable decisions crossed in the conventional way.

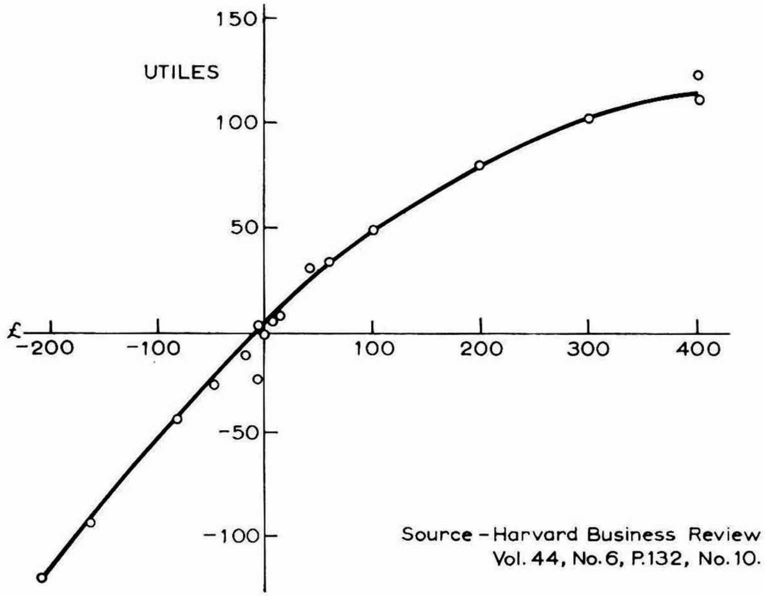
The standard handbook on this technique is "Analysis of decisions under uncertainty" by Schlaifer[2] but a good description together with a number of case studies is "Formal analysis of decisions" by Brown[3].

Utility theory

One of the problems of applying straightforward mathematical treatments to possible outcomes of a project is that money cannot be treated in all circumstances as equivalent. This may seem a strange doctrine, but a simple example will illustrate the point. Suppose the chance of winning money on the toss of a coin is being purchased where there is exactly a 50 per cent chance of success or failure. An attempt can then be made to ascribe a value to the chance of winning £2. Obviously the precise value is £1, but few people would be prepared to pay such a figure, and a random check showed offers of between 25p and £1. If the sum of money is increased to £100, then the percentage that people would pay drops even lower and offers ranged between £1 and £10.

Similarly, values can be placed on losing money, which is, of course, insurance. A typical case might be one for patent infringement where one stood to lose £50,000 with a 30 per cent chance of losing. The expected value of this decision is obviously £15,000 but one might well be prepared to settle out of court for £20,000 to avoid the risk of the larger loss.

It should be realised that an individual's reaction is different for his own money and for the company's money and in obtaining figures one must make this quite apparent. The method of operation is to plot on an X axis the financial sum involved, both in terms of profits and losses, and use an arbitrary scale on the Y axis usually called "utiles". The graph is drawn by asking the respondent a series of questions such as those previously posed, but preferably in rather more detail, and plotting his responses. Such a graph is shown in Fig. 2. A decision tree is then constructed, substituting utiles for financial values to do the calculations and obtaining expected values in utiles. These figures are then resubstituted on the graph to obtain the financial equivalent. Consideration of the effects of this treatment will show that one acts in an anti-gambling sense to prefer a number of outcomes which approach certainty rather than going for high risk situations. Thus in the example of coin tossing given, if one is prepared to toss the coin 50 times in succession and to pay 50p for each £2



Source – Harvard Business Review
Vol. 44, No. 6, P. 132, No. 10.

Fig. 2. Utility curve

chance, one finishes up paying considerably more than for the single chance £100 gamble. Of course the probability of winning £100 is reduced to a very low figure, but the probability of losing all is also reduced.

A good article on utility theory is given in the Harvard Business Review.[4]

Utility theory also has its value in judging the attitude of managers to risk and has been employed to see if people are in the right jobs. Obviously one would expect a research manager to take more risks than a financial director after due allowance is made for the scale of spending involved.

A practical problem

The three methods described can all be combined in a single project analysis. Obviously a great deal of calculation may be involved in a major research programme, and so a fairly simple example has been chosen to illustrate the method. The first requirement is to list out the alternatives as they present themselves during the early life of the project. Also, to simplify the procedures, future income will be discounted at a standard rate rather than attempting to work back to the full rate of return of the project using a DCF method.

As an example of a long term project for investigation, the development of a coating system for electron beam curing can be taken, assuming that one wishes to produce a polymer which is of value only for this specific curing method.

First the alternative actions are listed, as follows:

(1) start research work

(2) take a licence from another company

(3) wait and see

(4) do nothing

(3) and (4) are basically the same except that (4) implies a final decision. In practice there is no advantage in making the final decision so only the three first possibilities need be considered.

If course (3) is adopted, then at various time intervals the position can be changed, and the decision made to do research work or take a licence, but it can be anticipated that the chance of success with research work will diminish if only due to competitive patent activity, while the cost of a licence will probably increase as the licensor achieves commercial success, while the probability of its availability will diminish. A number of other options would probably be open; for example, there might be the alternatives of the purchasing of equipment or the hiring of equipment both in the case of research and that of licensing. It might also be possible to license for a wider market at extra cost, and further options might be in terms of having a joint arrangement with an end user, which in effect is a subsidy to increase the probability of supplying him with material.

To consider the main issue of whether to license or develop and whether the project is viable with either method. It will be seen that the licence can be taken on known terms at the outset, but there may still be the opportunity to do so later if the development work fails.

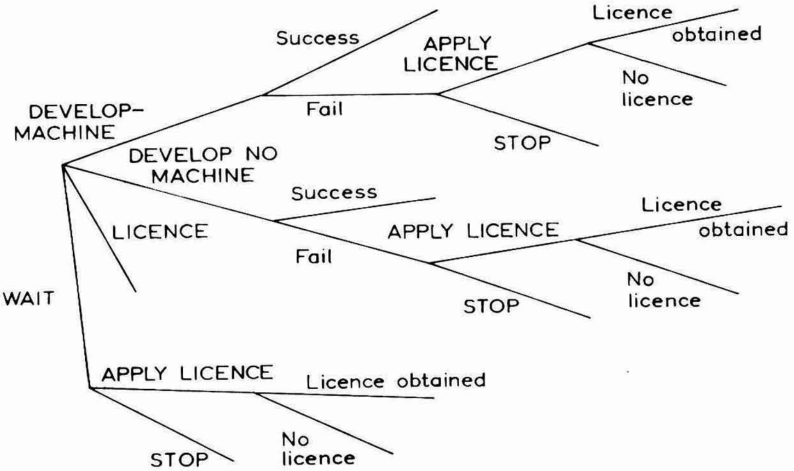


Fig. 3. E-beam decision tree

A decision tree, as shown in Fig. 3 is first constructed. This lists possible "acts" and the expected alternative "events." Costs, probabilities and expected profits are inserted. These figures are all best estimates available, but alternatives can be inserted at any stage, and indeed a useful method is to assess the decision tree separately with most likely and most pessimistic figures. The numbers listed below are illustrative rather than definitive and are in £1,000's.

Development cost per year: 15

Machine cost: 50

Machine hire: 3 years

Development time with machine: 3 years

Development time without machine: 4 years

Probability of successful development 0.6 with machine, 0.5 without

Cost of licence: 20 + 5% of sales

Probability of obtaining licence after 3 years 0.8, after 4 years 0.5

Estimated market share: 40%

Estimated profit on sales: 10%

Estimated market for own development, year 3—300 growing at 50% per year

Estimated market for licence (restricted territory) year 3—200 growing at 50% per year

Cost of applying for delayed licence to cover suspended development, transfer cost and negotiating expense 10, plus 1 year of time

Assumed total project life 10 years, i.e. 7 years of sales

From this table of estimates the derived figures can be calculated.

Own development. Total market sales

years 3-10 inclusive: 9550
years 4-10 inclusive: 9250

Licence. Total market sales

years 3-10 inclusive: 6380
years 4-10 inclusive: 6180
years 5-10 inclusive: 5880

Own development profit with machine

$$\frac{40}{100} \times \frac{9550}{10} = 382$$

Own development profit without machine

$$\frac{40}{100} \times \frac{9250}{10} = 370$$

Licence profit $$\frac{40}{100} \times \frac{6380}{20} - 20 = 108$$

Late licence profit (after machine) $$\frac{40}{100} \times \frac{6180}{20} - 20 = 104$$

Late licence profit (no machine) $$\frac{40}{100} \times \frac{5880}{20} - 20 = 98$$

Fig. 4 can then be constructed.

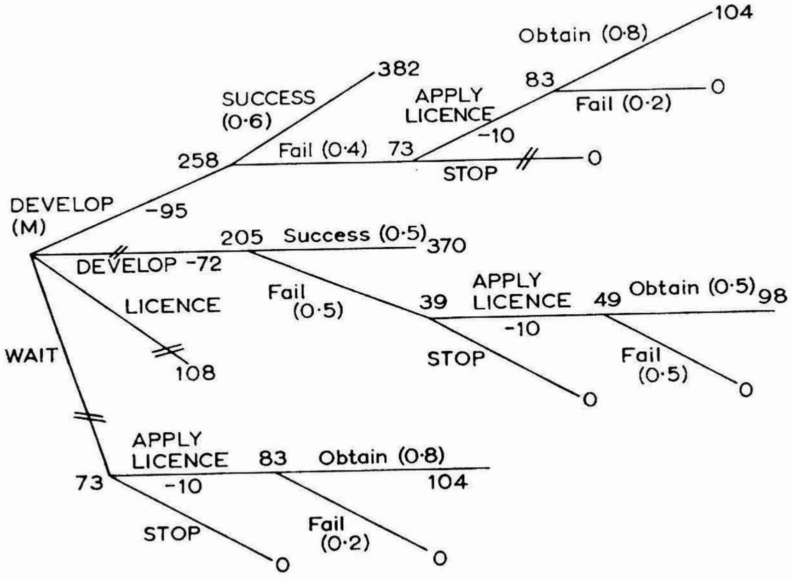


Fig. 4. E-beam decision tree, inserting probabilities

From this we an csee that the "expected values" are

Development with machine ..	.. 258 − 95 =	163
Development without machine	.. 205 − 72 =	133
Licence	..	108
Wait and licence	..	73

This apparently gives a clear decision in favour of development using a purchased machine, but two further considerations are important. The expenditure on the machine and development work is made considerably before the income builds up, so future income should be discounted at a sensible rate.

In Fig. 5 a rather low interest rate, 8 per cent, has been used on the money and both expenditures and income have been discounted on a yearly basis. The resulting present values demonstrate clearly that the obvious advantage for development is now no longer applicable and licensing is equally attractive. Development might still be chosen because the work may have "spin off" benefits and the machine will have a residual value at the end of the project, but the decision is marginal.

Finally the utility of the various alternatives is studied. It should be realised that "expected value" is a statistical figure that cannot be achieved. Thus the expected value of 163 in Fig. 4 is the average of two outcomes, namely a 60 per cent chance of a profit of 287 and a 40 per cent chance of a loss of 22. The attitude to risk therefore determines whether to prefer this alternative which has an expected value of 163, or the sum of 108 from licensing which in this context is risk free.

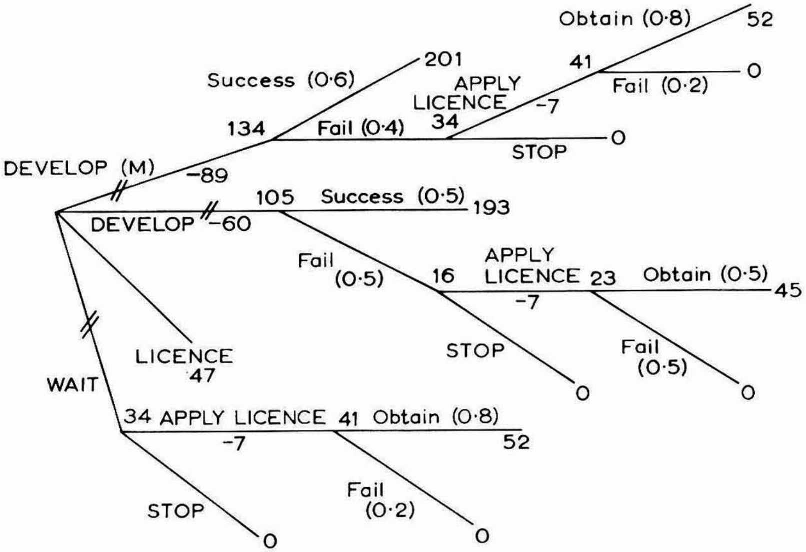


Fig. 5. E-beam decision tree. £1 discounted at 8% to obtain "present values"

In Fig. 6, utiles equivalent to the financial values of Fig. 4 are substituted and it is found that, with the individual responsible for Fig. 2 who is rated as moderately conservative, the certainty of 108 is preferred to the uncertainty of 163:

	Utiles	£ equivalent
1. Development with machine ..	40	76
2. Development without machine ..	27	42
3. Licence	53	108
4. Wait and licence	37	67

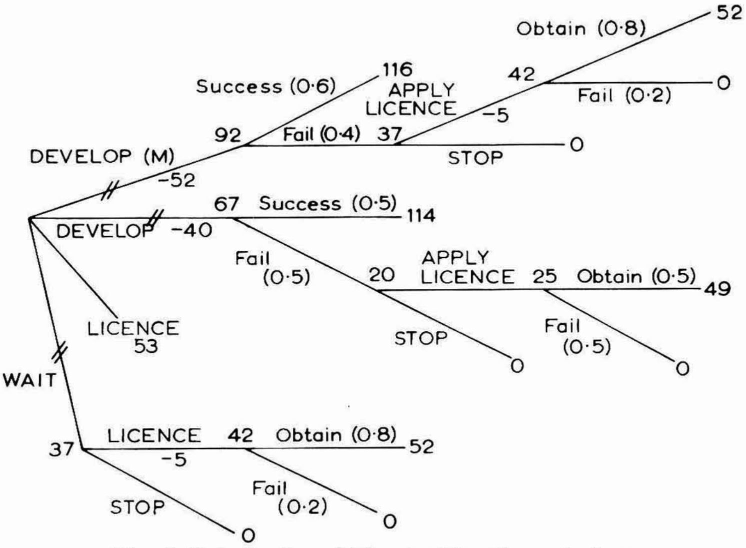


Fig. 6. Substitution of Fig. 4 with utile equivalents

It is, of course, then possible to combine the utile treatment with discounting to obtain the most definitive comparison, and this is done in Fig. 7.

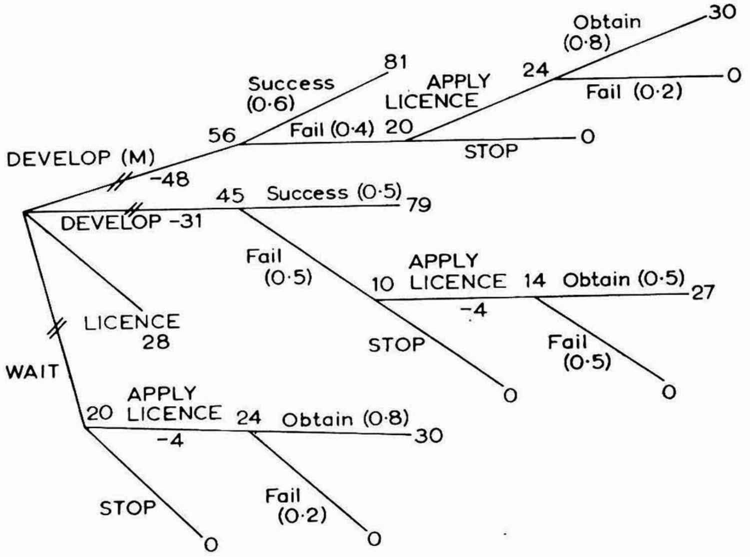


Fig. 7. E-beam decision tree. Utile substitution for present values

A single table compares the financial results by the various methods:

	Expected value	Present value of expected value	Utility equivalent	Present value of utility equivalent
1. Develop with machine ..	163	45	76	12
2. Develop without machine ..	133	45	42	20
3. Licence	108	47	108	47
4. Wait and licence	73	34	67	30

In the final analysis licensing or delayed licensing are preferred because the initial investment is smaller even though income is considerably reduced and also because in the example used the risk element of one's own development is avoided.

Conclusion

The methods shown are not intended to be used without regard to intuitive judgment and they can only be as useful as the prediction of costs, probabilities, and income is accurate. The mere mathematical exercise, however, is of value in forcing the research manager to consider the alternatives and outcomes in financial terms. What is certain is that many projects can be eliminated by such treatment. Inductive treatments can also be used to establish, for example, the market size necessary to make the project viable and then pass the responsibility on to marketing to decide if the required volume can be achieved.

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Discussion at the Torquay Conference

Mr E. L. French said that it seemed that the use of the utile system was another way of defining the business risk that a company was prepared to accept, and was therefore a question of judgement and not a question of any mathematical reasoning.

Mr A. G. North agreed it was just a way of converting a rather abstract feeling for what the company was prepared to risk, into numbers. It should have been pointed out that utility values only existed for individuals, but that an individual had a personal utility curve differing from the one which he drew as a member of a company. This was a useful way of comparing people within a company, because one could see at a glance who was a conservative, extreme conservative, gambler etc., from the shape of these curves. The method been proposed and used as a method of staff selection.

If Rolls Royce was taken as an example, it might be argued that if they had used the utile method they might not have gone bankrupt. A tremendous gain had been envisaged, but was sufficient consideration given to the possibility that if the costs soared, or if Lockheed went bankrupt then this would mean that Rolls Royce would go bankrupt? This was a very important exercise as it was easy to be drawn on by the attraction of a million pound profit, but forget the fact that a £100,000 loss might mean bankruptcy.

Mr D. S. Newton referred to the question of sensitivity. One of the big problems found in dealing with research problems which were hoped to become commercial successes, had been the long term change in the cost of raw materials, cost of labour etc. Was this normally taken into account? This was one area in which Rolls Royce erred, in that they did not take into consideration the possibility of escalation of costs.

Secondly, in the example of decision tree analysis, it had been concluded that licensing was probably the most profitable course. Had the cost of licensing been taken into consideration? This in itself could make a big hole in what appeared to be good profits.

Mr A. G. North, in answer to the second question, said that licensing costs had been included; in the paper this cost was quite substantial. It had been quoted as a transfer figure of £20,000 and 5 per cent of the selling price, which halved the 10 per cent profit. Licensing was still more attractive because of the big time gap between the investment and receiving reasonable receipts if development was undertaken.

In respect of the first point, changes in costs of raw materials and labour could be discounted on the grounds that they were occurring to everybody else simultaneously, and therefore the price of the product could rise. This would not apply if the product was the subject of subsidised competition or was offered at fixed prices, as in the Rolls Royce case.

In making a sensitivity analysis judgement, a simple scheme had been used. For example, for the profit on the material, two or three alternatives had been studied. A continuous spectrum of figures could be used to cover every conceivable event, as long as probabilities could be assigned in each case. In many cases, however, it was probably easiest to work through the exercise twice, once in terms of the most probable results and once in terms of pessimistic results.

Mr A. R. H. Tawn said that the vital point of these calculations was the question of assessing the probabilities that were put on the decision tree. In discounted cash flow one could obtain a good deal of guidance and put a realistic value on the discount rate; one could take the utility curves, which were factual. The real difficulty with a decision tree was in assessing the reliance that could be placed on the probabilities assigned. Was there any means whereby the accuracy of the estimate of the probabilities that were placed on the decision tree could be improved?

Mr A. G. North agreed that the method was an inexact science for the reason that Mr Tawn had mentioned. However, by using it to break down the problem into a series of smaller decisions, a semi-mathematical approach could be an aid to getting the right answer.

Mr D. R. Tucker asked about the effect of interaction. If everybody used the methods Mr North had outlined, there might be a more effective use made of research money, or alternatively, there might well be a lack of development and innovation because everyone was waiting for everybody else to make something to license. Would Mr North comment on the respective merits of these two ideas?

Mr North said that it was a very valid point, particularly when applied to market research. He didn't think that in the research field all firms would use the same numbers and have the same information, and thus there was little danger of everyone coming to the same conclusion. It was very much the case that companies were coming to the conclusion that they could not afford certain types of work, and that most analysis of research projects often killed a project that might otherwise start. There were relatively few occasions where the case looked so attractive that an immediate start was made.

Professor G. D. Parfitt referred to the question of measuring probability. He understood that the value of 0.5 was normally taken as a starting point, and as time passed was adjusted according to the operator's optimism or pessimism. Thus a project had some measure of success probability, but it seemed that once the project was started, one of the biggest problems was to stop it. Once scientists were involved in some absorbing project it might be very difficult to decide when, why, and how to stop. Would Mr North comment on how the probability changed, and how willing were managers to change the probability for a project, even to the extent of stopping the project?

Mr North replied that a flexible approach must obviously be maintained in considering stopping a project, particularly in departments where a decision was made to spend a certain amount of money and then kill the project regardless although it was 90 per cent of the way to completion. The probability could be reassessed at various times through the project; most research people were relatively optimistic, and usually the control would best come from someone who was less directly involved, and who could assign better probabilities to the project than the people with maximum involvement.

Mr J. Boroky asked about the valuation process that Mr North had described. The cash flow discount rate was a purely arbitrary value, and much depended on the manager concerned. For example, if a very pessimistic view was taken with a high discount rate, and short life build taken into consideration, the company would be put into a sort of suspended animation, or taking the opposite view the discount rate could be estimated wrongly, leading the company to bankruptcy.

When considering licensing, in his experience a lot of patents that companies licensed were not really a ready made solution to the problem. Additional efforts had to be made to get the project under way or additional amounts of money paid for know how, so the alternative was not so clear cut.

MR NORTH, dealing with the second point first, said that it was true that one must be prepared to spend money after taking the licence to convert the system to suit the particular market, and in the calculations allowance had been made for this.

The first point boiled down to the availability of money. It was a question of risk. If the cost of the money in the company, which was an average of bank loans and equity and reinvested money, was calculated and came to, say, 12 per cent, then it would be justifiable, if an inexhaustible amount of money was available, to carry out a project which was risk free for a return of 13 per cent. If there was a risk element involved, however, then a significantly greater potential was required. In practical terms, an inexhaustible supply of money was not available and therefore one was very often concerned with ranking several alternative possibilities. Within this context, if a calculation was made of the various possibilities, and these were ranked, then obviously the highest potential project was picked as a start, working through the rankings until all the funds were spent.

Next month's issue

The Honorary Editor has accepted the following papers for publication, and these are expected to appear in the January issue:

"An elastic factor determined from Monk micro-indentation measurements," *by R. Katz*

"Investigation of the water and ion permeation characteristics of certain polymers," *by J. Boxall, J. A. van Fraunhofer and S. C. Werren*

"Wood protection," *by G. L. Holbrow, A. F. Sherwood, D. Dasgupta, D. Gardiner, M. C. Gibson and M J. Haines*

J. Oil Col. Chem. Assoc. 1970, **54**, 1145-1158

Research and development—recruitment, education and training*

By P. Bennett

Chemical and Allied Products Industry Training Board, Staines, Middx.

Summary

The first part of this paper considers the changing pattern of recruitment of technologists to the surface coating industries and hence the need for a different approach to their training. The importance of a systematic approach to initial and further training is stressed. In the second part, the technician is considered. Again, the source of these support staff is changing and companies need to consider carefully their recruitment needs and the appropriate training to make and keep these staff fully effective.

Keywords *Miscellaneous*
training

Recherche et développement—recrutement, éducation et formation

Résumé

Dans la première partie de cet exposé on considère les changements qui se présentent dans le mode de recruter des technologues aux industries de revêtements superficiels, et par conséquent la nécessité d'employer un abord different en ce qui concerne leur formation. On souligne l'importance d'un abord rationnel à la formation préliminaire ou súbsequente. Dans la deuxième partie on considère le technicien. Dans ce cas également, la source de ce personnel secondaire se change et les entreprises doivent considerer soigneusement les besoins de leur programme de recrutement, et la formation nécessaire d'assurer et de maintenir l'efficacité de ce personnel.

Forschung und Entwicklung-Rekrutierung, Erziehung und Training

Zusammenfassung

Im ersten Teil dieses Vortrages wird das sich ändernde Bild der Rekrutierung von Technologen für die Industrien der Beschichtungsstoffen betrachtet, und in diesem Zusammenhang die Notwendigkeit, deren Training anders anzupacken. Die Wichtigkeit sowohl beim anfänglichen Training als auch bei der Weiterausbildung systematisch vorzugehen, wird betont. Im zweiten Teil werden die Techniker berücksichtigt. Auch hinsichtlich der Herkunft dieses Hilfspersonals gehen Änderungen vor sich. Unternehmer sollten ihren Bedarf an neuen Rekruten sorgfältig abwägen, ebenso die geeignetsten Trainingsmethoden, um tüchtiges Personal heranzuziehen, aber auch um sich dieses erhalten zu können.

Исследование и проектирование – набор штата, обучение и тренировка

Резюме

Первая часть статьи рассматривает перемены в системах набора технологов в промышленности поверхностных покрытий и потребность другого подхода к вопросу их тренировки. Подчеркивается важная роль систематического подхода к первоначальной и дальнейшей тренировке. Вторая часть статьи посвящена обсуждению роли техника. Здесь опять-таки источник этого дополнительного штата людей меняется и компании должны осторожно проверить свои требования по комплектованию и надлежащей тренировке, для полной эффективности этого персонала.

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*Presented to the Torquay Conference on 5 May 1971.

Introduction

It is only in recent years that technical advances have changed the approach of the paint and printing industries from craft to technology. In this type of environment the end products of firms, such as that which you the reader represent, have been judged by the craftsmen—the printer or the painter—and it is therefore not surprising that their methods of evaluating the final product were largely used as the acceptable standards. In recent years, however, the need for a more scientific basis has been accepted and technological development has taken place rapidly in the industries.

Technologists

In the past, in industries such as your own, where particular knowledge is involved, technologists have usually served an "apprenticeship" in the technician ranks. This has meant that, slowly and informally over a long period of time, the future technologist has gained a wide knowledge of the materials used in the industry and their particular advantages and disadvantages. He has been able to apply this knowledge later in developing and improving products and also in sorting out the shortcomings of existing ones. The view has been widely held that there is no substitute for this method of learning and that an extended period is necessary before a man can be assumed to be competent.

Unfortunately for this particular viewpoint, the rapid expansion of higher education has meant that there are increased opportunities for full time study, and the number of potential technologists entering directly from school has decreased. Many of the present entrants direct from school are less academically inclined than those of a few years ago, and are therefore less likely to reach the level of Grad.R.I.C. or specialist endorsement to H.N.C. It is therefore necessary to look for an alternative source of future scientists and technologists to work in these industries, and direct recruitment of science graduates has increased. In many cases these new entrants will have no direct knowledge of the particular technologies used in the industries that they are entering. They must, therefore, be given the "experience of years" rapidly so that they can become fully productive as quickly as possible. This is essential not only from the point of view of the company, which will want to make sure that the new graduate becomes effective in the shortest possible time, but also because the graduate, for his own satisfaction, will want to be playing a full part in the organisation as quickly as possible.

CAPITB recommendation

Recognising this need the Chemical and Allied Products Industry Training Board published, in August 1969, *Recommendation No. 2* "Recommendation for the immediate postgraduate training of engineers, scientists and technologists". This interim recommendation is currently being expanded by two working parties within the board. It is anticipated that, in the course of 1971, a modified and extended document with many more examples will be published. In this way the value of the recommendation to our industries should be increased, particularly by the provision of specific examples which can be used to develop, or modify, existing training programmes.

Philosophy

In the recommendation it is stressed that there are important considerations, other than merely giving the new graduate technical knowledge, that must be considered. In particular, in effecting the change from university to industry, the graduate may have to be reorientated on a number of basic issues. In the university he probably worked alone and arranged his own timetable. Certainly, if working at the research level, work was likely to be directed towards personal objectives within the basic discipline in a relatively static organisation, and communication was primarily with those of similar background, intellect and discipline. However, when he takes up an appointment in industry, the graduate will be working in a team towards company objectives within a dynamic situation. The work will involve many people and the graduate must be able to communicate effectively with those of different disciplines, backgrounds and intellect. He must also begin to realise that decisions are not taken solely on the basis of what is of intellectual interest, but on what is possible within the constraints of company or project objectives, time, money and—indeed most of all—the foibles of human beings. Perhaps for the first time, the graduate begins to realise that intellect is not the sole key to all situations. He must understand the complex nature of the industrial scene and that a much greater effort is often needed to develop, manufacture, market and sell a product than that required to discover it in the first place. A sense of urgency is vital in all work irrespective of the fact that it may be long term and fundamental. The graduate must realise that, if his company does not find the answer to a particular problem, then it is likely that one of its competitors will, and that it is not good enough to be second in the field, however good the second product may be.

When the graduate leaves university he is full of enthusiasm and wishes to make an early impact on industry. It is important, therefore, that he should start a course of training immediately he joins the company and not be left doing a routine job for a period of months before his training commences; otherwise he is likely to lose his early enthusiasm and be unreceptive to the training. Any training must result in the graduate's feeling wanted in the organisation; feeling that he is getting to grips rapidly with real problems; and finally that he is making a real contribution to the work of the particular section. Therefore, training in the early stages should be, as far as possible, specific to the needs of a particular job, but with consideration of possible future requirements both for his personal and job development.

Job specification

In the interim recommendation, one suggested approach to the training of new graduates is that this should be divided into three parts; induction, specific training and general training. However, it has been stressed that, before an effective training programme can be written, the particular job or group of similar jobs must be analysed so that the precise requirements of the job can be detailed. From an analysis of the job, a job specification may be written, and for this the following headings are suggested: job title; job objective; organisational relationships; main duties; limits of authority and knowledge, skills and attitudes.

Part of the job specification for a graduate chemist who is working on applied polymer research in a research department is reproduced as Table 1. This covers the main duties and part of the knowledge, skills and attitudes section. The job specification refers to the job that the chemist will be performing when he is fully competent and is not limited to that which he will be undertaking during the training period. The example is written in general terms, but each company will be able to write in detail the specific processes, equipment etc. with which the man will be involved. The writing of a specification ensures that all aspects of the man's job are covered and that these can be then incorporated in a training programme.

Table 1

Job specification for applied research chemist

(*Complete specification in Training Recommendation No. 2*)

Main duties

A. *Prescribed*

1. To work towards specific research objectives allocated to him by his superior.
2. To write the corresponding research programmes detailing the broad lines to be followed.
3. To forecast the time they will take and the resources required.
4. To be familiar with any process, test or procedure carried out in his section in connection with the programmes.
5. To use such techniques as are available (statistical, mathematical, chemical or mechanical) to achieve the research objectives with the minimum expenditure and effort.
6. To assign a selected proportion of the work to his subordinates, to supervise and assess their work and to be responsible for their effective employment.
7. To be responsible for their safety and on-the-job training and to suggest suitable off-the-job training and further education.
8. To motivate his subordinates by example and attitude, by consulting them and keeping them fully informed on relevant aspects of the work.
9. To ensure the accurate recording of all experimental data, conclusions and hypotheses in the appropriate form.
10. To communicate the progress and results of his work, and its significance to his supervisor and to other staff through reports and meetings, as the job objective requires.
11. To assist other staff in the pursuit of their objectives, as necessary.
12. To improve his own knowledge and expertise in appropriate areas of information and technique.
13. To consider the significance of each duty performed, and to allocate priorities between them, in relation to the objective of the job.

B. *Discretionary*

1. To arrange and supervise plant trials.
2. Within his job objective, to develop the product or process as he sees best.
3. To consult with other staff as he wishes.
4. To follow up speculative leads that may emerge and be relevant to the job objective, keeping his superior informed.

Table 1—cont.

Knowledge, skills and attitudes

(Degree of attainment: A = Appreciation; P = Practitioner; E = Expert)

Knowledge	Skill	Attitude
A. *To appreciate a problem and select lines for research*		
1. Company and departmental objectives (E)	1. To define problems (E)	A critical, enquiring and inventive frame of mind
2. Knowledge equivalent to a science degree (P)	2-3. To postulate possible routes to a solution (E)	
3. Relevant technology		
B. *To organise the work*		
1. Raw materials (E)	1-3. Process equipment operating and laboratory techniques needed for the work (P)	A determination to be professionally competent
2. Processes (E)		
3. Products (E)		
4. Hazards and safety regulations (E)	4. To handle any chemical or equipment safely (E)	
5. State of relevant present knowledge in science and technology (E)	5. To use all sources of information (libraries, filing systems, etc) (P)	
6. Patent position (A)		
7. Methods of planning research (P)	7 a. Problem analysis (E)	A systematic purposeful approach to work
	b. Critical examination technique (P)	
	c. Critical path scheduling (P)	
8. Mathematical, statistical, chemical and physical techniques available (A)	8. Use of relevant techniques including calculating machines and computers (A/P)	
9. Cost of materials, equipment and services (A)		Cost consciousness
10. Requisitioning procedures (A)		

Training programme

As mentioned earlier, it is considered that a training programme should comprise three parts: induction, specific job training and general training.

Induction training: this is divided into two parts, the first covering the information the new arrival needs immediately on entering the company, and the second part giving a general introduction to all aspects of the company and the environment in which it operates. The latter information should ideally be given within one or two months of the new graduate's joining, as by then he will have sufficient background to appreciate and comment on the information he is being given. It is interesting to note as one moves around our industries that there is tremendous variation in the quality of induction of an individual into a company. I am sure that you will agree that proper induction will ensure that the graduate settles into the company rapidly and is in the right frame of mind to assimilate the other parts of training.

Specific job training: is intended to give the trainee the necessary "on-the-job" training to understand all matters and aspects of the job he is undertaking and is essentially a form of planned experience. The trainee should be given a definite job during the training period and be expected to take responsibility—albeit limited—wherever possible. For example, it should be possible at a relatively early stage for a printing ink technologist to have direct contact with a customer and be responsible for solving a minor problem for him.

General training: there are certain areas of knowledge and skills which the graduate will need as he develops either as a specialist or potential manager in the technical or other fields. The various subjects should be covered at appropriate stages in the graduate's development and some suggested topics are: human relations, communication skills, accountancy, mathematical and statistical techniques, etc.

As in all situations, it is very important that the environment in which the training is given is right and that all those who in any way help to develop the trainee know in detail the purpose of their particular involvement with the training programme. If in the course of his training the graduate gains experience in a variety of locations, in addition to tutors for each part of the training, an overall tutor should be appointed. The graduate will look to him for help and advice at any stage of the training and the tutor will review the graduate's progress at appropriate stages. It is vital in this context that the training should have stated objectives and that those involved in giving the training understand these objectives and are fully convinced of their purpose.

Post-experience education and training

So far we have considered the training that a graduate receives in his first few years in a company, but we must also consider the graduate's total career in a company or companies. Thought should be given, therefore, at various stages in his career to his technical training needs, both in terms of general training and of up-dating specific training in his particular expertise, and also to his training needs if he is developing as a manager either in his own department or is moving into another area of company activity.

At the present time, the main source of external technical up-dating for the technologist is by attendance at conferences and seminars. One of the problems with this approach is that many people cast doubts upon its effectiveness. For example, the comment is made "I attended a conference but I gained more from the conversation around the bar than from the formal sessions". As technical knowledge is increasing exponentially, people will require more frequent up-dating in all aspects of their expertise.

Currently, the Chemical and Allied Products Industry Training Board is conducting a survey into the career patterns of graduates in our industries and is also attempting to determine their training needs. This investigation is only just beginning, but it is hoped that, through it, it may eventually be possible to arrange for courses covering most technical needs to be put on periodically, so that individuals' training needs may be satisfied.

Appraisal

In order to determine a particular individual's training needs, it is necessary for a company to arrange for a regular appraisal of its employees. Many books have been written on the subject of appraisal and its benefits, and the board has put forward its views in *Training Recommendation No. 1*, where one of the appendices soon to be published covers the appraisal interview. Not only will the firm gain benefit from appraisal in that it can set specific targets with its employees and hence monitor progress, but in doing so can also highlight the needs of the individual for specific and generalised training. It should be possible, therefore, to keep employees at peak performance continually through their careers. It is now becoming apparent that, in many industries, individuals are spending longer in a technical function and not moving off to other areas where a lesser degree of technical knowledge and ability is required. Therefore it is essential that everyone is kept technically up to date, as otherwise not only the individual but also the company will suffer.

Management training

Management training has been mentioned as a training need, and it is vitally important for any company to consider the management training needs of each individual as he progresses in the company. Again, a regular appraisal could also show up these needs and the appropriate training can then be arranged. Just because a man has been extremely good at his technology, there is no surety that he will succeed as a manager. He needs to be given the appropriate "tools" with which to do the job, and failure in the appointment without this help reflects as much on the company as on the individual. Again, although many management courses are available, only a very few of these are slanted to the research and development function, and it is possible that these may need further modification for specific industries.

Technicians

So far only the graduate/technologist level has been considered, and I would like now to move to the technician. Before considering the technician in detail, however, we should define the individuals being considered in this context.

Definition

The definition used in the "Report of the 1965 triennial manpower survey of engineers, scientists and technical supporting staff" describes technicians and other technical supporting staff as: "occupying a position between that of the qualified scientist, engineer, or technologist on the one hand, and the skilled foreman or craftsman or operative on the other. Their education and specialised skills enable them to exercise technical judgement. By this is meant an understanding, by reference to general principles, of the reasons for and the purpose of their work, rather than a reliance solely on established practices or accumulated skills." The survey also considers educational requirements and says that they "will possess qualifications such as the Higher or Ordinary National Diploma or Certificate, or the City and Guilds and similar nationally recognised awards. Some may possess a degree in science, engineering or technology. If a person does not possess a formal qualification this does not mean he is not a technician. In identifying technicians and other technical supporting staff it is essential to consider the job being done rather than the qualifications held." In describing the range of functions of the technicians, it included:

The detailed design and development, or the manufacture, erection or commissioning of equipment and structures; drawing, estimating, inspecting and testing equipment; use of measuring instruments; operating, maintaining and repairing machinery, plant and services and locating defects therein; process control; activities connected with research and development, testing of materials and components; technical advice to customers; servicing equipment; data processing; work study.

Assisting qualified scientists in such activities as physical measurements, collection and evaluation of experimental observations; the devising and setting up of experimental apparatus; the preparation of chemicals or similar preparations in other fields, photographic work; the taking and routine testing of product samples, chemical analysis, etc.

These definitions should make it clear that a very wide range of people is included under this title and it is not a limited group at the bottom of the ability range. It is not important in this context to "label" people in a particular way, and indeed many will not have "technician" in their title, but it is essential for everyone to be considering the same groups of individuals. There are also a number of people who are called technologists who will fall within this wide technician definition. We are therefore considering people who occupy a range of jobs which at one end are very similar to those of the graduate/technologist, although possibly more limited in scope, and at the other are very similar in demands upon him to those performed by an operator, where the technician is doing a job very much by rote.

Job specification

As we are dealing with such a wide range of jobs, it is important to know how each differs and to establish common elements, as otherwise appropriate education and training cannot be provided. An analysis of each discrete job should be carried out, and from this a job specification written. As for the technologist level, this will cover the duties of the technician and also the knowledge and skills required. Indeed, because of the need for a particular attitude towards the tasks, for example care and accuracy, it may be worthwhile to include these in the job specification so that appropriate training can be given. Reference should be made to the example given for the technologist for the general format.

Further education

Ideally, further education and training should be considered together, and it is therefore difficult to decide which should be considered first, but because the practice of encouraging youngsters to attend further education courses has been more usual than in-company training, this topic will now be discussed.

At the present time there are several types of courses on which the technician can embark. The two main routes are either the Ordinary and Higher National Certificate or Diploma Courses, possibly leading ultimately to membership of a professional body, or through the technician courses of the City and Guilds of London Institute. There is currently some indication that the number of youngsters entering the industries who will reach the academic level of the Higher National Certificate is decreasing. This is probably due to the increased opportunities for full time education with subsequent later entry into industry. It is probable, therefore, that a greater proportion of future new entrants will follow the technician courses of the City and Guilds of London Institute. These courses have been established in the paint and allied industries for a number of years with periodic modification in which many people have been involved, and there is therefore no need to discuss them in detail. However, one or two general observations can be made. The paint and printing ink industries have adopted a different approach to these technician courses, with the former having a specific course (C and G 357) for its industry, as a development from Ordinary National Certificate, and the latter having a range of courses which educate the man specifically from the time he joins the organisation. There are arguments in favour of each approach, the former giving an initial general education which can be of particular benefit for the technician's future development. On the other hand, with the latter approach the trainee can immediately see the relevance of what he is doing on his course to his work in the company. These two approaches need careful thought for the future.

Future developments: Most of you will have heard of the "Hazelgrave Report" on technician education, in which a restructuring of the main further education routes was suggested. More information should soon be available as to whether his committee's suggestions will be accepted and, if so, whether partially or completely. Certainly the idea of a common core with specialist options—particularly at the higher technician certificate level—has special attractions for technical areas which only attract sufficient numbers to run a very limited number of courses. Your industries are a case in point, as there are a relatively limited number of students and the question should certainly be posed as to whether there is sufficient commonality between the needs of the paint and printing ink industries to put on a common course with specialist options.

It is important that, whether the Hazelgrave proposals are accepted or not, some attempt is made to rationalise courses for the smaller industries so that they are more widely available.

Follow-up: With the range of courses available, any youngster embarking on a further education course should be given sound advice to ensure that the course is appropriate to his ability, and that he is likely to complete it successfully. Again the company should be seen to be interested in his progress, not only because it is giving full salary for 80 per cent work, but so that the youngster knows that gaining a qualification is worthwhile to his future. A simple but vital point. This is one of the facets of the role of the "apprentice master", but do firms always have someone with this responsibility who has the interest and enthusiasm to carry it through?

Training

Moving now to the training of the technician, we have already said that the job or group of jobs should be analysed and a job specification written. This will enable a detailed training programme to be prepared. It may now be useful to mention the current work in the CAPITB related to the technician areas.

CAPITB work

There is within the board at the present time a laboratory technicians' working party, which is examining the training of laboratory technicians. Its own work has been concerned with the training of chemical laboratory technicians and it has set up several study groups which will consider the relevance of the recommended training to particular specialist industries or groups. One of these study groups is considering the initial training needed by the technician in the surface coatings industries.

We expect their recommendations to be published to the industries towards the end of 1971, but unfortunately not in time for the Torquay Conference. However, the working party sees training developing for the chemical laboratory technician in the following manner. It considers that, after an initial general induction to the company, the trainee should have a generalised laboratory course lasting for approximately three months. This will introduce him, at an appreciation level, to all the techniques generally met in a laboratory. After that he will receive training in one or more specific laboratories depending on the range of knowledge and the degree of flexibility required by the company.

As mentioned above, the role of the study groups is to decide the appropriateness of the generalised laboratory course of training to their particular industries, and also to prepare specific modules of training to follow on from the basic course. Following the usual practice, the study groups comprise people knowledgeable of each industry and its needs both from the industrial and educational viewpoint.

Following on from this work in training, the study groups will make suggestions for the further education which should be associated with the in-company training. If the emphasis on in-company training (or similar training at college) is increased, there may be less need for the present emphasis on practical training in the technician courses. It is also important to see how far the in-company development and the further education course can proceed at rates to complement each other at the right time.

Entrants

A few companies have thought through their training needs and have produced good schemes, but unfortunately this is not the general rule. Even where training schemes operate, they may need reconsideration in the light of the changing pattern of recruitment. It was mentioned earlier that the traditional entrant to the laboratories with a range of GCE 'O' levels and one or more GCE 'A' levels is less in evidence and we are likely in the future to have three types of entrant to the laboratories. Indeed this is already the case in some areas and the three groups can be classified as: (a) a group recruited from school from a much broader range of abilities than in the past; (b) entrants who have completed a course of higher education; and (c) those who enter the industry after one or more other jobs.

Where there are three groups of very different backgrounds and abilities, people from different groups cannot be expected to learn at precisely the same rate. Group (b) would be expected to grasp points more rapidly than group (a) and possibly group (c). It will be necessary to consider carefully how far these need a common approach to their initial training, and indeed how far this is desirable. Unfortunately, at this point in time the study group have not crystallised their views and I do not wish to prejudge their findings. However, there are certain general points that can be made.

It is not always possible to recruit the most appropriate people for the industry because of competition from other companies etc. However, it should be possible, by aptitude and other tests, to select individuals who are capable of learning the technical skills in the industries rapidly. If this can be done it should help to guarantee that initial training is carried out in the shortest possible time, bearing in mind the man's future development. Again, it should be stressed that the job specification(s) will provide the basis for the development of the training programme.

Type of programme

All new entrants will require a basic introduction to the industry and to acquire certain skills and the appropriate related knowledge. Depending on circumstances, much of the related knowledge may appear in the further education course, but care should be taken to ensure that any omissions are covered in-company. The range of further training (modules) given will depend on the individual, his age, and potential. For example, if a new employee is recruited at the age of 30, he is likely to be earmarked for a specific job, and will therefore be given the training as shown to be necessary from the job specification. This is not implying that in due course he should not be given additional training when moved to another job.

In the case of the youngsters entering from school, they should, wherever possible, be given a range of experience to fit them for a large number of possible jobs in the company. This approach is equally important in the case of the entrant direct from higher education, who is likely to progress in the company.

Further development

As for the technologists, education and training is not completed when the technician has covered his initial training. Therefore, a regular appraisal of the technician and his needs is important. From this, appropriate further education and training can be arranged.

Conclusion

In this paper an overall view has been given of the education and training of staff in research and development. This is intended to show that it is important to ensure not only that the new entrant is given the appropriate initial education and training, but also that other needs that develop during a man's career are adequately covered. In this way a company will maintain the effectiveness of its staff throughout their careers and hence increase their value to the company.

[*Received 6 January 1971*

Discussion at the Torquay Conference

MR J. A. L. HAWKEY said that one of the greatest strengths of the printing ink industry was the training scheme initiated by the Technical Education Committee of OCCA and the Technical Training Board for the printing ink industry. This scheme had given a fresh start, and he had been privileged to be the first chief training master for the industry under the scheme. The strength of the idea was in the appointment of a training master in each company; this was not necessarily a technical man, but someone who would take a paternal interest in the educational progress of new recruits. This system led to the establishment of a general and satisfactory pattern of syllabus, examination and, particularly, internal training. However, to some extent, the weakness of the printing ink industry's training had arisen from this.

Printing ink was somewhat of a unique industry, being involved in the publication, packaging and chemical industries simultaneously. Particular, very specific, approaches to problems were found, and this had led the industry to be too specific in its attitude to training. Printing ink had been subdivided many times into different classifications, and over-specialisation had resulted. The printing ink industry was not very different from the paint industry; the speed at which unit volume of the products was applied over unit area was quite different, but otherwise the technologies were similar. However, such was the degree of specialisation of training in ink that it was very difficult for a technical worker to transfer to the paint industry. The training did not produce technologists with all-round knowledge and experience, and this, he felt, was its greatest weakness.

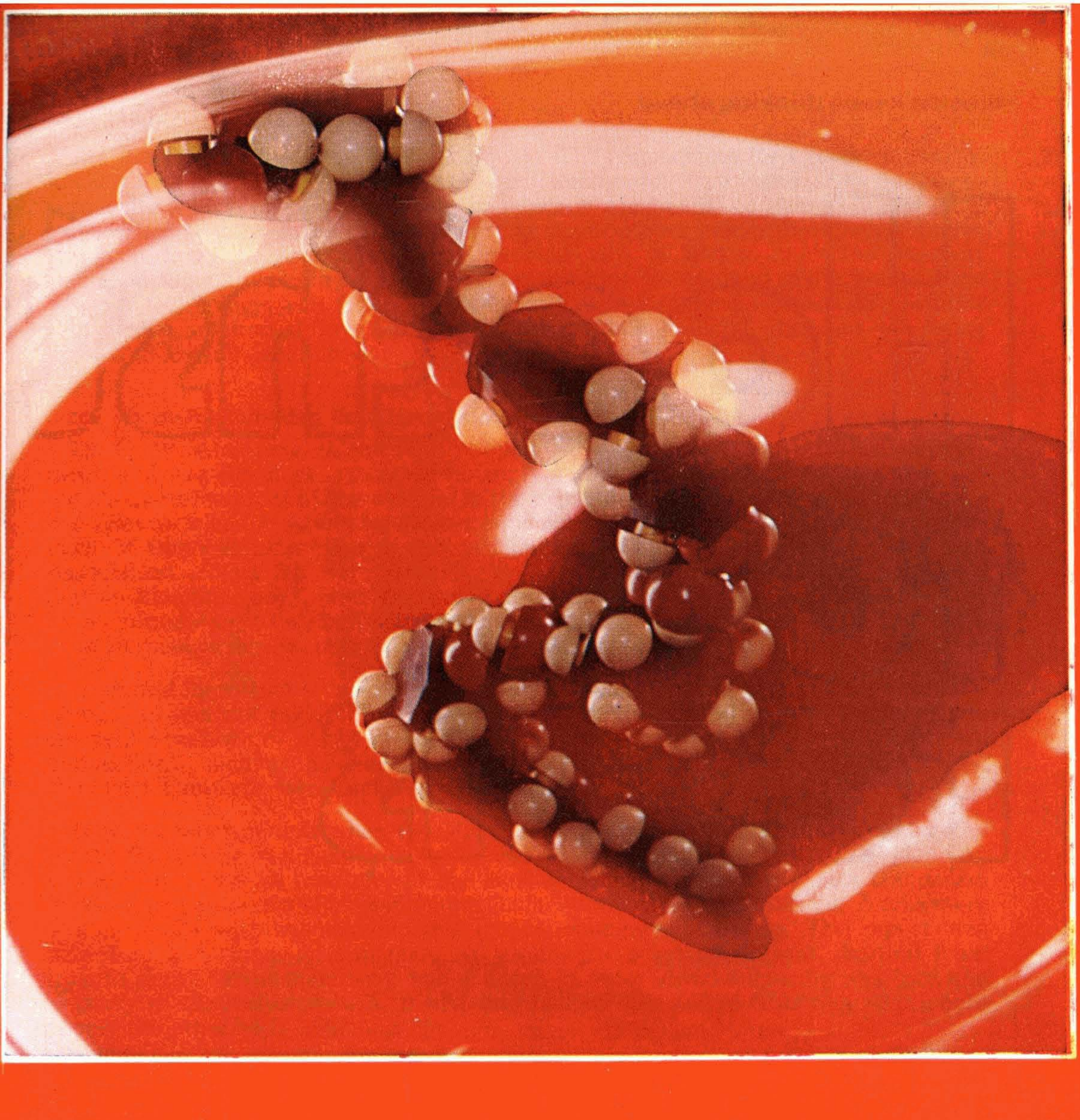
MR P. BENNETT agreed. This problem occurred in several industries, in particular the pharmaceutical industry, where there was subdivision into a large number of specialist fields.

DR G. W. ANDERSON (Chairman) remarked that one area of training that was grossly neglected by companies was that of making science and technology pay. This was surely best done by the employer, who alone could show the new entrant the company's criteria for selecting and progressing research projects, both in initiation of projects and during their progress to the shut-down point.

DR R. BULT said that one of the weaknesses of the paint industry on the continent was the way in which new graduates were received into the industry. In many cases, promising graduates left their company, and the industry, after a short period because no attempts were made to train them. A lot of valuable staff had been lost owing to this lack of training, and he felt that it was important that the situation was improved.

MR BENNETT agreed that this was a valuable point. The same situation occurred in the UK, in many industries. New graduates were recruited without sufficient thought as to how they would be trained, and for what they would be trained. Many of the larger companies had been accused of employing many of their graduates as technicians—this was one area in which the present financial climate could be said to be beneficial, since firms were examining how to use their skilled staff to the best possible advantage. He hoped that this situation would be maintained as the climate improved to a position of expansion. A graduate should be trained as a thinker, not only a doer, an "ideas man" capable of project development.

DR M. ELLINGER asked if, perhaps, too much of the blame for the lack of integration of the graduate was being placed on the employer. Often new graduates were academic in outlook, and tended to regard more practical problems as of less importance. The person involved had to have the ability and desire to adapt to industrial problems, to combine science and technology, and to achieve the high level of skill that would only be reached through experience.



Mr Bennett said that this was a fair point. The specification for a research chemist in the paper had included some of the items mentioned. This man had to be able to appreciate a problem and select lines of research. He had to be able to organise the work effectively, to make decisions and to develop and train subordinates. In the appreciation of the problems he was involved with, he had to know the company and departmental objectives, had to have a scientific background and a grasp of the relevant technology, and from there the skill to define the problem and postulate routes to a solution. When all these conditions were fulfilled, the man was being utilised to his full capabilities.

Open discussion following the Management Session at the Torquay Conference

Dr G. W. Anderson (Chairman) pointed out that the discussion was on management, and was therefore concerned not only with individual inventors, but also that the maximum number of the workers in the department were stimulated to have good and relevant ideas. It would be of interest if delegates could explain how the achievement of this was attempted in their various organisations. At the Paint Research Association it was felt, very strongly, that a clear target was very important, and that an industrial need, clearly outlined and including its potential value, was every bit as stimulating to a good scientist or technologist as something like a new piece of equipment, a new theory, or a new intermediate.

A second important stimulant lay in highlights of other peoples' science and technology. It was not possible to read as widely as had been the case, owing to the enormous number of publications that were now available. The "popular" science publications, such as Science Journal, New Scientist, the technical page of the Financial Times etc. were useful for this purpose.

It was important that when the idea came, action was taken before it got away. At the Paint Research Association, this was achieved by having a "forward planning group," in which all members of the staff took part. Whenever a new compound or piece of equipment that seemed particularly interesting was noticed, details were written down with the reason why it was thought interesting. The report was passed to a member of the planning group (an office which was changed from time to time). When there were half a dozen of these ideas, a meeting was held and in many of these sessions a man who had half an idea found a partner who would supply the other half.

Another stimulant was the occurrence of "hot spots". If something exciting happened in one lab, the members of another would wonder just how long it was since something like that happened in their lab, and how long it will be before it would happen again.

Had any other delegate any comments on the best methods of stimulating invention?

Mr J. A. L. Hawkey said that even in an average industrial lab there were usually a number of departments which tended to become a little segregated. Occasionally somebody, possibly a junior, went into another department and asked a "stupid" question about the work. This often meant that the workers were, for the first time, forced to think about what they were doing. The person who asked the "stupid" question went back to his own lab and said "do you know what I have just thought of?", and although it seemed to be something quite remote from what he had just seen, it was really the germ of a new idea. This situation occurred even in very small industrial organisations and it boiled down to difficulty in communications. This problem was always highlighted when people sheltered behind their own specialisation. It was often very difficult to get something out of the lab next door.

DR R. BULT remarked that the discussion had been mainly concerned with single projects. One often had the choice between a number of research possibilities and one had to evaluate which of the projects was to be tackled. Did anyone have experience with methods of evaluation of these sort of things?

MR E. L. FRENCH, pointing out that his company was concerned with building, said that he was part of a team of about thirty people working on internal development. It was a multi-disciplinary team composed of chemists, engineers and physicists. Most of the ideas which were investigated were concerned with innovation, and many were obtained by examining other industries, looking at newer developments and deciding if it was possible to cross-fertilise. For example, one interest was in polymer cements, where again mixed disciplines were involved and collaboration with polymer firms had been instigated. As a result, the possibility of producing a composite with interesting properties had been seen almost ten years ago.

One worrying factor was that, although an idea could evolve, certain people, by reason of their technical training, required a technical justification as to why the research project should be carried out, and also had to know the commercial viability. Unless a great deal of care was taken, the consideration of these factors could delay the project by up to two years. So a scheme was used, by which, if any of the staff had an idea, after a brief discussion they were allowed to carry out a preliminary investigation in the lab. A short report followed and if it showed that there was a grain of utility, then a proper research programme was worked out.

DR J. E. O. MAYNE said that he would like to make a few comments, as he had a foot both in the academic and industrial worlds. In the academic world, any ideas were immediately discussed, since time was not at a premium. But in industry the situation was quite different. He often felt that if only there were no customers, then he could get on and do some research. One of the pleas he would make was that people working in industry in the productive positions from which new ideas or processes might come, must be given time in which they could exercise and extend their minds, otherwise a whole series of valuable ideas would never come to fruition.

DR ANDERSON thought project appraisal possible by breaking down to relatively simple questions of size of research group, time needed for the work, possibility of patent cover, etc., on the technical side, and size of market, profitability, capital investment required, size of stock required, etc., on the commercial side. Competent managers could give immediate "guestimates" of these, giving a picture of size of research investment and possible commercial benefit.

These guestimates were accurate enough to compare one project with alternatives and were often surprisingly accurate.

MR W. V. MOORE said that the problem in his organisation was that of the inability of the researchers to communicate their ideas or their results clearly and concisely to other people. Was this unusual, or was it a general problem, and was it possible to remedy it by training?

MR P. BENNETT replied that it was a fairly general problem, but it was possible to remedy it. Training improved the ability of researchers to communicate with the planners etc., and the universities were at last beginning to realise it. Unfortunately, there was still a difficulty with graduates, who had had every help in learning, but little experience in communicating ideas once in the commercial environment. The best approach was to run courses designed to highlight report writing and communication problems, and show how to overcome them.

DR H. R. HAMBURG said that he thought that this problem was caused by too-early specialisation in the educational system. Graduates were produced who could not communicate their ideas adequately because of a lack of broadness in their education.

Reviews

FLUORESCENCE ANALYSIS

BY C. E. WHITE AND R. J. ARGAUER. New York: Marcel Dekker Inc. 1970, pp. x + 389. Price £8.90

Fluorescence analysis generally involves irradiating a material with ultraviolet radiation and measuring the emitted fluorescence with a fluorometer or spectrofluorometer. Many metals form highly fluorescent chelates with organic complexing agents, as a result of which they may be determined by fluorescence analysis. Reagents producing fluorescence are generally more specific and sensitive than colorimetric reagents and can be used for confirmatory tests in qualitative analytical schemes. Fluorescent indicators have many applications, for example where fluorescence changes in the presence of oxidising agents, metal ions or with pH. There are many uses of fluorometry in connection with chromatographic procedures. Applications of all these types are described in this book and there are also sections dealing specifically with agricultural and pharmaceutical materials. The special subjects of X-ray fluorescence or atomic fluorescence analysis are only briefly noted.

This is a sound text book on a fairly new form of analysis, on which little information has been previously available in book form. Full working details are given for many of the methods and all original references. It will be of value to any analyst interested in increasing his range of procedures.

L.A.O'NEILL

MACROMOLECULAR SYNTHESES, VOL. III

BY N. G. GAYLORD (Editor) New York: John Wiley & Sons Inc. 1969, pp. x + 170. Price: £5.60

This series was introduced in 1963 with the sub-title "A periodic publication of methods for the preparation of macromolecules." The methods were intended to be "checked in a rigorous way following the successful pattern of *Organic Syntheses*, so that they might be easily repeated by a student or a research worker." This was, and still is, an admirable objective: it remains to ascertain whether or not that objective has been achieved.

The presentation of *Organic Syntheses* has always assumed a high level of competence in "organic preps" on the part of those seeking to carry out its directions. Given this, the methods published may be said uniformly to give the promised result. Yields, degrees of purity, melting points, precautions, etc., have rarely been found incorrect or inappropriate, and, for this reason, the publication has achieved a high reputation among organic chemists. Can "*Macromolecular Syntheses*" measure up to this standard?

First, we must ask if those seeking to synthesise macromolecules need this degree of reproducibility, for, if competent polymer scientists, they will know that distribution of molecular weights and species can vary as a result of minute differences in purity of raw materials or in preparative technique; and they will usually know how to correct for such variations as they discover. The case for a rigidly standard synthetic method must rest on the need for workers in respectively isolated laboratories to produce safely, *exactly* the same polymer for the purpose of comparing or checking properties or performance. Many may feel that this is an unattainable goal in the present state of the art. Thus, secondly, we must consider the case for the synthesis of materials of *substantially* the same nature which differ in minor but measurable characteristics. This allows, perhaps, a somewhat lower degree of reproducibility in synthesis, but necessitates a correspondingly greater attention to the characterisation of the product.

Unless "*Macromolecular Syntheses*" can satisfy one or other of these criteria, it must fail and be reduced to the status of a cookery book, but little above the level of the directions found in the patent literature, so rightly criticised in the Preface to Volume I.

It must be said that, without comprehensive basic training in polymer laboratory techniques, such as might be derived from Sorenson and Campbell's excellent "Preparative Methods in Polymer Chemistry" (Interscience), many graduate and most undergraduate students will have difficulty in performing these syntheses without, at least minor, mishap. Essential precautions are often relegated to the "Notes" which follow the preparative instructions and, unhappily, even there they do not receive uniform treatment. Thus, whilst the dibutyl zinc-catalysed polymerisation of ε-caprolactam is clearly stated to require the use of sodium-dried toluene, the polymerisation of ethylene oxide by the same initiator merely requires the toluene used as solvent to be "dry" (how dry?). In the same vein, one is told to dry tetrahydrofuran with the sodium naphthalene complex before use in the anionic polymerisation of acrolein, but one is expected to know how to make the complex and how to use it. Flaming out the apparatus is apparently a necessary precaution before trying to polymerise thietane with boron trifluoride, yet the notoriously inefficient desiccant calcium chloride is recommended as a protection against the ingress of atmospheric moisture. This reviewer would hesitate to let loose his students with carbon oxysulphide (used in the preparation of poly-(nonamethylene urea)) with a mere admonition to the effect that it is a "somewhat hazardous gas."

Descriptions of polymers are sometimes far less than adequate, and nowhere is this more evident than in the title "Oil modified alkyd resin" which heads an account of the synthesis of an alcoholysis-processed, safflower-oil-modified, glycerol-pentaerythritol-diethyleneglycol phthalate. As one of a family of thousands of "oil modified alkyd resins" it must surely be more clearly defined, and the reader be not left to work out for himself its oil-length, phthalic content, hydroxyl excess, etc.

Finally, whilst some of the syntheses are associated with notes on the characterisation of the product, many are not, and there seems to be no correlation between difficulty of synthesis and need for characterisation. A most useful note on the preparation of amorphous polyacetaldehyde deals with the merits of the particular technique recommended. Such would appear more valuable as a general feature than the ubiquitous addenda mentioning alternative methods

of synthesis, which slavishly follow the pattern of "Organic Syntheses," and which, whilst justified in that publication, are of lesser consequence in this.

Thus, with regret for ourselves and our fellow-workers, and with sympathy for the Editor, we opine that the publication still falls short of the standards which we think should be set. In fairness, it must be said that the Editor seems to be aware of this, is appealing for help from the polymer scientists of the world, and is determined to achieve his goal. More power to his elbow; he has embraced a daring philosophy which deserves to succeed. Perhaps the length of this review will indicate our appreciation of his aims and our concern for his success.

A. R. H. TAWN

The efficient use of titanium dioxide pigments in organic coatings*

By J. G. Hoogerbeets

NV Titaandioxydefabriek Tiofine, Louis Couperusplein 19, PO Box 190, The Hague, Holland

Introduction

In considering the efficient use of titanium dioxide pigments in organic coatings, attention should be paid to brightness, hiding power and tinting strength and to the ways in which these properties can best be developed. Basically manufacturers of titanium dioxide pigments are selling hiding power and tinting strength.

It is a well-established and universally recognised fact that an opaque white pigment does not have a fixed hiding power and that this is a characteristic of the overall total formulation, which contains the pigment as a light-scattering or light-reflecting material.

Hiding power is related to the type, the amount and the distribution of the opaque pigment within the body of the film applied to a surface. It also depends on the distribution of the wavelength in the light striking the surface and which is subject to observation or measurement. The light source and viewing conditions are most important and will affect the apparent degree of hiding power.

Standardisation of the method of assessment or measurement is essential if consistent and reproducible results are to be obtained in either visual rating or instrumental measurement.

A study of the optical and physical attributes of titanium dioxide pigments in relation to their hiding and tinting properties, shows that the very high opacity contributed by titanium dioxide pigments is a result of the high refractive index of these pigments in relation to that of the vehicle.

According to Fresnel's law, the reflectance R of a pigment dispersion can be expressed in terms of the relevant refractive indices by the equation:

$$R = \frac{I}{I_o} = \left[\frac{\mu_p - \mu_v}{\mu_p + \mu_v}\right]^2$$

where μ_p is the refractive index of the pigment and μ_v is the refractive index of the vehicle.

Thus, the higher index of refraction of rutile pigments, in comparison with those of anatase or any other white pigments, indicates that they have the potential to provide a greater hiding power.

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*Based on a lecture presented to the Irish Section on 17 September 1971.

The reflectance, *R*, expressed as a percentage gives the proportion of the incident light that is reflected, and is dimensionless. It relates to the reflection of one single pigment particle. When considering the reflectance of a pigmented formulation or paint film containing many pigment particles, this *R* value should be integrated over the whole field, taking into account other factors, such as: the particle size and its distribution, the pigment volume concentration, the thickness of the film, and the extent to which the particles are wetted by the binder.

The tinting strength is closely related to hiding power, but not directly so mathematically.

In dealing with white pigments of very similar colour characteristics and chemical type, it has generally been assumed that the tinting strength would provide a reasonably reliable indication of potential hiding power.

The relative tinting strength of a pigment is easily determined experimentally. If properly measured and correctly interpreted, it can provide useful information regarding the opacity characteristics of a pigment.

Attempts have been made to relate the hiding power to the tinting strength. Such relationships are only approximations and depend, of course, on the selection and assigned value of the reference standard.

The tinting strength and hiding power of pure white coatings depend on many of the same factors, so that there is quite a close relationship between them, as will be shown later.

Optical aspects

It has been shown that the reflecting properties of a pigment particle depend on the difference between the refractive indices of that particle and of the vehicle surrounding it. The refractive index of a substance is dependent on the wavelength of the light with which the index is determined. Therefore the reflective properties of a pigment are different for each wavelength. The refractive index of titanium dioxide has a fixed value at each wavelength and cannot be changed.

Light is an electromagnetic wave. For visible light, the length of the wave may vary from 0.4—0.8 microns, which embraces the whole range of colour. At a wavelength of 0.4 microns, light has a violet colour, and as the wavelength increases, the colour gradually changes from violet to blue-green-yellow-orange-red, without a sharp line of demarcation.

When such a wave reaches the interface between the particle and the vehicle, because of the different refractive indices of these two substances, the light is scattered and reflected.

It would be deduced that the surface area of the pigment, for any given volume, should be as large as possible; consequently, the pigment particles should be as small as possible.

Fig. 1 illustrates diagramatically what happens when an electromagnetic wave of light strikes a small pigment particle. The largest particle will reflect the light when the wave enters and leaves it but the smallest particle will not intercept the wave; obviously it is too small to be optically effective.

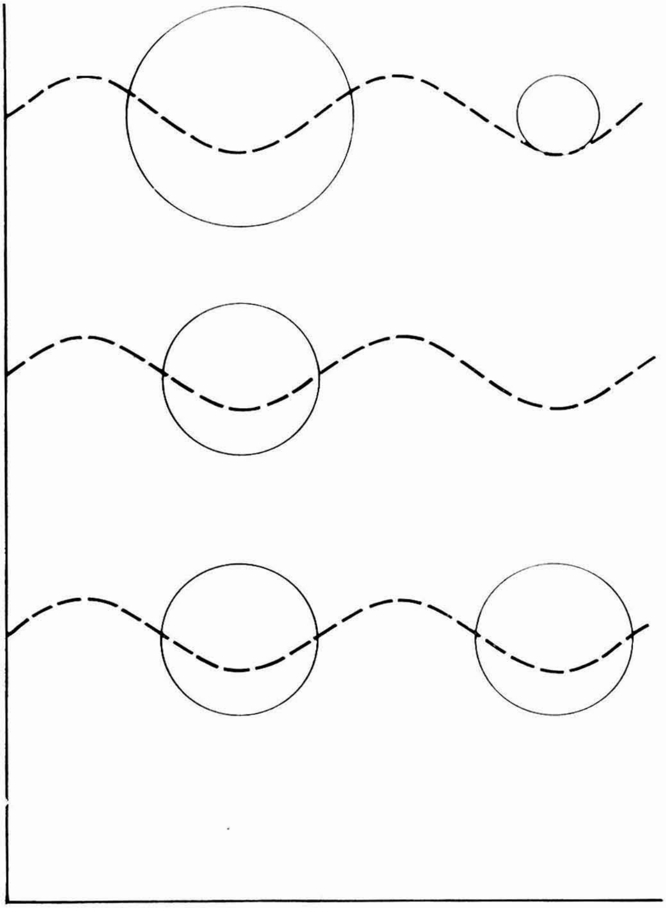


Fig. 1. Diagrammatic representation of light falling on pigment particles

The two intermediate size particles have diameters equal to half the wavelength. The reflections at each surface will be in phase and reinforce each other.

Evidently, a particle size of half the wavelength of the incident light will be the most effective.

The reflections from the two particles will be in phase and will reinforce each other when the distance between the particles is also equal to half the wavelength of the incident light.

As the human eye is most sensitive to yellow light, which has a wavelength of about 0.5 microns, the optimum particle size for a white pigment will be 0.25 microns. This also means that the particle will be less effective at other wavelengths.

Red light, which has a long wavelength, will pass the particle and penetrate deeper into a paint film.

Blue light, which has a short wavelength, will be reflected, but less effectively so than yellow light.

Fig. 1 also shows that the reflection is at an optimum when the distance between the particles is half the wavelength of the incident light. Consequently, the efficiency of the pigment depends on its spacing in the coating, on the pigment volume concentration and on the degree of dispersion. When the particles, which are here assumed to be spheres, have a diameter of 0.25 microns and the distance between the particles is also 0.25 microns, it can be calculated that the optimum pigment volume concentration should be 12.7 per cent.

An increase in the pigment volume concentration beyond this point does, in fact, cause an increase both in the tinting strength and hiding power. It is only up to a PVC of approximately 12 per cent, however, that the relation is a linear one. The value of 12 per cent deviates from the value of 12.7 per cent calculated, because the particles are not actually spherical and dispersion is never ideal.

At higher PVC levels, the particles are too close to each other, and the pigment efficiency will decrease. The practical relation between the hiding power and pigment volume concentration is shown in Fig. 2.

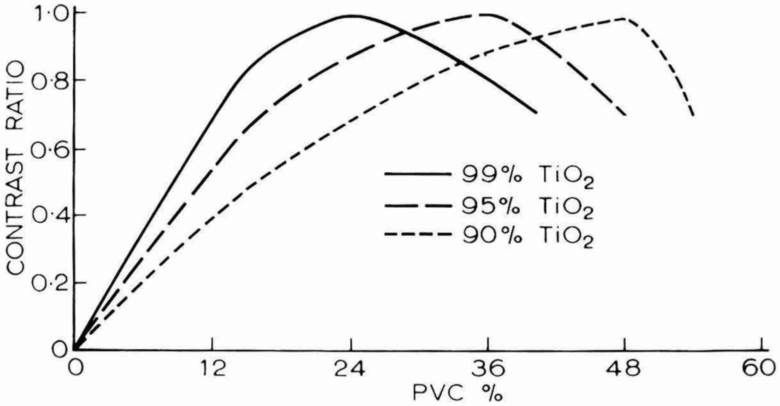


Fig. 2. Relation between contrast ratio and PVC

The curves for the three TiO_2 pigments show linear increases in opacity as the pigment volume concentration is increased, up to approximately 12 per cent.

The opacity obtained over the range of PVC levels of 0 to 12 per cent depends on the titanium dioxide content of the pigment (i.e. on different coating levels); the more titanium dioxide present, the greater the opacity obtained.

At PVC levels higher than 12 per cent, the curves start to level off to a maximum, because the particles become too close together. After reaching a maximum value, the opacity decreases again, owing to flocculation of the pigment.

The more resistant the pigment is to flocculation, the higher the PVC level at which the maximum opacity is achieved. Generally, the resistance of a pigment to flocculation improves with the quality or the heaviness of its coating. Therefore, in some types of paint, the maximum may be obtained at a higher PVC level when the titanium dioxide content of the pigment decreases.

It follows from the data presented in Fig. 2 that:

a titanium dioxide pigment is only used to its full advantage at PVC levels lower than 12 per cent;

at PVC levels higher than that at which the maximum opacity is obtained, extender pigments should be used because there is no advantage in adding further titanium dioxide pigment;

and the higher the level of PVC to be used, the lower should be the titanium dioxide content of a pigment.

With regard to these curves, it should be pointed out that the maximum for a given pigment will not always be found at a definite PVC level, because the opacity depends on the binder present; the better its wetting properties with regard to a given pigment, the higher the PVC level at which the maximum opacity will be obtained.

The hiding power and tinting strength are related to each other, as already mentioned, because these two properties depend on many of the same factors.

Fig. 3 shows these properties as a function of the pigment volume concentration. There is no relationship between the scales on which the hiding power and tinting strength are plotted, but it will be seen that the curves are quite similar, and that both show a decrease in pigment efficiency with an increase in the pigment volume concentration.

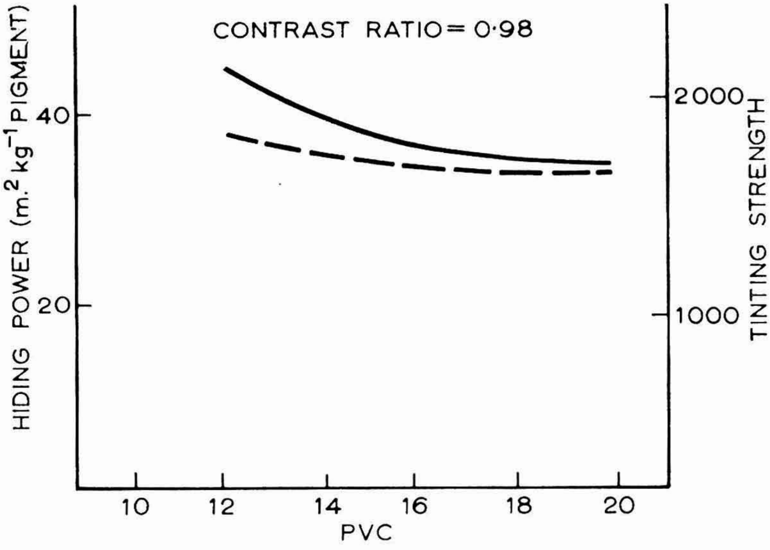


Fig. 3. Hiding power and tinting strength as a function of PVC

There are several important aspects of this observation. In the first place, the curves provide an explanation of the changes in the hiding power and the depth of tint which take place when coatings containing volatile solvents dry. Evaporation of the solvent causes the PVC to increase.

Secondly, greatest pigment efficiency can be obtained when the pigment is present in the lowest practical volume concentration consistent with the total opacity required and with the limitations imposed by film thickness.

Various factors that influence the opacity and tinting strength have been discussed. Some of these factors are inherent either in the material or the pigment; the refractive index and primary particle size cannot be changed, once the pigment has been produced. The factors which can be influenced in the formulation and the manufacture of a pigmented product are the PVC and the correct spacing of the particles in the product. The formulator must choose the right PVC and the producer has to take care to obtain good dispersion, so that the pigment is dispersed to primary particles as far as possible.

Effect of PVC

It is important to realise the change of film properties in relation to the change in the PVC. Fig. 4 illustrates this relationship for various properties. The abscissa gives the PVC, but there is no scale on the ordinate. As already stated, the hiding power increases linearly up to a PVC of approximately 12 per cent to reach a maximum at a PVC of 27 per cent. A sudden increase in opacity occurs at a PVC of approximately 55 per cent, indicated here as the critical pigment volume concentration (CPVC).

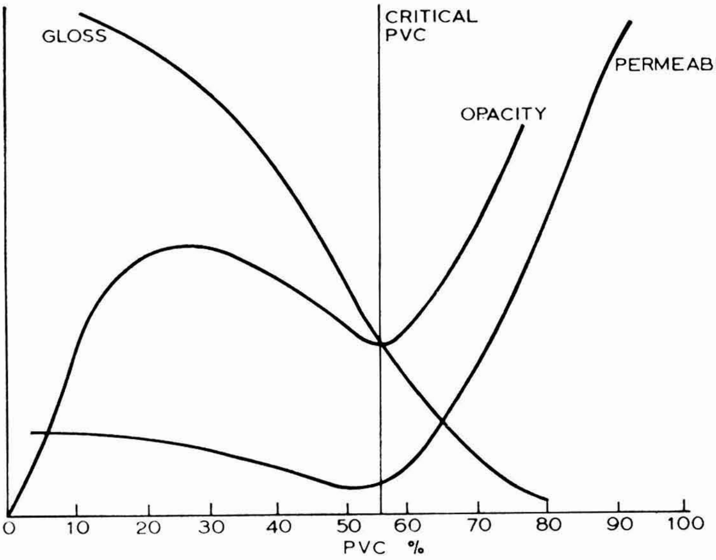


Fig. 4. Relation of film properties and PVC

At the CPVC the pigment particles touch and just enough binder is present to fill the voids between them. At higher PVC levels the particles cannot get closer together and less binder is present; consequently, space between the particles is not completely filled by binder, and air will be present. The opacity increases rapidly, because the refractive index of the medium decreases rapidly from about 1.5 for the medium at the CPVC to 1.0 for air at a PVC of 100 per cent.

At PVC levels higher than the CPVC, the so-called "dry hiding" occurs. The addition of extenders, such as chalk and clays, will also increase the opacity, because more of the binder between the pigment particles is replaced by air. The film will be porous, and blistering is not likely to occur at such high levels of pigmentation. On drying, the film cannot contract and the adhesive forces will not be counteracted by forces due to shrinkage. The cohesive forces will be rather low and very low at PVC levels of 80-90 per cent. Films pigmented at these PVC levels will not be affected by contractive forces and consequently will not peel. Such films are ideal for interior wall paints.

As pigments are less permeable than organic binders, the minimum permeability is found at the CPVC. At lower levels of PVC the permeability increases to an almost constant value at low pigmentation, as determined by the permeability of the binder.

At the CPVC, the permeability reaches a minimum value and no forces due to shrinkage will interfere with adhesive forces. At this level of pigmentation the surface of the film has a flat appearance. Consequently, the CPVC is the ideal level of pigmentation for primers. For various other reasons, however, the addition of more binder may be advantageous.

As just enough binder is present at the CPVC to wet the pigment particles and to fill the voids between them, little binder is left to form an adhesive film after drying is completed. In order to develop optimum adhesion, a little more binder should be added. Such an addition will also decrease any porosity and improve the enamel hold-out. Flexibility will be poor, and primers pigmented just below the CPVC will only be of value on dimensionally stable substrates, such as concrete, brick and plaster.

In order to achieve high gloss, the PVC for titanium dioxide pigments should be lower than 30 per cent, but not less than 6 per cent. One of the functions the pigment has to perform is to protect the organic binder against photochemical degradation. At very low PVC levels, too little pigment is present to offer adequate protection, and although chalking should not occur, the film may fail by peeling long before the gloss has been lost, as may happen with a varnish.

Once the right PVC has been chosen and the formulation established, production can commence. The main operation is always the grinding of the pigment to a stable dispersion in the vehicle. The aim of this operation is to achieve a dispersion of well-wetted primary particles.

Degree of dispersion

From the above discussion, it is easy to understand that the pigment is only used to advantage when primary particles are present in the final film. Consequently, not only should the pigment be well dispersed initially, but also care should be taken to ensure that the primary particles in the wet paint do not flocculate during storage or during the application and drying of the film.

The process of grinding a pigment is often controlled by means of a fineness of grind gauge. This method, however, will only provide a single and inadequate indication, because it only shows the size of the biggest particles present. A fineness of grind of 5 microns is considered to be very good. In this case, the biggest agglomerates present are still composed of at least 20 primary particles. Furthermore, there is no information on the size distribution of the particles smaller than 5 microns. Fig. 5 illustrates some possible size distributions of particles of less than 5 microns.

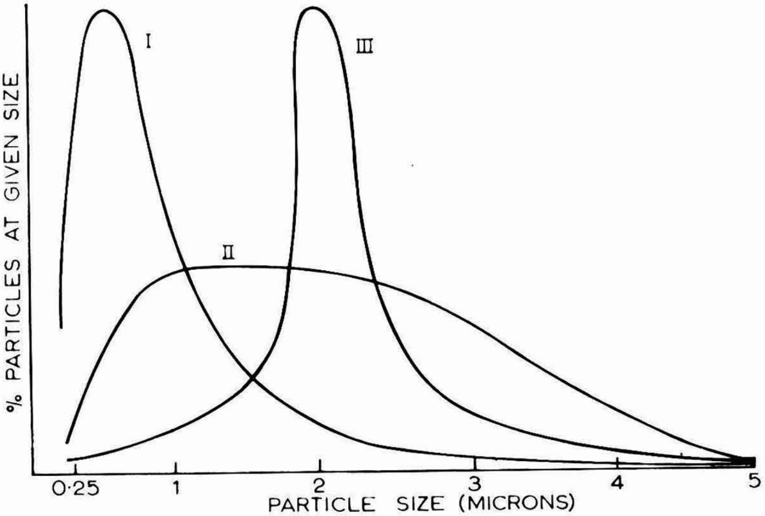


Fig. 5. Particle size distribution below maximum fineness of grind

Curve I illustrates the behaviour of a well-dispersed pigment under optimum conditions. The goal of 100 per cent primary particles can rarely be achieved. The paint for which this curve is valid will be bright, and will have a neutral tone, high tinting strength and opacity. In this case, the potential optical properties of the formulation are almost fully utilised.

Although maximum fineness of grind has been achieved, the formulation illustrated in curve II needs further processing. This will not be as bright and opaque as formulation I, and it will have a more yellow tone and lower tinting strength.

Prolonged grinding of the formulation should transform curve II into curve I; the brightness will increase and the tone will become more neutral, while the tinting strength and opacity will improve. If the particle size distribution is as shown in curve III, the tone will be brown, and neither the brightness, opacity nor the tinting strength will develop properly.

The situation illustrated by curve III may occur when the mechanical forces, such as those applied by roller mill or ball mill, are applied properly, but where the surface tension of the vehicle is too great to allow the surface of the particles to be wetted and separated in the absence of adequate mechanical forces. It is improbable that prolonged processing would give an improvement in any of the optical properties in the last case. The use of another grinding medium, other grinding equipment or the addition of a wetting agent should be considered.

Although the determination of the maximum fineness of grind with a gauge is important in relation to properties such as sedimentation and the development of gloss, it is much more effective to control the grinding process by an evaluation of the optical properties obtained. After all, it is precisely because of these properties that a pigment is incorporated in a formulation. Fig. 6

illustrates the development of various properties during the grinding process for a particular formulation.

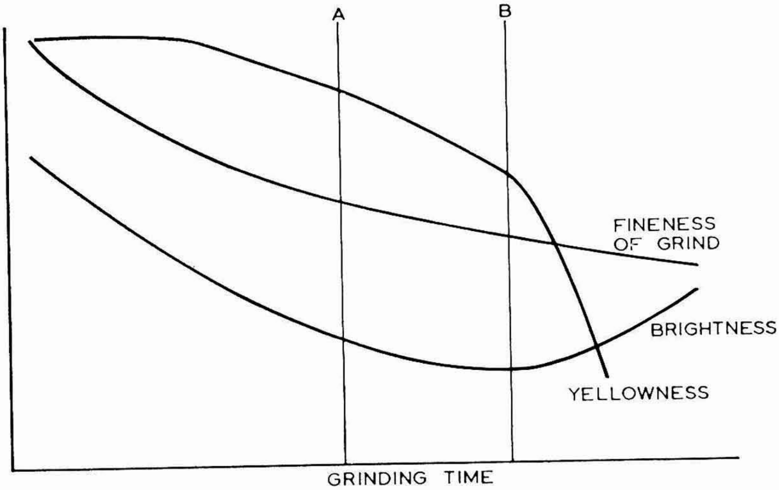


Fig. 6. Development of properties during the grinding process

The fineness of grind, as determined by a gauge such as the Hegman, diminishes as shown. The brightness decreases initially before increasing again. The paste gradually becomes less yellow. When the fineness of grind is considered to be sufficient after grinding time *A*, the brightness will still be rather low, and the appearance will be rather yellow. It is seen that, to develop the optical properties fully, a grinding time of at least *B* is necessary.

The fineness of grind obtained after grinding time *B* is not necessarily 10 or 5 microns. These graphs may be valid for a fineness of grind of 5 microns after grinding time *A*; in that case, obtaining a fineness of grind of 5 microns certainly means insufficient dispersion and the grinding operation should be adapted in such a way that the brightness passes its minimum (and the yellowness starts to drop rapidly) before sufficient fineness of grind is achieved.

A situation as illustrated by Fig. 7 is more satisfactory. In comparison with the preceding graph, the curves for brightness and yellowness have shifted to the left. The possibilities available to effect such a shift and thus to give a faster development of optical properties relative to the development of fineness may now be considered.

Grinding

When a bag of pigment is stored, the primary particles adhere together to form so-called "air agglomerates". During grinding, these air agglomerates must be broken down into primary particles, and the surface of each particle wetted by the vehicle, so that molecules from the binder, contained in the grinding vehicle, can be adsorbed on the surface. This adsorption is needed later to stabilise the pigment dispersion.

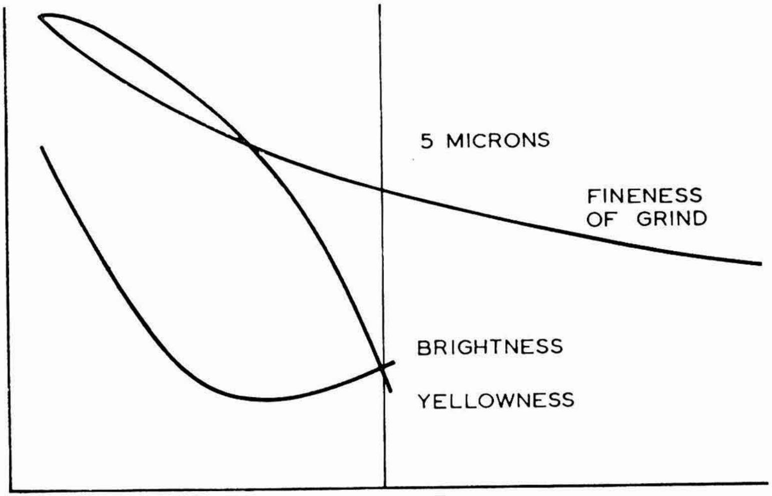


Fig. 7. Development of various properties during the grinding process

Both mechanical and physico-chemical forces are available to break down the air agglomerates. Mechanical forces are the shear stresses exerted on the paste by the grinding equipment used. Physico-chemical forces are due to the interfacial tension between the surface of the pigment and the vehicle.

Mechanical forces are more important in the case of rather large air agglomerates. It may be stated that the best use of the grinding equipment is most important in developing an adequate fineness of grind. On the other hand, the physico-chemical forces are more important in the case of rather small agglomerates; in order to achieve an adequate particle size distribution below the maximum the wetting of the pigment surface by the vehicle is of special importance.

The best use of the grinding equipment involves not only the achievement of sufficient fineness of grind, but also its capacity regarding the quantity of pigment handled. Grinding equipment is only used to full advantage when as much pigment as possible is handled per batch or per unit of time. Consequently, the pigment paste should be as heavily loaded with pigment as easy handling and speed ot dispersion will allow.

The best method to determine the optimum formulation for the triple roll mill is a modified Gardner-Coleman method for determining the oil absorption. The Gardner-Coleman method involves the determination of the oil absorption with raw linseed oil, having an acid value of 3-4; a glass beaker is used. The end point is reached when the pigment lump just adheres to the glass. In order to find the optimum composition of a grinding paste, it is preferable to carry out the same test using the actual vehicle to be used in the formulation at various percentages of non-volatile material. These percentages should be chosen to be as high as possible.

The relation of the percentage non-volatile content in the vehicle to the quantity of vehicle necessary to reach the end point for a given quantity of pigment is illustrated in Fig. 8.

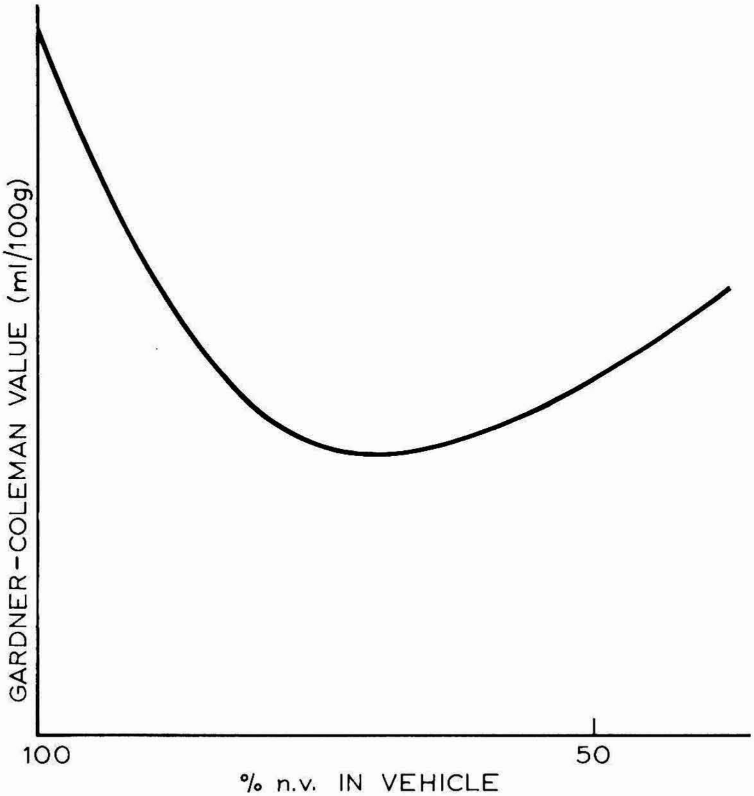


Fig. 8. Effect of non-volatile content on Gardner-Coleman value

It is shown that, for a given vehicle, a minimum quantity is necessary to achieve the appropriate consistency for the paste to be ground over a triple roll mill. Consequently, when using this vehicle, the paste will contain a maximum percentage of pigment, and the mill will be used to full capacity. Although this is not the place for a detailed discussion of triple-roll milling, the following remarks may be of interest:

The actual grinding over these mills takes place only in the "nip" between the rolls, and hence only a small quantity of paste is ground for a very short time. For this reason, the paste should be very well pre-mixed before milling. Secondly, the vehicle is allowed only a very short time to penetrate the particles, which are separated by the shear forces. Consequently, the vehicle should be free-flowing and of low viscosity. When grinding in a high-viscosity vehicle, such as a vinyl solution, the best results are obtained over a low-speed roll mill.

Vehicles used for triple-roll milling should contain 70-100 per cent non-volatile material. If it is found that a 60 per cent non-volatile vehicle gives the best results, the formulator should make sure that the mill is operated at low speed, if possible, or else a different type of equipment should be used.

There is a similar relation between the percentage non-volatile of the vehicle and the quantity of vehicle needed for appropriate consistency in the determination of ball milling formulations. In this case, the well-known Daniel titration method is used. Because the paste for ball milling should be free-flowing, the percentage non-volatile in the vehicle should be between 10 and 30 per cent.

Because the vehicle present in the mill-base has a very low solids content, the addition of more concentrated vehicle afterwards may give rise to "pigment", or "colloidal shock". For ball milling, the vehicle is used with a 10-20 per cent higher percentage non-volatile than that indicated by the Daniel titration, i.e. a 22-24 per cent solids vehicle is used when a 20 per cent vehicle is found by titration to be the best.

In addition, the combined solvents in the mill-base should be less powerful than those in the vehicle to be added. When the resin is dissolved in normal white spirit, it is appropriate to add some solely aliphatic solvent to the mill-base.

The dispersion of a pigment paste in a high-speed impeller requires a different method to be used. Stanford and Guggenheim evaluated a method which is based on the determination of the oil absorption value according to the Gardner-Coleman method.

Stanford and Guggenheim multiply the Gardner-Coleman oil absorption value by a factor, F, calculated from vehicle data:

$$\text{Guggenheim factor, } F, = 0.9 + \frac{\%\text{ non-volatiles in medium}}{145} + \frac{\text{Viscosity of medium at } 25^{\circ}\text{C in poise}}{40}$$

This method of determining the mill-base composition for use in an impeller uses pigment and vehicle data. The pigment/vehicle relationship, however, is not involved, nor are the wetting properties of the vehicle relative to the pigment taken into account. Therefore, it would seem better to use the actual vehicle to determine the Gardner-Coleman vehicle absorption, instead of using the oil absorption.

Pigment/vehicle interaction

Having considered above the best way to apply mechanical forces to a grinding paste in order to achieve sufficient fineness of grind, some consideration should be given to the pigment/vehicle relationship. This is of importance with regard to the wetting properties, in order to achieve a favourable particle size distribution below the maximum as indicated by the fineness gauge.

Two factors are involved in this relationship. In the first place, there is the surface tension of the vehicle relative to that of the pigment surface. This surface tension is responsible for wetting the primary pigment particles and for releasing them from the agglomerates. Secondly, the vehicle should provide molecules which will adsorb strongly on the surface of the particles in sufficient quantity.

These physico-chemical aspects of pigment dispersion are affected by the characteristics of the pigment and the "vehicle", as well as by the binder.

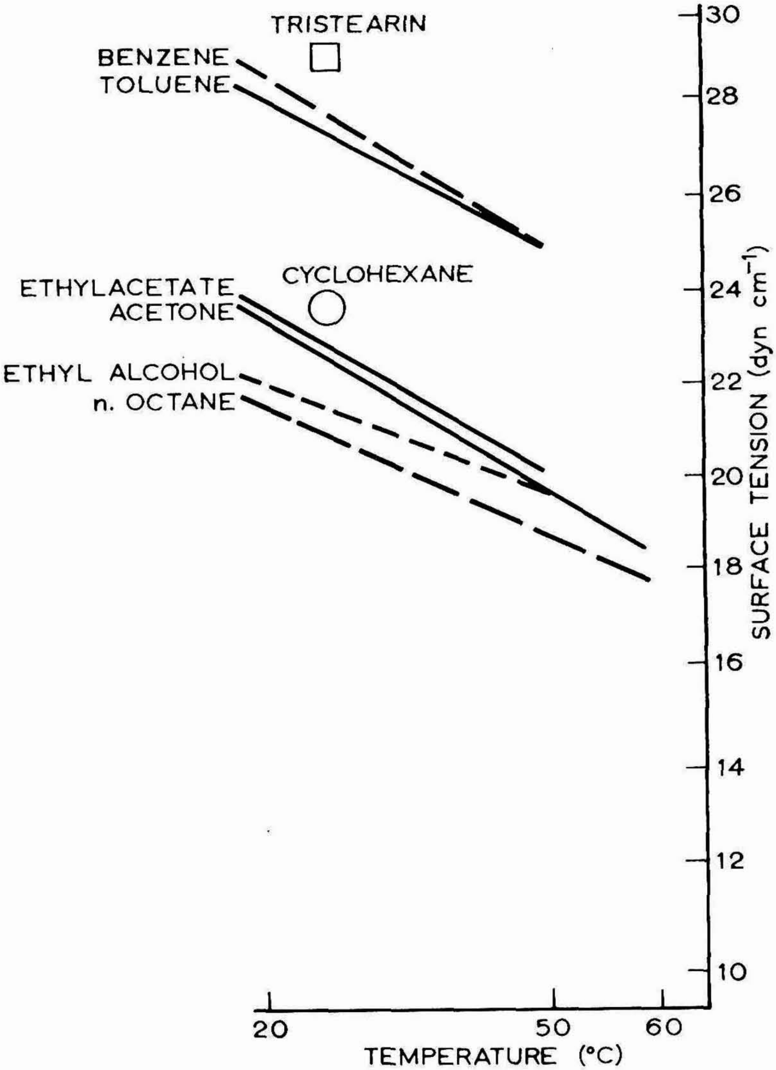


Fig. 9. Surface tensions of various organic liquids at an air interface

The "vehicle" consists of binders, solvents and, possibly, auxiliary materials, and is responsible for the initial wetting of the pigment particles.

Fig. 9 gives some information on the surface tension of various organic liquids. It includes aromatic solvents, such as benzene and toluene, the aliphatics cyclohexane and *n*-octane, and the well-known solvents acetone and ethyl acetate, together with ethyl alcohol and tristearin. On the ordinate, the surface tension is given in dyn cm^{-1}. All values are roughly between 20 and 30 dyn cm^{-1}.

It might be concluded that, as all solvents have about equal surface tensions, a change of solvent, from this point of view, is of only little use.

Quite obviously, the surface tension depends on the temperature, and drops when the temperature rises. The rise in temperature during grinding is to be considered as a favourable effect of the mechanical action exerted on the paste.

If the paste used is properly formulated, the rise in temperature during grinding assists in giving a tone which is blue in comparison with that of the same formulation produced in a ball mill or a triple-roll mill. The formulation processed in an impeller may, however, not have as high a gloss nor as good a fineness of grind. Consequently, the impeller is a very good disperser, as regards the particle size distribution below a given maximum fineness of grind. After dispersing a pigment in an impeller, the paste should be refined, for instance, by passing it through a sand or pearl mill.

It follows from these considerations that the impeller should not be considered the most suitable apparatus for pre-mixing pastes to be processed later in the sand mill, but as a grinding equipment for pastes which have to be refined later by a sand mill.

The surface tension of common solvents proves to be limited to a narrow range of 20-30 dyn cm^{-1}. Compared to the value for water (72.8 dyn cm^{-1}) and for mercury (472 dyn cm^{-1}), the surface tension of solvents is rather low. The marked differences in the surface tension of various vehicles are due to the resin. It may be necessary to add wetting agents to lower the surface tension of a resin solution to any considerable extent.

The addition of special solvents to a mill-base may be important from another point of view. An alkyd resin solution has a given viscosity because the alkyd molecules cling together and are not very mobile in solution. After the addition of solvents, such as butanol and ethylene glycol, the viscosity of an alkyd solution drops considerably, much more so than when an equal quantity of white spirit is added. Consequently, polar solvents, such as these alcohols, improve the mobility of alkyd molecules in solution.

Although when such solvents are added, the viscosity of an alkyd solution for ball milling at, for example, 20 per cent non-volatile, does not drop appreciably, the speed with which the binder molecules migrate to the pigment surface will be higher and a stable pigment dispersion may be obtained in a shorter time. It is thought that such additions may even help to improve stability.

A pigment dispersion will be stable when sufficient binder molecules are permanently and correctly adsorbed on the surface of the particles. It is a well-known fact that a pigment preferentially adsorbs the low-molecular weight binder components of a grinding vehicle. Consequently, the binder used for grinding the pigment should be able to provide a sufficient amount of the low-molecular weight material. On the other hand, the pigment should have a low demand for such material, have a low oil-absorption value or, rather, have a small surface with regard to its particle size.

The pigment surface should also have correct polarity with respect to the material available for adsorption and, in this respect, the after-treatment given to the pigment during its manufacture is of importance.

Surface treatment of pigments

Titanium dioxide pigments are produced and marketed as both treated and untreated types. These types differ both in price and quality. The after-treatment is aimed at satisfying requirements in the more sophisticated fields of application. The pigment is usually treated with alumina or alumina/silica, and most treated pigments have a TiO_2 content of approximately 95 per cent. For some speciality types, the content may be as low as 90 per cent or even 83 per cent. Such treatment has two end-effects. It prevents the particles from coming into too close proximity to each other and, consequently, the surfaces of the pigment particles themselves cannot actually touch. The wetting characteristics of the particles are also influenced by the amount and type of treatment, as are the photochemical stability and the chalking resistance. Furthermore, many modern titanium dioxide pigments are treated with organic materials as well as with the inorganic materials alumina and silica. Amines, polyalcohols, organic acids or silanes, either separately or in combination, may be used for such treatment. These organic materials are added to give a further improvement in the wetting properties and also to increase the dry storage stability, so as to prevent the formation of air agglomerates.

Although their use is advantageous from the point of view of dispersibility, organically treated pigments may in some formulations interfere with the drying properties of air-drying enamels.

Treating titanium dioxide pigments with inorganic materials, alone or in combination with organic materials, will improve the dispersibility and the spacing of the particles in the formulation. Consequently, the treatment will generally improve the optical performance, and the brightness, tinting strength and opacity of treated pigments will be superior to those of untreated pigments.

Fig. 10 illustrates the relationship between the relative tinting strength and

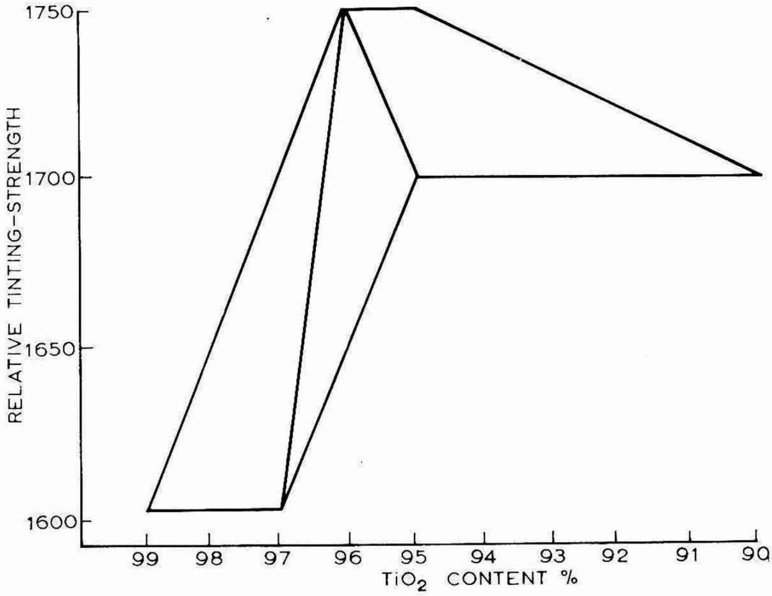


Fig. 10. Relative tinting strength

the TiO_2 content of a series of rutile pigments, produced by a TiO_2 manufacturer. The influence of the treatment as discussed here is quite evident. The deviation from a neat curve is due to differences in the particle size and the type of treatment.

Conclusion

In conclusion, it may be stated that the efficient use of titanium dioxide pigments involves many factors, including:

the correct choice of the pigment grade to be used;

the selection of the best pigment volume concentration;

the proper evaluation of the degree of dispersibility.

It has also been shown that:

in theory, full advantage is only derived from the optical properties of TiO_2 pigments up to a PVC level of approximately 12 per cent; in practice, however, PVC levels of 12 to 27 per cent are necessary in order to meet practical requirements;

titanium dioxide pigments, as such, should never be used at PVC levels above a given maximum;

for the proper evaluation of the dispersibility, a fineness of grind gauge is insufficient; the information given by it should be supplemented by optical data.

Manchester Section

Two-pack epoxy finishes

Some 55 members and guests attended a meeting at the Manchester Literary and Philosophical Society on Wednesday 15 September 1971.

In the absence of Mr Mitchell, Mr F. Redman took the chair and introduced Mr A. McWilliam, who proceeded to give a paper entitled "Two-pack epoxy finishes."

After briefly reviewing the history of epoxy resins, Mr McWilliam went on to describe the formulation of a solvent based two-pack epoxy paint. Dealing first with the epoxy resin, he showed that only the two lower melting point solid resins need be considered. Secondly, the hardener component was limited to the amine type, of which a higher viscosity reactive polyamide probably gave the best combination of properties. In discussing solvent blends he emphasised the point that lower water solubility materials gave the best results and gave as an example the butanol isomers.

On the subject of pigmentation, he indicated that most oxide pigments were eminently suitable, but to obtain bright yellows a compromise between price, chemical resistance and colour retention had to be made. One of the problems of formulation was demonstrated by showing the effect of two apparently similar hardeners on the shade of an organic yellow pigmented material.

After discussing primer pigmentation Mr McWilliam concluded with a short survey of solventless types.

After a lively discussion which extended the information on solventless systems considerably, Mr F. B. Windsor proposed the vote of thanks.

A.MCW.

Newcastle Section

Works visit

On Wednesday 13 October, a party of 11 Students and visitors visited the Carlton Weathering Station of Tioxide International Ltd. After a brief historical review of the development of titanium dioxide, the visitors were given a tour of the laboratories, where the necessary equipment for the examination of exposed paint panels was explained. The members then braved the North East weather and went outside to inspect some of the many panels on exposure. The type of work and the results obtained were ably explained by Mr Oakley, assisted by Mr Fuller. The meteorological station that forms part of the site was also explained before the members, some suffering from "exposure", returned to the laboratory to thaw out. Mr Oakley finally explained the workings of the automatic recording instruments which are used to observe the weather conditions at the station.

This first event of the 1971/72 session was extremely profitable and gave the members many points to think about on the return journey.

T.H.

Information Received

(In case of difficulty regarding addresses, members and subscribers to the JOURNAL *should apply for details to Director & Secretary of the Association at the address shown on the front cover.)*

Albro Fillers and Engineering Company Limited has introduced a range of depositing fillers designed for products that are packed in the hot molten state and solidify when cold. The product is supplied to an insulated tank, and deposited through steam or electrically heated valves to containers below. Two models are available, a hand-operated type which travels on rails above the containers to be filled, and an automatic type, which is fed by conveyor; in each case, accurately metered quantities of the material are delivered by the valves.

Unithane 655W, a urethane alkyd resin designed for use in clear and pigmented one-pack urethane finishes, either alone or in combination with thixotropic alkyds or urethanes, is the subject of "CV Post 13," issued by **Cray Valley Products Ltd.** Experimental results illustrating the excellent hardness, abrasion resistance and colour retention and the rapid drying claimed for formulations based on the product are shown.

International Colloids Ltd. has recently introduced low viscosity pumpable versions of its carbon black and pigment dispersions. The first range of dispersions to be available in this form is the *Plastosperse 17* plasticiser dispersion series for use in flexible pvc, pvc plastisols, polyethers, polyesters and polyurethanes.

The development of a range of exceptionally high colour dispersions in polyethylene "A" wax, the *Intersperse* range, has also been announced. The first *Intersperse* product, *53/1*, containing 70 per cent high jet furnace carbon black, is now available.

International Colloids has also commenced a new service to customers. A department has been set up at the Widnes factory to specialise in the dispersion of all kinds of chemicals in a variety of liquid and solid media, using materials supplied by the customer if required.

Leaflets issued by **Hansen GmbH KG** describe the company's range of equipment for filter presses. Hansen can supply high grade filter press frames and plates, chamber filter plates and accessories made from high density polyethylene and polypropylene, soft and hard rubber with steel core, metal or wood. Details are given of the equipment supplied by Hansen for the **CIBA-GEIGY** filter press system.

A new class of thermoplastic elastomers has been developed by **Du Pont.** The new *Hytrel* materials are described as polyester elastomers, and are related to *Dacron* polyester fibre and *Mylar* polyester film. Supplied in pellets in three hardness grades, the new elastomers are said to combine the properties of high performance elastomers with the high speed processing advantages of thermoplastics: no vulcanisation is required.

It has also been announced that Du Pont's *Fairprene* coated fabrics and sheet stock for diaphragms, gaskets, etc., are now available from **The Du Pont Company (United Kingdom) Limited.** The *Armalon* range of TFE fluorocarbon resin-coated glass fabrics, tapes, laminates and impregnated felts will also be marketed by the UK company.

The Baglan Bay factory of **BP Chemicals International Limited** is the subject of a new leaflet recently published by the company. The leaflet traces the growth of the Baglan Bay site, and summarises the current £100m expansion programme, with particular reference to the products and their end-uses. Copies are available from BP.

Kronos Titanium Pigments Limited has recently announced that it has been appointed sole distributor for all products made by **The Baker Castor Oil Company** of the USA. The Baker range of products includes thixotropes for: viscosity control, pigment/filter suspension, flow control, thixotropic body, sag/slump control, colour uniformity, penetration control and improved brushability/levelling.

A 12-page booklet has recently been issued by **Dynamit Nobel AG,** giving details of *Trogamid T*, a new amorphous, transparent polyamide for injection mouldings. Unlike earlier, crystalline, polyamides, *Trogamid T* is claimed to be permanently transparent, even in thick sections. Full technical details are given in the booklet, together with advantages in certain end uses compared with existing materials.

Three new thermosetting resins developed especially to provide high standards of durability and formability in coil coating formulations have been introduced by **Synthetic Resins Limited.** *Scoplas 101SB* is an oil-free saturated polyester suitable for one-coat stoving application. Optimum film performance is obtained when modified with 20 per cent amino resin at stoving schedules of the order of two minutes at 240°C. *Scoplas 201SB* is also an oil-free alkyd, silicone modified for maximum outdoor durability. Excellent adhesion, flexibility, formability, and fade and chip resistance are claimed for formulations based on this resin. Optimum film performance is claimed for melamine modified formulations stoving for 60 to 90 seconds at 300°C. *Scopacron 800SB* is a thermosetting silicone modified acrylamide resin for modification with melamine. It is claimed that its film properties are only marginally lower than those of *Scoplas 201SB* with similar stoving schedules, while it is less expensive.

Technical bulletins on all three resins are available from SRL.

An improved version of *Raybo 24—Drytain* is now being marketed by **Raybo Chemical Company** of the USA. An organic lead complex that acts as a lead reservoir to prevent loss of dry in paints during storage, the improved *Raybo 24* has lower viscosity and thus freer-flowing properties, and, it is claimed, much improved performance.

ICI Ltd. has introduced a new grade of PTFE lubricant powder. The new powder, *Fluon L170*, has a smaller particle size (4 microns) than the earlier grades, and it is also friable, breaking down to particle sizes claimed to be as low as 0.1 microns under the action of shear. This renders it more effective in reducing surface friction and wear than earlier grades, which tended to agglomerate under conditions of high shear.

"Pigmentation of surface coatings with carbon black pastes in alkyd resins and carbon black/nitrocellulose chips" is the title of a new brochure from the pigments division of **Degussa.** The leaflet is available in English, German or French.

A new company, **Starchem Limited,** has recently been formed to supply a range of cleaning products for the paint finishing industry. Initially, Starchem offers tack cloths and specialised chemical cleaners; a new type of white tack cloth, based on bleached cloth and water-white safety impregnant can be supplied.

It has recently been announced that **Revertex Holdings Limited** has acquired the goodwill (including the UK trademark *Polimul*) and know-how of the pva and acrylic emulsion business of **Dunlop Limited.** The transfer of production to Revertex's Harlow plant is under way, and is expected to be complete by the end of the year. In connection with the acquisition, Revertex has issued 318,187 new ordinary shares of 25 pence each, which rank pari passu in all respects with the existing ordinary shares of Revertex.

A comprehensive range of new litho black inks has been introduced by **Coates Brothers Inks Ltd.** Five basic types are available, and the range includes two gloss blacks, three quality half-tone blacks, four label and carton blacks, one for small offset machines, and two jobbing blacks—one for perfectors.

Two new pigments have been introduced by **Badische Anilin-& Soda-Fabrik** AG. *Heliogen Blue 7044T* is a new beta-form phthalocyanine blue, specially developed for toluene gravure printing inks, in which it is claimed to have exceptionally good flow behaviour and good flocculation stability. *Paliogen Yellow 1870* is a new flavanthrone pigment, redder in shade than *Paliogen Yellow 1560*. It is claimed to have high colour strength combined with good transparency and fastness to light, heat and weather, and is recommended for pale shades and metal effect lacquers.

It has recently been announced that **Carson Paripan Ltd.** and **Hadfields (Merton) Ltd.**, the jointly run paint activity of the **Bestobell** group, have reached agreement with the German/Belgian owned **Desowag-Bayer Company** to market its range of coatings, stains, and preservatives for wood preservation in Great Britain. These products have been marketed in the UK since the early 1950s by **Desowag-Bayer Ltd.**, which will cease trading at the end of the year, by which time its entire operation will have been entirely integrated into the Carson/Hadfield group. This move represents a diversification for Carson/Hadfield, which has previously dealt only in decorative, industrial and marine paints, and is part of the company's planned expansion into a number of fields allied to its operations.

Manchester

The fibre optics colorimeter and its application

On Friday 8 October, 52 members and guests attended at the Bolton Institute of Technology to hear a paper entitled "The fibre optics colorimeter and its application", read by Mr D. Irish of the Paint Research Association.

Mr Irish pointed out that the major portion of his paper had already been published by I. G. H. Ishak (*JOCCA*, 1971, **54**, 129). However, he added a number of details regarding a commercial model which is expected to be available in early 1972.

A lively discussion period followed during which Mr Irish pointed out that high temperature limitations were mainly due to the adhesive used for fixing the optical elements, and that work was being carried out at PRA on modifications for use with polychromatic type finishes. A further point was that the instrument was intended as a control, particularly in-line, and is not expected to replace in any way a spectrophotometer.

Mr M. Kerr proposed the vote of thanks which was carried with enthusiasm.

A.McW.

Midlands

New developments in marine paints

The 152nd meeting of the Midlands Section was held at the Birmingham Chamber of Commerce on Friday 24 September 1971, with the Section Chairman, Mr H. J. Griffiths, in the chair. The Chairman welcomed 22 members and guests to this the first meeting of the new season.

A lecture was given by Mr K. S. Ford, of ICI Limited Mond Division, entitled "New developments in marine paints." Mr Ford began by emphasising the importance of recent changes in shipping practice in the planning of their development programme. With the closure of the Suez Canal and the development of super tankers to negotiate the Cape route, a number of important factors emerged. Ships were bigger, crews were smaller, running costs might be £2,500 per day, building costs were high and, therefore, as the ship only made a profit when the propeller turned, it was important to take advantage of fast turnaround and increased efficiency in building. Developments in marine paints, therefore, led to high duty coatings of long service life which were readily touched in with a short docking cycle. Also influencing the importance of high build coatings was the claim by the TNO in Holland that a 10 per cent fuel saving was possible by use of a smooth hull.

Mr Ford covered the work programme in three main areas, namely application, surface preparation and performance testing. For application, airless spray techniques had proved the most efficient, particularly in the coating over deep pits. The subject of surface preparation was covered in some detail, with reference to the Swedish standards and showing photographs of surface profiles obtainable by various treatments. Performance testing was carried out on rafts floating in the Menai Straights and off Poole Harbour and by sea wall exposure on the Mersey.

The first exposure series covered various pigmentations and the use of either bentonite clay or hydrogenated castor oil as thixotrope. Results showed an upper limit on pigment volume concentration of around 34 per cent for best performance and a difference between the two thixotropes. Cross hatch adhesion varied considerably, being better with the HCO thixotrope and worse at high titanium dioxide loadings. The second experimental series evaluated various grades of chlorinated rubber and various plasticisers in metallic lead and zinc rich formulations. Good results were obtained using a mixture of 40/35/25 of chlorinated rubber/solid plasticiser/liquid plasticiser. It was also shown that the use of a single 10cp grade of chlorinated rubber gave better results than the results of mixed 5 cp/20 cp grades. As extenders, micronised dolomite and talc were preferred.

Problems were frequently encountered with the airless spray application in a honeycomb effect developing in the dry coating; solvent balance obviously played an important part but extender variation seemed to be an important variable.

The third and final experimental series covered variations of primer and surface preparations. The whole lecture was extremely well illustrated with tables of results that really required a longer study to obtain the full benefit, and Mr Ford completed his talk by showing a short videotronic film on the subject of marine painting. A number of questions were raised from the floor and dealt with by Mr Ford before Mr F. Cole proposed a vote of thanks and the Chairman closed the Meeting.

The full text of this lecture has been accepted for publication, and will appear in the *Journal* early in 1972.

R.J.K.

West Riding

"Liquid inks—on tap?"

The first meeting of the session was held at the Griffin Hotel, Leeds on 15 September 1971. A paper entitled "Liquid inks—on tap?" was presented by Mr R. Colquohoun of Winnetts, Limited. The lecturer explained that the term "liquid inks" was used to limit his paper to gravure and flexographic printing inks.

Mr Colquohoun discussed the problems of colour matching; often this had to be done from an inadequate sample such as an artist's crude colour wash and he stressed the need for samples of the stock to be printed for optimum results. In the manufacture of the ink, one had a choice of pigments, solvents, resins and modifiers. Only if the ink maker had a close knowledge of the printer, his plant and the end use of the printed matter could a satisfactory ink be produced. For example, inks likely to come into contact with foodstuffs were usually required to meet various legislative requirements on items such as lead content. The point was made that lead-free pigments were normally required for food use but copper and brass powder, used as gold pigments, were allowable. Mr Colquohoun regarded this as an anomolous situation due, in part, to the lack of liaison between various parts of the industry.

In the manufacture of the ink, the well known dispersion methods were all used to some extent and the advantages and disadvantages of each were briefly discussed. With the aid of a variety of samples of printed matter, Mr Colquohoun outlined some of the faults which could arise and problems to be anticipated. Plastic films were being used to an increasing extent in packaging and these normally needed pretreatment before printing. This pretreatment required close control to avoid variable results on printing.

Flexographic inks were of two types. The so-called aniline inks, comprising dyestuff and spirit soluble resin in alcohol solvent, were fast drying and widely used for printing paper bags etc. Pigmented inks, where a pigment was dispersed in a varnish, provided superior performance and could be used on a variety of surfaces. Gravure inks were also of the latter type.

Research in the industry was continuous, as liquid inks were continually being modified to meet changes in requirements, and tended to be of a short term nature as changes came quickly. Mr Colquohoun entered a strong plea for closer liaison between the ink maker, the printer and the print user to ensure that the industry kept pace with new developments. In this way, the ink maker would be better able to approach the printers ideal of having the correct ink available "on tap."

Mr Colquohoun's lively presentation evoked many questions and Mr J. Groom expressed the thanks of all present.

R.C.

Notes and News

24
OCCA

Technical Exhibition

17-21 April 1972

The international forum for technological display and discussion in the surface coatings industries

The Exhibition Committee is pleased to report that the first list of exhibitors to whom space has been allocated at 24-OCCA includes representatives from 12 overseas countries—Austria, Belgium, Canada, Denmark, Finland, France, Germany, Holland, Italy, Sweden, Switzerland and the United States of America. Of the exhibitors, 12 have never shown at previous OCCA Technical Exhibitions, whilst 12 others did not show at the 1971 Exhibition.

The Exhibition will once again take place in the Empire Hall, Olympia, London W14, the hours of opening being as follows:

Monday 17 April	..	15.00-18.30
Tuesday 18 April	..	09.30-18.30
Wednesday 19 April	..	09.30-18.30
Thursday 20 April	..	09.30-18.30
Friday 21 April	..	09-30-16.00

As visitors to previous OCCA Exhibitions will recall, a feature of these events is the circulation of copies of the *Official Guide* many weeks in advance, in order to assist those planning to visit the Exhibition to obtain the maximum benefit from the Exhibition. Each member of the Association, wherever resident, will be sent a copy upon publication and copies will also be sent individually without charge to chemists and technologists on the Continent of Europe, to technical colleges, and—through the courtesy of trade associations—to companies in the paint, printing ink and pigment industries in the United Kingdom. These copies will contain visitors' identification cards and hotel accommodation reservation leaflets.

A leaflet has also been produced which gives general information in six languages (French, German, Italian, Russian, Spanish and English) and copies of these will be sent to many paint and printing ink manufacturing companies on the Continent of Europe. Copies are also available to intending visitors and they will be despatched without charge upon application to the Association's office.

Special folders for technical literature will be once again distributed free of charge at the entrance to the Empire Hall. Facilities available at the Empire Hall include a licensed restaurant and two licensed buffets, one on each of the two floors on which the Exhibition will be located. Escalators to and from the first floor will be in operation throughout the hours of opening and attractive seating areas—which have long been a feature of OCCA Exhibitions—will be provided on both floors.

As in previous years, the Exhibition Luncheon will be held at the Savoy Hotel, London, WC2, on the opening day, 17 April 1972. Principal officers of other scientific bodies, industrial research associations, training boards, organisations representing both suppliers and consumers and members of both the national and technical press will be invited to attend. Fuller details will be circulated in due course and a form of application for tickets will be included in each copy of the *Official Guide*.

Following the practice at previous Exhibitions, a stand will be devoted to Technical Education and parties of sixth form science and technical college students will be invited to attend in the mornings, when they will be given short introductory talks before touring the Exhibition. The Technical Education Stand will not only show the courses available in the technology of the paint, printing ink and allied industries and the technical careers open to new entrants, but will also prominently feature information about the newly instituted optional Professional Grade for Ordinary Members of the Association, which was first announced at the Exhibition Luncheon in 1971.

Representatives from 38 overseas countries attended the 1971 Exhibition, and in order to assist the ever increasing number of both visitors and exhibiting companies from overseas, interpreters will again be in attendance (French/German/Italian/Spanish). Banking and postal facilities, which have been much appreciated by visitors and exhibitors alike at the past exhibitions, will once again be available.

There will be no charge for admission to the Exhibition, or for copies of the *Official Guide*, which will be available from the Association's Information Centre at the Exhibition or from the Association's offices prior to the Exhibition.

Any company or individual who wishes to receive a copy of the *Official Guide*, when available, should write to the Director & Secretary at the Association's offices.

The first list of exhibitors to whom stand space has been allocated is given below.

First list of Exhibitors

Albright & Wilson Ltd.
*Allied Chemical International SA
†Amalgamated Oxides (1939) Ltd.
Amoco Chemicals Europe
Anchor Chemical Co. Ltd.
*F:a Andersson Andersson
†Ashby, Morris, Ltd.
*Atlantic Richfield Co.
Baker Castor Oil Company
BIP Chemicals Ltd.
Blagden, Victor, & Co. Ltd.
Boulton, William, Ltd.
*Bowater Industrial Packaging Ltd.
†British Steel Corporation
*Bromhead & Dennison Ltd.
Cabot Carbon Ltd.
Cal/Ink Chemical Co. of Canada Ltd.
Campbell, Rex, & Co. Ltd.
†Carless, Capel & Leonard Ltd.
CdF Chimie
Cornelius Chemical Co. Ltd.
†Cray Valley Products Ltd.
Crosfield, Joseph, & Sons Ltd.
Croxton & Garry Ltd.
Daniel Products Company
Degussa
Diaf A/S
†Du Pont De Nemours International SA
†Durham Raw Materials Ltd.
Eastman Chemical International AG
Elcometer Instruments Ltd.
Ferranti Ltd.
Francaise des Matieres Colorantes
†Gebruder Netzsch Maschinenfabrik
†Grace GmbH
†Henkel & Cie GmbH
Hercules Powder Co. Ltd.
*Hunter Associates Laboratory Inc.
Imperial Chemical Industries Ltd.
Kingsley & Keith Ltd.

Kollmorgen (UK) Ltd.
*Langer, Georg M., & Co.
Laporte Industries Ltd.
*Leneta Company, The
Lennig Chemicals Ltd.
Marchant Brothers Ltd.
Microscal Ltd.
Montecatini Edison SpA
Nagema Transportmaschinen Export/Import
Noury and Van der Lande NV
Paint Manufacture (Morgan-Grampian (Publishers) Ltd.)
Paint Research Association
Polymers, Paint & Colour Journal (Industrial Newspapers Ltd.)
Research Equipment (London) Ltd.
Resinous Chemicals Ltd.
Rhone-Poulenc Redis
†RK Chemical Co. Ltd.
Roehm GmbH
Sachtleben AG
Sawell Publications Ltd.
Scado NV
Schering AG
Sheen Instruments (Sales) Ltd.
Shell International Chemical Co. Ltd.
Silver, Peter, & Sons (Engineers) Ltd.
*Society of Dyers and Colourists, The
Steetley Company Ltd.
†Sterling Colour Company Ltd.
Swan, Thomas, & Co. Ltd.
*Talkumwerke Naintsch
Tioxide International Ltd.
Titanium Intermediates Ltd.
Torsion Balance Co. (GB) Ltd., The
Ugine Kuhlmann
Vuorikemia Oy
Winkworth Machinery Ltd.
Winn & Coales (Denso) Ltd.
*Winter Osakeyhtio
*Worsdall Chemical Co. Ltd.

**Denotes companies who have not previously shown at OCCA Exhibitions.*

†Denotes companies who did not show at the 1970 Exhibition.

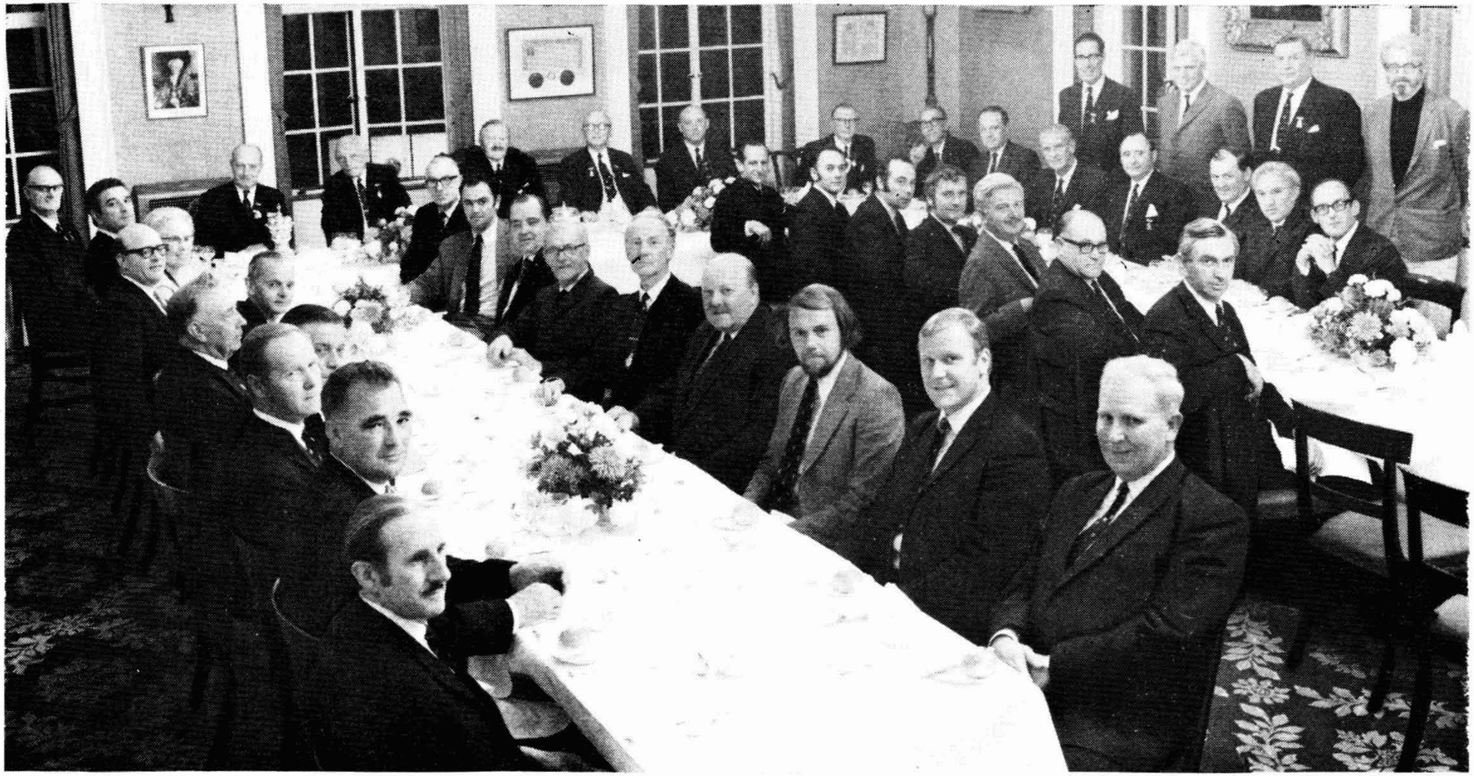
Reunion Dinner of Past Presidents, Past Honorary Officers, Honorary Members and Council

On Wednesday 6 October, the reunion dinner of Past Presidents, Past Honorary Officers, Honorary Members and Council was held in the Court Room at Wax Chandlers' Hall. The guests, who included five Past Presidents (of whom two are Honorary Members) and five Past Honorary Officers, assembled for a short reception before the dinner.

As is customary, the President, Mr A. W. Blenkinsop, proposed the loyal toast, and went on to review the Association's activities over the preceding year.

He pointed out that, since the reunion dinner in alternate years is now combined with the Foundation Lecture, it was a year since his predecessor had addressed the company and, in that period, three major items stood out in the Association's affairs. First was the introduction, after many years of discussion, of an optional Professional Grade for Ordinary Members. It had proved possible to do this without in any way upsetting the Association's present structure, changing its name or altering its Articles. The President emphasised that the main burden of effort had been to provide the same educational identity with the surface coatings industries as existed in many other countries, bearing in mind particularly personnel under 30 years of age; thus the Licentiate grade was considered to be of primary importance. Also, he could not stress too strongly that this was an optional grade—it was not intended to force anyone to enter it, nor would those who did have any extra rights.

Secondly, the Association had held its second Exhibition at Olympia. As the Association had moved to Olympia in a hurry, it had not been possible to enter into negotiations about the dates offered, and it had been felt that a risk was



Past Presidents' Dinner. Top table (*left to right*) Mr F. Sowerbutts (President 1967-69) Dr H. W. Keenan (President 1944-47) The President (Mr A. W. Blenkinsop) Mr H. Gosling (President 1953-55) Mr P. J. Gay (President 1959-61) Dr S. H. Bell (President 1965-67). Standing (*left to right*) Mr A. G. Holt (Elective Member) Dr A. Lowe (Representative, South African) Mr H. R. Touchin (Elective Member) Mr M. H. M. Arnold (Hon. Editor 1955-58). Right hand table, facing camera (*left to right*) Mr S. G. Tinsley (Hon. Research and Development Officer 1945) Mr D. S. Newton (Hon. Secretary, and Hon. Editor 1962-65) Mr F. Cooper (Hon. Treasurer) Mr N. H. Seymour (Vice-President) Mr J. E. Mitchell (Elective Member) Mr S. Duckworth (Representative, Manchester) Mr F. D. Robinson (Representative, Hull). Right hand table, back to camera (*left to right*) Mr E. M. Burns (Representative, Scottish) Mr H. J. Griffiths (Chairman, Midlands) Mr. D. E. Hopper (Representative, Midlands) Mr D. J. Morris (Elective Member) Mr I. S. Moll (Vice-President) Dr J. B. Harrison (Hon. Research and Development Officer 1958-63) Mr I. C. R. Bews (Hon. Editor 1959-62 and Hon. Secretary 1962-69)

Left-hand table, right side (*left to right*) Mr R. S. Law (Hon. Secretary 1947-54) Mr J. N. McKean (Retiring Representative, West Riding) Mr F. D. H. Sharp (Chairman, Irish) Mr S. R. Finn (Hon. Editor) Mr D. E. Eddowes (Chairman, London) Dr V. T. Crowl (Elective Member) Mr R. Wood (Assistant Editor) Mr P. L. Smith (Administrative Assistant) Mr N. S. Pearce (Assistant Secretary) Left hand table, left side (*top to bottom*) Mr F. Schollick (Vice-President) Mr L. H. Silver (Vice-President) Mrs K. Driver (Chairman, West Riding) Mr D. Morris (Newly-elected Representative, West Riding) Mr W. H. Tatton (Representative, Thames Valley) Mr B. Jacob (Chairman, Thames Valley) Mr A. T. S. Rudram (Elective Member, and Hon. Research and Development Officer 1963-69) Mr P. L. Gollop (Chairman, Bristol) Mr A. A. Duell (Chairman, Newcastle) Mr R. H. H. Hamblin (Director & Secretary) involved in holding it in June, owing to the effects of holidays and difficulties in finding accommodation in London. In the event, however, the Exhibition was by far the largest ever to be held by the Association, and attracted almost the same number of visitors as the previous year, the number of overseas countries represented in the Overseas Visitors' book (38) being the same. Preparations were now in hand for the 24th Exhibition, to be held in April 1972.

Thirdly, the Association's Conference had been held in Torquay, the fourth occasion on which this venue had been used since 1957. Difficulties had been caused by the postal strike, curtailing the amount of publicity material that would reach non-members, and a drop in numbers of non-members had been anticipated. In fact, 280 people registered, compared with about 350 on previous occasions, but in considering the difficulties found by other conferences in the earlier part of the year, and the particular economic problems of the industries, this could be considered a satisfactory result. A fuller programme of technical sessions had been arranged, as well as a management session and three workshop sessions, and all were well attended.

In retrospect, had the timing of these Association events been as usual, although a June conference might have attracted more non-members, the holding of the Exhibition in April would have been made very difficult by the postal strike occurring at the time when *Official Guides* and other literature should have been circulated. Thus, the Association had managed to deal with the problems arising from the postal dispute both by design and accident!

Section activities were continuing both at home and overseas and showed considerable progress; Mr Blenkinsop had already visited the Midlands Section, and looked forward to visiting several others during his first year of office.

In conclusion, he thanked all present for attending the reunion dinner, and hoped that they were enjoying the evening.

After a short recess, the President gave a short talk on the petrochemicals industry, in which he had spent nearly all his working life. Mr Blenkinsop outlined the mushrooming growth of the industry over the past forty years, and speculated on prospects for the future.

Dr H. W. Keenan, the senior Past President present at the dinner, followed Mr Blenkinsop, saying how sorry he was, and no doubt the other Members were, that the Association's oldest Past President and a Founder Member, Dr H. Houlston Morgan, was not able to be present. Dr Keenan felt that he was merely substituting for him, and asked that best wishes of all present should be sent to Dr Morgan.

Other Members who addressed the company were Dr S. H. Bell (Past President), Mr F. D. H. Sharp (Chairman, Irish Section), Mr D. E. Hopper (Representative, Midlands Section), and Mrs K. Driver (Chairman, West Riding Section).

R.W.

Optional Professional Grade for Ordinary Members

Members are reminded that the formation of an optional Professional Grade for Ordinary Members was announced in the September issue of the *Journal*, pages 916-921. Reprints of the announcement, which includes the full regulations for admission to the Professional Grade, are available from the Association's offices, as are forms for application; it is hoped to publish the first list of Ordinary Members admitted to the Professional Grade in the January 1972 issue of the *Journal*.

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 attempt 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.

Report of Meeting of Council

A Meeting of Council took place on 6 October 1971 at Wax Chandlers' Hall, with the President, Mr A. W. Blenkinsop, in the Chair. There were 31 other members of Council present, together with Mr J. N. McKean, the retiring representative of the West Riding Section to whom best wishes were extended upon his appointment to a post, within his company's organisation, in the Far East. The President opened the Meeting by welcoming to the Council Mr D. Morris, who was replacing Mr McKean as the West Riding representative on Council, Mr H. R. Touchin, who was filling the vacancy created by the resignation of Mr D. M. James, (Elective Member) and Mr F. Schollick, a Vice-President previously attached to the South African Section, of which he had been Chairman, and who was now living in London.

Council was pleased to receive a report that the optional Professional Grade for Ordinary Members had been very well received not only by members but also by technical colleges, trade associations, other learned societies and institutions and the training board. A pleasing feature of the applications was that amongst those received were some applying for the Licentiate Grade, and the applicants had submitted the topics of their dissertation for approval by the Professional Grade Committee. It was hoped to issue the first list of admissions to the Professional Grade in the January issue of the *Journal*.

The arrangements for the Association's Dinner Dance, to be held at the Savoy Hotel on Friday 12 May 1972, were approved and details of this function will be sent to all members at the beginning of the New Year.

Council also discussed the arrangements for the holding of the next Annual General Meeting, which will take place on Wednesday 7 June 1972 at Wax Chandlers' Hall, and was pleased to learn that a former Clerk to the Worshipful Company of Wax Chandlers, Mr C. G. Todd, had agreed to give a short talk after the AGM on the history of the Company and to display historical documents, silver and other regalia. Full details of the Annual General Meeting and this lecture will be circulated to members in due course.

The next Foundation Lecture (which is held in years alternate to the Past Presidents' Dinner) will take place in October 1972, and details of the Lecture will be announced in the *Journal* and also sent individually to members in the usual way. It is hoped that, following the precedent set at the Fiftieth Anniversary Celebrations in 1968, a short Commemorative Service at the Parish Church of Saint Vedast-alias-Foster, which is near the Association's offices, will precede the giving of the Foundation Lecture at the Painter's Hall.

Council received reports on the 1971 Exhibition and the arrangements for the 1972 Exhibition and gave authority for the seal to be affixed to a lease for the hire of the Empire Hall for April 1974, thus booking the venue for the next three years (April 1972, May 1973 and April 1974).

The Income and Expenditure Account for the first half of the year, the balance sheet as at 30 June, the estimates for July to December 1971, and the accounts for the Torquay Conference, all of which had been previously circulated with explanatory notes, were accepted.

In accordance with Article 15, the names of members whose 1971 subscription had not been received had been removed from the Register of Members.

As announced in the October issue of the *Journal*, the extracts from Part VII of the Paint Technology Manuals (Works Practice) will be printed in the Student Review section of the *Journal* during 1972, and it was reported that five parts had already been prepared by the Hon. Editor, Mr S. R. Finn.

It was reported that arrangements were being made to ensure that the Association was represented by an OCCA-designated paper at the FATIPEC Congress in Florence in June 1972. Council was disappointed to learn that the paper which had originally been suggested for this purpose was no longer available.

Reports from the Sections in the United Kingdom and overseas were received, and Section Chairmen or Representatives drew attention to particular items in these reports.

A short discussion took place on the pattern of OCCA Conferences, and this will be further discussed when considering the arrangements for the next Conference which will take place at the Grand Hotel, Eastbourne, from 19 to 23 June 1973. Further details will be announced in due course, both in the *Journal* and in a leaflet to members.

Mr A. R. H. Tawn (Hon. Research & Development Officer) reported that he would be attending the Annual Meeting of the Federation of Societies of Paint Technology in Detroit later in October and Council asked Mr Tawn to convey its greetings to the meeting, where the official OCCA paper would be delivered by Dr D. A. Plant.

At the conclusion of the meeting, Members were reminded by the President that the Reunion Dinner for the Past Presidents, Past Honorary Officers, Honorary Members and Members of Council, would take place that evening in the Wax Chandlers' Hall and a report of this function, together with a photograph, are given elsewhere in this issue of the *Journal*.

Hull Section

Film Evening

At the first meeting of the present session, held at the Queens Hotel, Hull on 4 October, two films were shown in place of the previously advertised programme. It is expected that members will have the opportunity of hearing Mr Groom's lecture on pigment dispersion later in the year.

The first film, introduced by Mr F. D. Robinson, was entitled "Who killed the sale?" and showed that others besides the salesman may be responsible for the loss of new business. In a short playlet concerning a fictitious company, a number of incidents were enacted involving sales representative, foreman, receptionist, warehouse staff, secretary and managing director. These culminated in generating sufficient ill feeling in the customer to kill the sale. In the discussion which followed the audience agreed that the customer was at all times the most important person and felt that personnel at all levels in industry would benefit from seeing the film.

The second film, "Pollution" was produced by BP. Sufficient information was presented in the final part of the film to encourage the belief that the battle against pollution is not yet lost.

J.A.H.

Midlands Section

At the Midlands Section Ladies Evening (left to right): The President (Mr A. W. Blenkinsop), Mrs Blenkinsop, Mrs Griffiths, Mr H. J. Griffiths (Chairman, Midlands Section)

Annual Ladies Evening

The Annual Ladies Evening of the Midlands Section was held at the Botanical Gardens, Edgbaston, on Friday 17 September 1971. A total of 205 members, ladies and guests sat down to an excellent meal. The speeches were brief and to the point and were introduced by the Hon. Secretary, Mr D. E. Hopper, as Toastmaster.

The Chairman, Mr H. J. Griffiths, proposed a toast to the ladies and guests. His speech was planned to cover the new regulations for the OCCA qualifications but was scooped by that week's publication of the *Journal*. Instead, after a humorous treatment of the subject of women's liberation, he concluded that equality cannot possibly exist as women are superior in every way. The Chairman welcomed as guests the President, Mr A. W. Blenkinsop and Mrs Blenkinsop; Mr and Mrs Staples on behalf of the Paintmakers' Association; Mr and Mrs Suddaby on behalf of the Birmingham Paint, Varnish and Lacquer Club; Mrs K. Driver of the West Riding Section, the first Lady Section Chairman; the Chairmen and their wives from the London, Bristol, Newcastle and Thames Valley Sections and Mr R. H. Hamblin, Director & Secretary.

In replying on behalf of the ladies and guests, the President, Mr A. W. Blenkinsop, began in a humorous manner and recorded warmly his gratitude for the contribution of the Midlands Section to the deliberations of Council, in particular on the recent issues of education and qualifications. On this, his first visit to the Midlands Section, he was pleased to see so many old friends from far and near.

He also noted that the Midlands were renowned for social activities involving the ladies including, of course, the annual Newton Friend Lecture. Mr Blenkinsop concluded by wishing continued success to the Section.

Mrs K. Driver, Chairman of the West Riding Section, gave a special thanks for the Ladies' Gift which she considered to be eminently successful and referred to the tremendous amount of consideration necessary in making a suitable choice. After the meal, dancing continued until 1 a.m. to the music of the Hilltones and a very convivial evening was enjoyed by all.

R.J.K.

New Zealand Sections

Ninth Convention at Wairakei

The ninth annual conference of the New Zealand Sections, held over the weekend of 6-8 August, marked the twenty-first year of activities for the Oil and Colour Chemists' Association in New Zealand. A record number of delegates and their wives registered for the conference, which was organised by the Auckland Section. Enlarged and improved facilities at the Wairakei Hotel set the scene for a busy programme of technical and social activities.

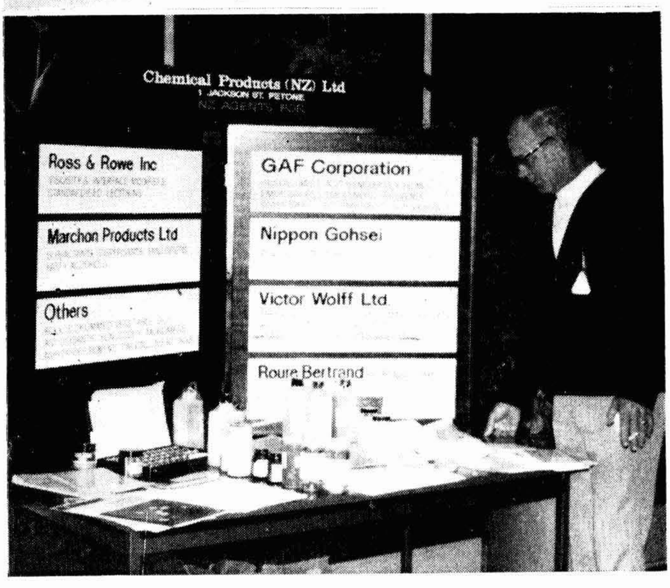
The joint meeting of the Auckland and Wellington Section committees discussed information received during the year and Mr P. B. Hunt reported back on his meetings in London with the Auckland Section's Representative on Council (Mr F. Sowerbutts) and the Director & Secretary (Mr R. H. Hamblin). Professional grades of membership would be introduced in the near future. As a result of the report to Council by the Working Party on education training and qualifications, it had been found possible to introduce the levels of Fellow, Associate and Licentiate without the need to alter the name or character of the Oil and Colour Chemists' Association. A sub-committee has been established to make recommendations for selection in New Zealand, as high standards must be set to ensure acceptance of the professional grades as recognised qualifications.

On display throughout the weekend were commercial applications of advances in the chemistry of surface coatings in this year's Trade Exhibition. This important supplement to the educational programme provides a focus for the latest materials, equipment and technology from those manufacturers supplying the paint, varnish, printing ink and allied industries.

Following a cocktail hour in the main lounge on Friday evening, delegates dined and were addressed after dinner by the Postmaster General, Mr McCready. He congratulated members on their twenty-one years of progress and a specially prepared birthday cake was cut by the New Zealand Vice-President, Mr T. Whitfield, and his wife.

On Saturday morning, the first lecture of the technical session was presented by Mr P. C. Edwards of the New Zealand Fibrous Plaster Manufacturers' Association. Mr Peter Edwards screened a film on the manufacture and application of fibrous plaster and then spoke with particular emphasis on its properties as a substrate for surface coatings. The formation of mildew on fibrous plaster ceilings was discussed and from research done by the DSIR it was found that only when fungal spores, excessive moisture and organic media were present would mould growth occur. Fibrous plaster, being inorganic, was inherently free from mould attack and the use of suitable fungicides in surface coatings would control the problem.

At the second session of the morning, Mr R. D. Bell of Australian Titan Products read a paper entitled "The secondary effects of additives". Additives were used in all aspects of paint manufacture and although their effectiveness could not be denied, it was suggested that insufficient consideration was given



Above: A view of the front of the Wairakei Hotel
Below: Mr O. E. Rutledge, the Chairman of the Auckland Section, examines one of the exhibits in the exhibition held during the Convention

to the effects that they have on other paint properties. Mr Bell gave examples of conflicting additives commonly used and illustrated his address with slides. Additives which affect the rheology of a paint were particularly liable to deleterious effects and it was concluded that secondary effects must also be checked when an additive is under evaluation.

Professor A. L. Titchener, lecturer at the Engineering School of the University of Auckland, ended the morning session with his paper, "Prevention of corrosion by design". The professor gave many practical examples of the way that unnecessary corrosion was caused by poor architectural and engineering design. He showed that very little thought for maintenance was given when steel structures are assembled and the failure of surface coatings to protect against corrosion could often be traced to faults in the original design.

During Saturday afternoon a full programme of sporting activities was conducted, and the two Sections of OCCA clashed over golf, indoor bowls, table tennis, snooker and chess. Non-sporting delegates went for jet-boat jaunts and trout fishing excursions, although no limit bags were reported.

Saturday evening saw the hotel dining room transformed into a maharajah's palace offering a well-spiced menu of Indian dishes with exotic names and flavours. Superb waxen sculptures decorated the buffet table and all the hotel staff were dressed in saris or immaculate Indian costumes. After the meal, delegates and their wives attended the Convention Ball in the new lecture hall and festivities faded away into the early hours of the morning.

The Sunday morning session was opened by Mr C. H. Edwards, Director the Standards Association of New Zealand. Mr Edwards spoke on the vital subject of metrication in industry and he told delegates of the progress made in the United Kingdom, particularly with regard to the metric standards adopted by the paint manufacturers there. It was clear that the economic survival of New Zealand in a metricated world depended upon acceptance of these international standards into its way of life.

Further thoughts on the economy were raised by Mr C. R. Larsen, a well known consulting economist, in his address "Current economic and political trends in New Zealand". This witty and stimulating speech was well received by delegates and Mr Larsen's hard-hitting opinions provoked some spirited questions. After spelling out the limited growth of the paint industry over recent years, he observed that private enterprise activity could not expand production as fast as it would like because of the limited capital resources available after public spending absorbs 45 per cent of the Gross National Product. The only hope New Zealand had of raising productivity was through increased capital formation in the private sector of the economy.

Over the morning tea break Mr R. D. Bell showed a film entitled "Some aspects of film formation in latex paints". This subject was of interest to nearly all delegates and the accelerated filming of coalescence of loaded acrylic latices produced some startling effects. High power micrographs revealed the changes in binding power of various latex vehicles with different types of fillers and the conditions which led to film cracking were clearly demonstrated.

At a brief ceremony, the Auckland Section Chairman thanked the speakers and the delegates for their attendance and Wellington Section extended an invitation to join them at Conference '72.

News of Members

Mr R. A. Bulbeck, an Ordinary Member attached to the Thames Valley Section, has recently passed with credit the examination leading to the Full Technological Certificate of the City & Guilds of London Institute in paint technology.

Mr L. Tasker, an Ordinary Member attached until recently to the Hull Section, has moved to Malta. Mr Tasker, now attached to the General Overseas Section, will be in Valletta for a period of approximately six months from 6 October 1971, advising and assisting in the establishment of a decorative paint factory.

Obituaries

Dr F. A. Askew

We report with regret the death of Dr F. A. Askew, an Ordinary Member attached to the London Section, on 13 September, aged 64. Dr Askew, who was a Member of the Association for more than 20 years, was well-known and respected in the technical circles of printing and printing inks throughout the world, and was editor-in-chief of the latest issue of the Printing Ink Manual.

A. J. Becalick

It is with regret that we report the sudden death on 12 September of Mr A. J. Becalick, an Ordinary Member attached to the Manchester Section.

Mr Becalick was climbing in Snowdonia when he collapsed with heart failure and was dead on arrival at hospital.

He was well known in the area as the representative of Lennig Chemicals Ltd.

Powder Coating Conference

The third conference in the series on powder coating sponsored by the journal "Industrial Finishing and Surface Coatings," will be held at the Connaught Rooms, London on 15 and 16 February 1972. A small exhibition will be held in conjunction with the conference, which is to be opened by Dr G. de W. Anderson, the director of the Paint Research Association and an Ordinary Member attached to the London Section.

The conference is intended to up-date industrial finishers using the process by reviewing developments since the last UK conference two years ago, and also to provide an introduction to those not yet using the process. Full details are available from the Editor, Industrial Finishing and Surface Coatings, 157 Hagden Lane, Watford WD1 8LW.

Chemical Society Summer School 1972

The Chemical Society is to organise a summer school entitled "Computers in chemistry" at the University of Manchester Institute of Science and Technology from 10—15 September 1972. Primarily intended for those with no experience of computers, the school, which will comprise about 50 per cent lectures and 50 per cent practical tutorials, will provide a basic grounding in the construction and operation of computers, and include their use in the chemical industry. If sufficient participants have previous experience of computers, an alternative scheme of work dealing with more advanced aspects will be made available.

Full details can be obtained from Dr M. D. Robinson at the Chemical Society, Burlington House, Piccadilly, London W1V 0BN.

Protective coatings for underwater application

The industrial coatings consultancy and inspection service of Metal and Pipeline Endurance Ltd., in conjunction with the City of London Polytechnic, is to hold a one-day symposium on the above topic at the Sir John Cass College School of Navigation on 4 January 1972. Further information is available from the Registrar, City of London Polytechnic, Jewry Street, London EC3.

Association Notices

Applications for membership

It is felt that the members would like to be reminded of the standard of competence for the election of candidates to Ordinary Membership of the Association, as laid down by the Council, when they are sponsoring candidates for election. The qualifications for the granting of Ordinary Membership at the present time are:

1. A degree in a scientific subject or any generally accepted equivalent qualification; or an approved technological

qualification in a subject covered by the Association.

2. Or where there is adequate evidence of the technical competence of the candidate other than the obtaining of the qualifications mentioned above, the qualifying period of practice in the industries covered by the Association shall be normally not less than seven years.

Associate Membership is open to those employed in the industries who do not qualify for Ordinary Membership.

The Council has further resolved that Student Membership should be open without restriction to the age of 21 years and may be extended to 25 years of age, where candidates are following courses of technical study to the satisfaction of their employers or technical college lecturers.

Retired members

Council also wishes it to be known widely that in 1962 it introduced a reduced membership subscription rate for members who have retired from business. This applies to a member who has completed 20 years as an Ordinary or Associate Member and has retired from business, and normally has reached the age of 60; he may apply for his name to be retained on the Register of Members at an annual subscription rate of £1.05 and he will retain the same rights of membership as the class of membership to which he was attached upon retirement.

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

Change of address

Members changing their address are urged to inform the Association's office immediately so as to avoid any misdirection of mail. This is particularly important as far as the *Journal* is concerned.

Will members please note that since membership of the Association is entirely on an individual basis, if notification of the change of an address for a company is sent to the Association's office this will not necessarily guarantee the change of address in the Association's records of the member concerned unless the name of the member is stated on the communication.

Binding of the "Journal"

Members will be pleased to know that W. Heffer & Sons Ltd., Hills Road, Cambridge, will undertake the binding of back volumes of the Association's *Journal* sent in by individual members at a cost of £2.50 per volume.

Members wishing to avail themselves of this facility should send the parts direct to W. Heffer & Sons Ltd., enclosing a remittance of £2.50 and ensuring that notes bearing their names and addresses are enclosed with the parcels.

1972 members' subscriptions

Members are reminded that 1972 Membership subscriptions to the Association are payable on 1 January 1972. Forms were despatched to all members in October or November, depending upon address.

New members may like to know that the Commissioners of Inland Revenue have approved of the Association for the purpose of the Finance Act 1958, Section 16, so that a member subject to United Kingdom income tax is entitled to a deduction from the amount of his emoluments assessable to income tax for the whole of his annual subscription to the Association, provided the subscription is defrayed out of the emoluments of his office or employment and that the interests covered by the objects of the Association are relevant to such office or employment.

Claims for adjustment of PAYE code numbers should be made on form P.358, copies of which may be obtained from local tax offices.

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

BOLAM, ION BARROW, 110 Malvern Road, Preston Grange Estate, North Shields, Northumberland. (*Newcastle*)

CAMPION, DECLAN F. J., BSc, 10 Pinewood Villas, Willow Park, Dublin 11. (*Irish*)

GOODMAN, ROBERT JOHN, BSc, 11 Emerson Court, Wimbledon Hill Road, London SW19. (*London*)

HANDLEY, ROGER GEORGE, 12 Southlands Road, Goostrey, Crewe CW4 8JF (*Manchester*)

LOKE, YEEN LOW, BSc, 177 Tan Yew Lai Garden, Jalan Puchong, Petaling, Kuala Lumpur, Malaysia. (*Overseas*)

MAGALHAIS, FERNANDO, Rua Vasco Santana N-12, Lavradio, Portugal. (*Overseas*)

STANLEY, MICHAEL PATRICK, BSc, 74 Manor Road, Medomsley, Co. Durham. (*Newcastle*)

TARR, KENNETH, ARIC, Alcombe, Hillersland, Coleford, Gloucester. (*Bristol*)

VIGUS, DAVID EDWARD, BA, 159 Kentwood Hill, Tilehurst, Reading, Berkshire. (*London*)

Associate Member

SEVERINO, EDMUNDO, Avenida 20, No. 39-50, Barquisimeto, Venezuela. (*Overseas*)

Student

TOOKE-KIRBY, DAVID HENRY, School of Chemistry, Bath University of Technology, Claverton Down, Bath, Somerset. (*Bristol*)

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.

Thursday 2 December

Newcastle Section: "Flame retardant coatings—the whys and wherefores" by Mr A. G. Walker of Associated Lead Manufacturers Ltd., to be held at the Royal Turks Head Hotel, Grey Street, Newcastle upon Tyne, at 6.30 p.m.

Monday 6 December

Hull Section: "Emulsion polymers for exterior paints—a comparative study" by Mr K. A. Safe of Vinyl Products Ltd., to be held at Queen's Hotel, Hull, at 7.00 p.m.

Tuesday 7 December

Thames Valley—Student Group: Open invitation lecture to senior members "Microbiology and corrosion" by Dr E. Pankhurst of the Gas Council, to be held in the Main Lecture Theatre, Slough College, at 4.00 p.m.

Wednesday 8 December

London Section: "What's bugging your paint" by Catherine E. Skinner, Microbiological Unit, Paint Research Association, to be held at the South Bank Polytechnic at 7.00 p.m.

Newcastle Section—Student Group: "Instrumental colour measurement" by Mr J. Bravey of British Paints and Chemicals, to be held at the Newcastle Polytechnic, Ellison Place, Newcastle upon Tyne, at 3.00 p.m.

Manchester Section: "One man's views on new approaches to paint manufacturing techniques" by Mr B. Lucas of Joseph Mason & Co. Ltd., to be held at the Royal Institution, Colquitt Street, Liverpool, at 6.30 p.m.

Thursday 9 December

Irish Section: Ladies Night: "Reminiscences" by Dr F. Stoyle of Protem (Ireland) Ltd., to be held at the Clarence Hotel, Wellington Quay, Dublin, at 8.00 p.m.

Scottish Section: "Modern trends in building and building finishes, including paints" by Mr D. K. Barron of the Building Research Station, to be held at the St. Enoch Hotel, Glasgow, at 6.00 p.m.

Midland Section—Trent Valley Branch: "A layman's view of paint" by Mr J. R. Bourne of Mebon Limited, to be held at the British Rail School of Transport, London Road, Derby, at 7.00 p.m.

West Riding Section: Joint meeting with the Society of Dyers and Colourists. "A funny thing happened to me on the way to the Patent Office" by Mr A. T. Ransom, to be held at Bradford University at 7.30 p.m.

Saturday 11 December

Scottish Section—Student Group: Joint meeting. "Organic pigments for use in printing inks" by Mr D. White of Farbwerke Hoechst AG, to be held at the St. Enoch Hotel, Glasgow, at 10.00 a.m.

Monday 13 December

London Section: Joint meeting with Colloid and Surface Chemistry Group of the SCI, "Colloidal aspects of printing inks" by Dr W. Carr of Ciba-Geigy (UK) Ltd., to be held at 14 Belgrave Square, London SW1, at 6.00 p.m.

Wednesday 15 December

Scottish Section—Eastern Branch: "Inter-personnel relationships" by Mr R. M. McKenzie of the Department of Business Studies, Edinburgh University, to be held at the Carlton Hotel, North Bridge, Edinburgh, at 7.30 p.m.

Monday 3 January

Hull Section: "Current thinking on flame retardant paints" by Mr A. G. Walker of Associated Lead Manufacturers Ltd., to be held at the Queens Hotel, George Street, Hull, at 7.00 p.m.

Thursday 6 January

Newcastle Section: "The use of zinc oxide in photocopying techniques" by Mr P. J. Robinson of Durham Chemicals Ltd., to be held at the Royal Turks Head Hotel, Grey Street, Newcastle upon Tyne, at 6.30 p.m.

Tuesday 11 January

Scottish Section—Eastern Branch: Joint meeting with BPBMA. "Developments in ink technology" by Mr G. H. Hutchinson of A. B. Fleming & Co. Ltd., to be held at the Carlton Hotel, North Bridge, Edinburgh, at 6.45 p.m.

Thames Valley Section—Student Group: "Colour" by Mr R. Jeffs of ICI Ltd., Pigments Division, to be held in the main Lecture Theatre, Slough College, at 4.00 p.m.

West Riding Section: "The functions of the Factory Inspectorate" by Mr P. F. J. Buchanan (HM Inspector of Factories, Leeds West District), to be held at the Griffin Hotel, Boar Lane, Leeds, at 7.30 p.m.

Wednesday 12 January

London Section: "The effects of lithographic ink ingredients" by Mr J. R. Groom and Mr K. Atkinson of Sandoz Products Ltd., to be held at the South Bank Polytechnic, Borough Road, SE1, at 7.00 p.m.

Manchester Section—Student Group: "Chlorinated rubber in inks and surface coatings" by Dr D. R. Sayers of ICI Ltd., Mond Division, to be held at the Manchester Literary and Philosophical Society at 4.30 p.m.

Newcastle Section—Student Group: "Marine paints" by Mr W. Hall of British Paints & Chemicals, to be held at the Newcastle Polytechnic, Ellison Place, Newcastle upon Tyne, at 3.00 p.m.

Friday 14 January

Manchester Section: "Pyrolysis gas chromatography" by Mr C. E. Roland Jones of Vinyl Products Ltd., to be held at the Manchester Literary and Philosophical Society, 36 George Street, Manchester 1, at 6.30 p.m.

Scottish Section: Annual Dinner Dance, to be held at the Kintyre Suite, Central Hotel, Glasgow, at 6.30 for 7.00 p.m.

Thursday 20 January

London Section—Southern Branch: Joint meeting with the Institute of Metal Finishing. "Electrodeposition" by Mr McKay of Berger Paints Ltd., to be held at the Lecture Theatre, Chemistry Department, Portsmouth Polytechnic, Burnaby Road, Portsmouth, at 7.30 p.m.

Scottish Section: "Modern trends in printing inks" by Mr G. H. Hutchinson of A. B. Fleming & Co. Ltd., to be held at the St. Enoch Hotel, Glasgow, at 6.00 p.m.

Thames Valley Section: "Painting and printing on plastics" by Mr J. R. Taylor of BP Chemicals International Ltd., and Mr R. G. Kinsman of Winstones Ltd., to be held at the Beech Tree Hotel, Maxwell Road, Beaconsfield, Buckinghamshire, at 7.00 p.m.

Friday 21 January

Irish Section: "Magazine production by the web offset process" by Mr G. F. Jones of Irish Printing Inks Ltd., to be held at the Clarence Hotel, Wellington Quay, Dublin, at 8.00 p.m.

Midlands Section: Annual Dinner Lecture: "Coil coating in the seventies" by Mr P. D. Winchcombe of British Steel Corporation, to be held at the Chamber of Commerce and Industry, 75 Harborne Road, Birmingham, at 6.30 p.m.

Saturday 22 January

Scottish Section—Student Group: "The future of plastics" by Dr N. Grassie of the University of Glasgow, to be held at the St. Enoch Hotel, Glasgow, at 10.00 a.m.

Wednesday 26 January

London Section: "Building paints"—No. 2 in a series on "Surface coatings—their use and abuse", to be held at the South Bank Polytechnic from 2.15 p.m. to 5.30 p.m.

Scottish Section—Eastern Branch: "Aerosols, past, present—future" by Mr D. Lake of DH Industries Ltd., to be held at the Carlton Hotel, North Bridge, Edinburgh, at 7.30 p.m.

Friday 28 January

Bristol Section: Joint meeting with the South Western Branch of the Institute of Printing. "Practical pigment dispersion" by Mr J. Groom and Mr H. Baker of Sandoz Products Ltd., to be held at the Royal Hotel, Bristol, at 7.15 p.m.

Bristol Section Dinner Dance. Please note change of date to Thursday 23 March.

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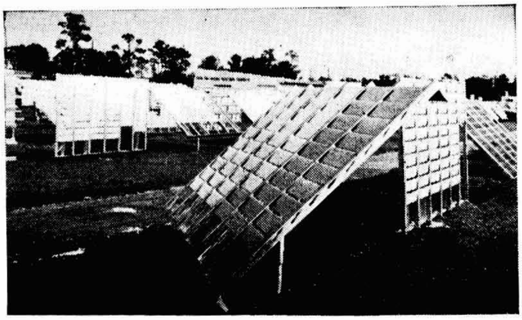

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