INDEX TO ADVERTISERS

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Transactions and Communications

Factors which affect the efficiency of ball milling*

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Summary

Using pigment particle size measurement as the criterion of dispersion and hence grinding efficiency, the effect of the following factors on the efficiency of ball milling of decorative paint stainers was determined: size and speed of the mill; mill base composition; size and shape of the grinding media; percentage ball loading; milling time; mill charge; effect of viscosity and temperature.

A comparison was made of the efficiency of stainer and co-milling techniques.

The pigment particle sizes were measured by an indirect technique based on colour strength determination in conjunction with a previously determined master curve showing the relationship between colour strength and particle size. The results were checked periodically by absolute size measurements on a disc centrifuge.

The main work was carried out with a β phthalocyanine blue and a long oil soya penta alkyd resin.

Some of the findings were examined to see if they applied to other pigments and other resins.

The work has established in detail the effect of operating variables on the grinding efficiency, but the main conclusion is that modern ball milling techniques are not far from the optimum.

Keywords

Les facteurs qui influent l'efficacité du procédé de broyage à billes

Résumé

En utilisant la granulometrie en tant que critère de dispersion et ainsi de l'efficacité de broyage, on a déterminé l'influence sur l'efficacité du broyage à billes des pâtes colorantes pour peintures décoratives qu'exercent les facteurs suivants; les dimensions et la vitesse de rotation du broyeur; la composition de la masse broyante, la grandeur et la forme de l'agent de broyage, la quantité, en pourcentage, de billes, la durée du broyage, l'influence de la viscosité et de la température à la fois.

On a fait une comparaison des deux techniques pour la préparation des peintures colorées soit par l'incorporation d'une pâte colorante à une peinture de base fabriquée préalablement, soit où toutes les deux opérations sont effectuées simultanément lors d'une seul procédé de broyage.

Les grandeurs particulaires étaient mesurées par une technique où il s'agit de déterminer le pouvoir colorant au moyens d'une maître-courbe qui exprime le rapport entre le pouvoir colorant et la grandeur particulaire. Périodiquement les résultats ont été vérifiés en déterminant la vraie grandeur particulaire à l'aide du centrifugeur à disque.

L'étude était effectuée en principe sur un bleu de phtalocyanine du type β et une résine penta-alkyde longue en huile de soja.

On a examiné certaines conclusions afin de trouver si elles sont valables également dans le cas d'autres pigments et résines.

L'étude a établi dans une manière assez détaillée l'effet que portent les variables opératrices sur l'efficacité de broyage, or la conclusion principale c'est que les techniques actuelles de broyage ne sont pas loins de l'optimale.

Faktoren, die das Mahlen mit Kugelmühlen Beeinflussen

Zusammenfassung

Unter Benutzung von Messungen der Pigmentteilchengrösse als Masstab für den Dispersionsgrad und daher auch der Mahlwirkung wurde der Einfluss folgender Faktoren auf den Wirkungsgrad der Kugelmühlenleistung für dekorative Farbtonabdeckpasten bestimmt: Grösse und Geschwindigkeit der Mühle; Zusammensetzung des Mahlkonzentrates; Grösse und Form der Mahlkugeln; Prozent der Kugelladung; Mahldauer; Art des Füllgutes; Einfluss von Viskosität und Temperatur.

Ein Vergleich zwischen der Nützlichkeit der Anwendung von Abtönpasten und der Ko-Vermahlungstechniken wurde vorgenommen.

Die Pigmentpartikelgrössen wurden mittels einer indirekten Technik gemessen, die auf Bestimmung der Farbkraft in Verbindung mit einer zuvor bestimmten Masterkurve beruhen, aus welcher die Beziehungen zwischen Farbkraft und Teilchengrösse hervorgeht. Die Resultate wurden periodisch durch Messungen der absoluten Grösse mittels der Scheibenzentrifuge kontrolliert.

In der Hauptsache wurde die Arbeit mit einem β-Phthalozyaninblau und einem langöligen Soja-Penta-Alkydharz durchgeführt.

Einige Resultate wurden daraufhin geprüft, ob sie auch auf andere Pigmente und Harze anwendbar wären.

Die Arbeit hat im einzelnen die Auswirkung der den Wirkungsgrad beeinflusenden Variablen festgelegt, der wichtigste Schluss ist jedoch, dass moderne Kugelmühlentechniken nicht weit vom Optimum entfernt sind.

Факторы влияющие на эффективность шаровых мельниц

Резюме

Применяя измерение величины пигментной частицы как критерий дисперсии и тем самым эффективности измельчения, определялось влияние следующих факторов на продуктивность размалывания в шаровых мельницах декоративных красочных паст: габарита и скорости мельницы, состава красочной пасты, размера и формы абразивного материала, процента шаровой нагрузки, времени размельчения, заряда мельницы и влияния вязкости и температуры.

Делается сравнение эффективности технологии перемалывания расцветки и совместного размельчения.

Величина пигментных частиц измерялась косвенным методом, основанном на определении красящей способности в совокупности с ранее определенной образцовой кривой, иллюстрирующей зависимость между красящей способностью и размером частицы. Результаты проверялись периодически абсолютным измерением размера на дисковой центрифуге.

Главная часть работы проводилась с фталоцианиновой синью и жирной соевой пента-алкидной смолой.

Некоторые из найденных результатов анализировались, чтобы выяснить их отношение к другим пигментам и смолам.

Работа детально установила влияние оперативных рабочих переменных на эффективность размалывания, но главным выводом является то что современная технология шарового размалывания близка к оптимальной.

Introduction

Paints (and inks) are essentially dispersions of pigments in suitable vehicles. The dispersion process is difficult because pigment powders are light, fluffy and heavily aggregated. This aggregation is inevitable. The basic particle size of most organic pigments is less that 0.1μ and if the pigment powders consisted solely of particles of this size, free from aggregation, they would, in fact, not be powders but dusts or smokes and would be completely impracticable to handle. The aggregates consist of up to a million basic particles, and even at this level of aggregation pigment powders tend to give rise to unpleasant dusts on handling. The breaking down of these aggregates is a slow and difficult process and for this reason dispersion is a slow and difficult process, yet the extent to which dispersion is carried out has important effects on the resultant paint or ink films. It affects strength, shade, brightness, bronzing, gloss, weathering, opacity and transparency. Many application defects are dependent on the degree of dispersion: flocculation, flotation, flooding, brush marks etc. The flow properties of the actual paint or ink are also affected by the extent to which the dispersion process is carried out.

As dispersing the pigment is the key step in the actual manufacture of paints and inks (as distinct from formulating them), as it is a slow and expensive step, and as the degree to which it is carried out affects many properties of the resulting product, it would appear to be essential that this step should be controlled as closely as possible. The conditions for optimum dispersion for any particular equipment should be known and the progress of the dispersion should be capable of being followed, so that the milling process can be stopped whenever the necessary balance has been achieved between economics and performance.

These thoughts are, of course, not new. Unfortunately, they have not been put into practice because the measurement of dispersion is remarkably difficult. The use of grinding gauges has been shown to be very unsatisfactory as a method of assessing dispersion, but no satisfactory alternative method has yet emerged.

In these circumstances, optimum grinding conditions have evolved slowly over the years by dint of trial, error and experience. The assessment of dispersion has been qualitative with respect to some application properties, such as colour strength, gloss or flow.

There is no suggestion that this tremendous wealth of experience has not resulted in a satisfactory way of operating milling processes or one that is far removed from the optimum. However, as new and reliable methods of assessing dispersion have been developed, it is a matter of prudence to use these to check current manufacturing techniques.

This is what the author has attempted to do. It is now possible to measure the dispersion of many organic pigments in certain vehicles accurately and reproducibly, and this technique has been used to investigate, in detail, the factors which control the efficiency of one of the oldest forms of pigment grinding, namely ball milling.

Experimental

Dispersion measurement

It is now possible to measure the actual particle size of the organic pigment in decorative paint stainers, subject to certain restrictions, both directly and indirectly.

The direct measurement is made by centrifugal sedimentation in a Joyce-Loebl disc centrifuge. In this method, the stainer is carefully diluted to a pigmentation level of 0.5 per cent, and 1ml of this dilution is injected into a spinning disc on to the surface of a mixture of white spirit and carbon tetra-chloride. After sedimenting for a pre-determined time, the suspension is sucked off to a fixed depth, and the amount of pigment in this sample is determined analytically. This gives the percentage of pigment below a certain size level. The process is repeated with different times and speeds and a size distribution curve for the original stainer is gradually built up.

Such size distribution curves take at least two whole days' full-time work to be obtained. Therefore, although the method gives an accurate measure of the pigment dispersion in stainers, it is too slow to use in any comprehensive investigation such as was envisaged.

The indirect method relies on the reduction of the stainer with a standard white paint to a known depth of colour, and the accurate measurement of the colour value of a dry film made from this reduction. The colour strength can be measured accurately and quickly on a spectrophotometer. If a master curve that gives the relationship between colour value and particle size of the organic pigment for the same reduction is available, then, knowing the colour value of a specific paint, the mean particle size of the organic pigment can be read off from the graph.

The mean diameter of the pigment in a large number of stainers can be determined in a day by this indirect method, provided a master graph is available.

Factors investigated

The factors it was proposed to investigate were as follows:

Size of the mill,
Speed of the mill,
Mill base composition,
Size and shape of grinding media,
Percentage ball loading in the mill,
Milling time,
Mill charge,
Effect of viscosity,
Effect of temperature,
Co-milling compared with the added stainer technique.

Systems examined

A large number of resin media are available and there is an even larger number of pigments. There is no guarantee that all pigments will behave in the same

way in the ball mill, but it was obviously impossible to examine every system in detail. Some selection had to be made. The choice made is outlined below.

The resin used was an air-drying long oil soya penta alkyd resin (Beckosol P470). The pigment used initially was a β copper phthalocyanine blue, Irgalite Blue GLSM. The advantages of this system are as shown below.

The resin is completely thinnable in white spirit and the pigment is non-bleeding in this thinner. This is a prerequisite for direct particle size measurements.

A curve showing the relationship between the colour value of stainers based on this pigment at 1:12.5 reductions with titanium dioxide is available[1] (Fig. 1). This curve extends over wide range of dispersion and exhibits a marked variation of colour strength with particle size. Colour strength should therefore be a sensitive guide to dispersion.
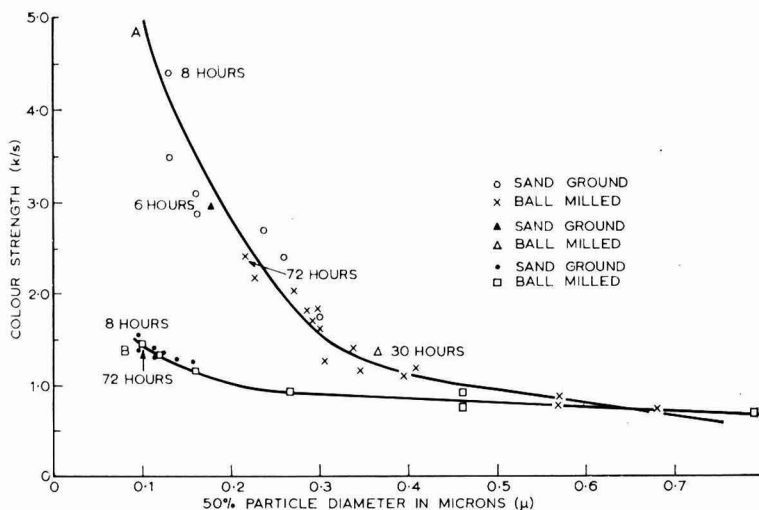
Fig. 1. **Particle size of paint stainers versus colour strength of titanium dioxide reductions (1:12.5)**

(A) copper phthalocyanine blue
    beta form (Irgalite Blue GLS) O X
    stabilised alpha form (Irgalite Blue BSC)   △   ▲
(B) Pigment Green B (Irgalite Green DBN)

Previous work[2] has shown that this particular pigment in this particular resin disperses in a reasonable manner in the ball mill; not too slowly nor too rapidly.

Procedure

The changes were rung on all the factors likely to affect the grinding efficiency of the ball mill using Blue GLSM and Beckosol P470 as the main components.

The dispersion level achieved at the end of each experiment was determined by the indirect method. A small amount of the stainer was reduced with a standard white paint made from titanium oxide in Beckosol P470. This contained

25 per cent TiO$_2$ at a P/B ratio of 1/1.59 and had been ball milled for 24 hours. The reduction of the blue in each case was 1:12.5. A film of the reduced paint was drawn down on board with a block applicator. After drying, it was examined on a Hardy Spectrophotometer and its K/S value determined. The mean diameter corresponding to this was read off from the master curve shown in Fig. 1.

At appropriate times, checks were made on this technique, by measuring the size distribution of the pigment in the stainers by the direct method using the Joyce-Loebl disc centrifuge.

When the project was completed, some of the findings were examined to see if they were applicable to other pigments and other resins.

A comparison was also made of the relative efficiencies of a co-milling of Blue GLSM and titanium oxide and the corresponding stainer addition technique.

Results

The size of the ball mill

In day to day laboratory ball mill trials, 1lb honey jars are used. For the large number of trials envisaged it was essential to see if the results obtained from experiments with these jars had any relevance to results obtained with larger mills, or whether efficiency depended on the size of the mill. The literature is uncertain on this point.

One factor which does alter with the size of the mill is its critical speed. This is defined as the speed at which the balls are just held against the wall of the mill by centrifugal force. It can be expressed mathematically by the formula:

$$\frac{54.14 \times \text{rpm}}{\sqrt{r}}$$ where r = the internal radius measured in feet.

To obtain pigment dispersion, the mills must be rotated at speeds less than their critical speeds.

Ball mills of the following nominal capacities were used: 1 pint, 2 pint, $\frac{1}{2}$ gallon, 1 gallon, 2 gallon.

Their dimensions were measured and their critical speeds calculated. These are shown in Table 1.

Table 1
Critical speeds of different sized mills

Nominal capacity			r (in feet)	$\sqrt{r}$	Critical speed (rpm)	Volume (ml)
1 pint	..	..	0.148	0.385	140.6	500
2 pint	..	..	0.183	0.428	126.5	1,000
$\frac{1}{2}$ gallon	..	..	0.212	0.460	117.7	2,500
1 gallon	..	..	0.291	0.539	100.5	5,000
2 gallon	..	..	0.377	0.614	88.2	10,000

As a starting point in terms of formulation of the millbase, the following was used:

	Blue GLSM	20g	
	Beckosol P470	40g	mixed together
	White Spirit	38.8g	before adding the pigment

Mill for 24h

Add   Beckosol P470   50g   to stabilise millbase

Mill for 1h

Add	Beckosol P470	46.4g
	Driers	4.8g
	Total	200.0g

This formulation was in general use in the paint laboratories. It has evolved from previous experience and from discussions with pigment users.

Specification

Millbase		Final Paint	
Medium Solids ..	35.5%	Medium Solids ..	53%
% Pigment ..	20.2	% Pigment ..	10
P/B ratio ..	1/1.39	P/B ratio ..	1/4.77

This is the formulation normally used in 1lb honey jars of 300ml volume, containing also 300g of steatite balls. This weight of balls gives an apparent volume of 200ml, i.e. an apparent ball loading of 66.6 per cent by volume. For use in the pot mills, the formulation was scaled up proportionately.

Paints were prepared in the various mills rotating at equal speeds, i.e. at the same revs per minute and also rotating at approximately 40 per cent of their critical speeds.

They were then reduced with a standard white paint (1:12.5) and the colour strengths of films of the reduced paints were examined on a GE spectrophotometer for their K/S values, which are directly proportional to their colour strengths.

The results are given in Tables 2 and 3.

Table 2
Rotation at equal speeds

Size of the mill			K/S value	Mean size from graph (μ)	rpm	% Critical speed
1 pint	..	..	1.535	0.315	56	40
2 pint	..	..	1.535	0.315	59	47
½ gallon	..	..	1.520	0.320	53	45
1 gallon	..	..	1.680	0.285	57	57
2 gallon	..	..	2.080	0.240	54	61

Conclusion: There is no doubt that under these conditions the largest mill is most efficient.

Table 3

Rotation at similar percentages of the critical speed

Size of the mill			K/S value	Mean size from graph (μ)	rpm	% Critical speed
1 pint	..	..	1.535	0.315	56	40
2 pint	..	..	1.535	0.315	59	47
½ gallon	..	..	1.520	0.320	53	45
1 gallon	..	..	1.562	0.310	42	41
2 gallon	..	..	1.503	0.330	36	41

Conclusion: Provided that other things are equal, then grinding efficiency is independent of the size of the mill if the rotation is carried out at the same percentage of the critical speed.

A direct comparison was then carried out between a pint pot mill and a 1lb glass honey jar, using steatite balls in both. Apart from the size difference, there is also a difference in grinding surfaces, e.g. from steatite to pot and steatite to glass.

Millbases were ground in both at 20 per cent pigmentation, P/B ratio 1/1.39, using a 35 per cent medium solids vehicle, being reduced after 24 hours milling to 10 per cent pigmentation with a P/B ratio of 1/4.77.

1:12.5 reductions with the standard white gloss paint were made and evaluated for colour strength and particle size of the blue pigment.

Results are shown in Table 4.

Table 4

1 lb honey jar versus 1 pint pot mill

Mill		K/S	Mean particle size (μ)	rpm	% Critical speed
1 lb honey jar	..	1.57	0.310	80	51
1 pint pot mill	..	1.57	0.310	70	50

The slight difference in percentage of the critical speeds is shown later not to be significant.

Conclusion: There are no differences in the dispersing efficiencies of 1lb glass honey jars and larger pot mills.

The remainder of the work was therefore carried out in the honey jars.

Speed of rotation of the mill

The critical speed of a 1lb honey jar was calculated to be 158 rpm.

By placing the jars on various available types of laboratory rollers, rotational speeds of 55, 80, 100, 120, 140 and 180 rpm could be obtained, corresponding to percentage critical speeds of 34, 51, 63, 76, 89 and 114.

Stainers were made, grinding with both steatite and steel balls, using the same millbases and formulations, in the honey jars and grinding for 20 hours at the different speeds available.

Reductions of 1:12.5 with the standard white were made and evaluated for colour strengths and hence particle sizes.

Results are shown in Tables 5 and 6.

Table 5
Effect of speed of rotation—steatite balls

% Critical speed	K/S value	Mean particle size (μ)
34	1.410	0.340
51	1.580	0.305
63	1.660	0.290
76	1.760	0.275
89	1.785	0.270
114	1.585	0.305

Table 6
Effect of speed of rotation—steel balls

% Critical speed	K/S value	Mean particle size (μ)
34	1.910	0.255
51	2.070	0.235
63	2.160	0.225
76	2.270	0.215
89	2.300	0.210
114	2.100	0.230

These results are shown graphically in Fig. 2, where both the colour strengths (K/S values) and particle sizes are plotted against the percentage critical speeds.
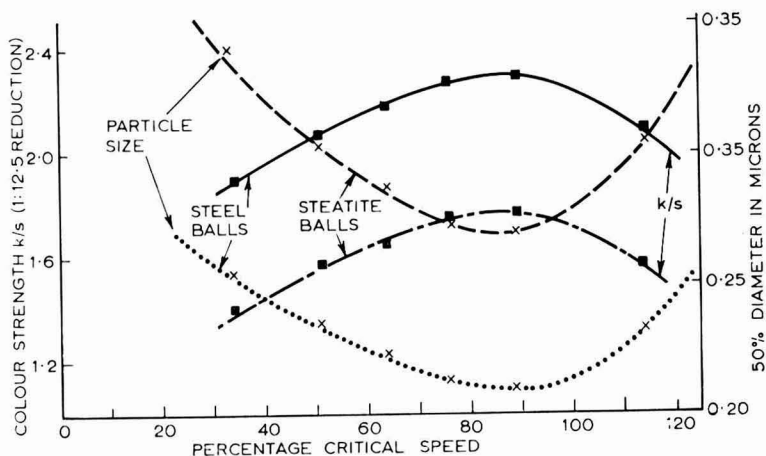
Fig. 2. Irgalite Blue GLSM. Colour strength and particle size in relation to percentage critical speed

With both types of balls, the colour strength goes through a shallow maximum with increasing speeds. Similarly, the mean diameters achieved go through a corresponding shallow minimum. In subsequent graphs, for the sake of clarity, only the colour strengths are plotted against the operational variable.

Conclusion: Rotational speed does affect the grinding efficiency of ball mills, the optimum speed being in the region of 70–95 per cent of the critical speed.

Future work was carried out at a percentage critical speed of 73.

Millbase composition using steatite balls

The following factors were examined: percentage medium solids of the vehicle; percentage pigmentation; pigment/binder ratio.

Percentage medium solids of the vehicle in the millbase: Ball millings were carried out keeping the pigmentation level constant at 20 per cent and varying the medium solids of the vehicle between 5 per cent and 70 per cent. After 24 hours' ball milling, the paints were reduced to 10 per cent pigmentation.

Reductions with a standard white paint at 1:12.5 were prepared and evaluated for colour strength and hence particle size.

Table 7
Effect of percentage medium solids (steatite balls)

% Medium solids	K/S value	Mean particle size (μ)
5	1.035	0.445
10	1.390	0.327
15	1.480	0.315
20	1.550	0.305
25	1.670	0.285
30	1.720	0.275
35	1.720	0.275
40	1.670	0.285
45	1.560	0.300
50	1.470	0.320
55	1.290	0.355
60	1.050	0.440
65	0.538	0.9
70	0.446	0.9

The results are given in Table 7 and illustrated graphically in Fig. 3.

The graph of colour strength versus percentage medium solids shows that, at a pigmentation level of 20 per cent, a maximum occurs in the region from 30 per cent to 35 per cent medium solids.

Consequently, for further work, a 30 per cent medium solids has been used.

Percentage pigmentation: Ball millings were made keeping the medium solids at 30 per cent and varying the pigmentation level from 15 to 30 per cent.

After 24 hours' milling, each millbase was reduced to a paint with 10 per cent pigmentation. Reductions were made with a standard white paint at 1:12.5 and evaluated for colour strength and hence particle size.

The results are given in Table 8.
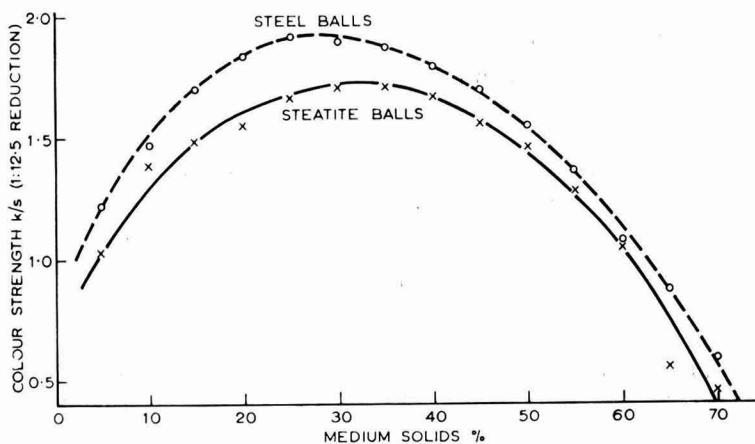
Fig. 3. Irgalite Blue GLSM. Colour strength in relation to medium solids content at 20 per cent
pigmentation

Table 8
Effect of pigmentation level (steatite balls)

% Pigment	K/S value	Mean particle size (μ)
15	1.70	0.280
20	1.72	0.275
25	1.50	0.310
30	1.21	0.375

From these results it is seen that a pigmentation level of from 15 to 20 per cent
gives greater colour strength and smaller particle size, i.e., better dispersion.
The upper limit of 20 per cent is obviously the more practical figure.

From the above results for optimum medium solids and pigmentation level,
the following formulation emerges as giving the greatest colour strength and
hence smallest particle size and greatest degree of dispersion after the chosen
milling time.

Millbase

	20.0g	pigment	
	34.3g	Beckosol P470 ⎫	being mixed together
	45.7g	white spirit ⎭	before addition of pigment
Mill for 24h			
Add	45.6g	Beckosol P470	to stabilise mill base
	4.4g	Driers	
Total	200.0g		

Specification:

	Millbase	Pigmentation	..	..	20%
		Medium solids	..	..	30%
		Pigment/binder ratio	..	1/1.2

The final paint composition may vary but a typical formulation would be:

Pigmentation	..	..	10%
Medium solids	..	..	50.5%
Pigment/binder ratio	..	1/4.55

This method for determining the optimum millbase formulation takes much longer than the Daniel Flow Point method, but it is doubtful whether this latter technique is of much value when using organic pigments giving rise to a complicated rheology.

In this work $\frac{3}{8}$in diameter steatite balls were used, and the work was repeated using steel balls $\frac{3}{16}$ in in diameter.

The effect on colour strength and mean particle size of varying the percentage medium solids is shown in Table 9 and graphically in Fig. 3.

Table 9
Effect of percentage medium solids (steel balls)

% Medium solids	K/S value	Mean particle size (μ)
5	1.230	0.410
10	1.476	0.320
15	1.705	0.285
20	1.835	0.260
25	1.925	0.245
30	1.900	0.250
35	1.875	0.255
40	1.805	0.277
45	1.700	0.280
50	1.550	0.310
55	1.360	0.345
60	1.070	0.435
65	0.875	0.520
70	0.591	0.700

The graph of colour strength versus percentage medium solids shows a maximum in the range 25–35 per cent medium solids when the pigmentation level is 20 per cent. For further work, when using steel balls, a 25 per cent medium solids composition was selected.

The optimum pigmentation level was found by carrying out ball millings at 25 per cent medium solids and varying the pigmentation level from 15 per cent to 30 per cent.

Each millbase was reduced to 10 per cent pigment and 1:12.5 reductions made with a standard white gloss paint and evaluated for colour strengths and particle size. The results are given in Table 10.

Table 10
Effect of pigmentation level (steel balls)

% Pigment	K/S value	Mean particle size (μ)
15	2.010	0.235
20	2.010	0.235
25	1.925	0.245
30	1.290	0.350

This table shows that the optimum pigmentation level is in the region of 15–20 per cent, the upper limit of 20 per cent being the more practical figure.

A repeat of this series of tests at a medium solids content of 30 per cent gave the same result, the optimum pigmentation level being 15–20 per cent.

The optimum conditions of millbase formulation are, therefore, seen to be practically identical when using either steatite or steel balls, namely a medium solids of 30 per cent and a pigmentation of 20 per cent, and these are the conditions used in subsequent work.

Size and shape of grinding media

In order to determine the effect of size on grinding efficiency, experiments were carried out with steel balls of $\frac{3}{16}$in and $\frac{1}{2}$in diameter and with steatite balls of $\frac{3}{8}$in and $\frac{3}{4}$in diameter. The formulations used were the same as those in the examination of the effect of ball mill size and evaluation was carried out in the usual way.

Results are given in Tables 11 and 12.

Table 11
Effect of size of steel balls*

Diameter (in)	K/S value	Mean particle diameter (μ)
$\frac{3}{16}$	1.71	0.285
$\frac{1}{2}$	1.20	0.375

*The same total weight of balls was used in each grind.

Table 12
Effect of size of steatite balls*

Diameter (in)	K/S value	Mean particle diameter (μ)
$\frac{3}{8}$	1.430	0.325
$\frac{3}{4}$	1.155	0.39

*The same total weight of balls was used in each grind.

To determine the effect of shape, the efficiency of ¾in diameter steatite balls was compared with that of commercial pebbles, stated to be similar in size and density. Results are given in Table 13.

Table 13
Comparison of steatite balls and pebbles

Grinding media	K/S value	Mean particle diameter (μ)
Steatite balls (¾in)	1.155	0.39
Pebbles (¾in approx.)	1.140	0.40

From these results it can be concluded that : the size of the grinding media *is* critical, and the shape of the grinding media is not critical.

The effect of the size of steatite balls was investigated in more detail using the optimum millbase formulation and pigmentation level found previously. Evaluation of the dispersions obtained was by the usual method. Results are given in Table 14.

Table 14
Effect of the size of grinding media (steatite)

Diameter (in)	K/S value	Mean particle diameter (μ)
⅛	1.81	0.265
¼	1.77	0.270
⅜	1.72	0.280
½	1.58	0.300
¾	1.36	0.335

These results are plotted in Fig. 4 and confirm that the smaller is the diameter of the grinding media, the greater the colour strength obtained, and therefore the better the dispersion. In this series the same total weights of the different sizes of balls were used, and these all had the same apparent volume.
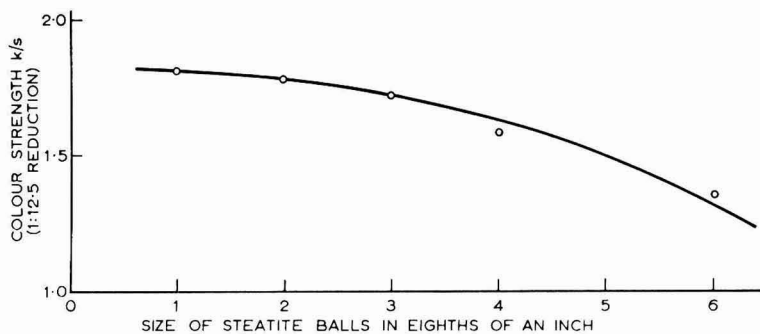
Fig. 4. Irgalite Blue GLSM. Colour strength in relation to size of steatite balls

Percentage ball loading

The optimum ball loading for ⅜in steatite balls was determined in another series of ball millings. The ball loadings in the honey jars were as shown in Table 15.

Table 15
Per cent loadings (steatite balls)

Apparent volume of balls (ml)	% Ball loading	Weight of balls (g)
50	16.6	75
100	33.3	150
150	50.0	225
200	66.6	300
250	83.3	375
300	100.0	450

The formulations were the same as those used in the determination of optimum mill base composition, the milling time was 20 hours and the resultant paint stainers were evaluated in the usual way. The results are given in Table 16 and shown graphically in Fig. 5.

Table 16
Effect of ball loading (steatite balls)

% Ball loading	K/S value	Mean particle diameter (μ)
16.6	1.396	0.335
33.3	1.580	0.305
50.0	1.640	0.295
66.6	1.740	0.280
83.3	1.720	0.280
100.0	1.604	0.300
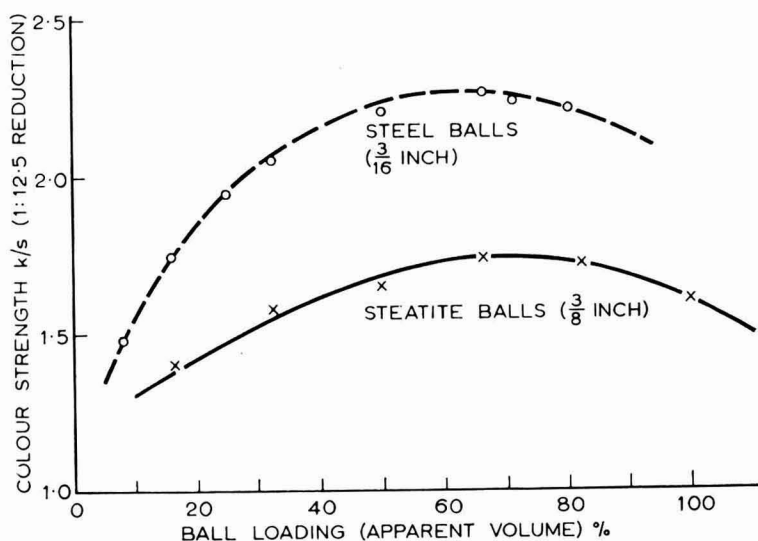
Fig. 5. Irgalite Blue GLSM. Colour strength in relation to ball loading

The graph shows that the maximum colour strength and dispersion is obtained with ball loadings of 66–83 per cent by apparent volume. The maximum is a rather shallow one and a reduction of ball loading to 50 per cent would only reduce the colour value by 4–5 per cent.

The series of ball millings were repeated with $\frac{3}{16}$ in steel balls. The results are given in Table 17 and shown graphically in Fig. 5.

Table 17
Effect of ball loading (steel balls)

% Ball loading	K/S value	Mean particle diameter (μ)
8.33	1.47	0.320
16.66	1.75	0.275
25.00	1.94	0.250
33.3	2.04	0.235
50.00	2.20	0.220
66.60	2.25	0.215
71.30	2.23	0.217
80.00	2.20	0.220

Again the graph shows a maximum in the effect of ball loading on colour strength and dispersion, the maximum occurring in the region 50 to 80 per cent. This is somewhat lower than in the case of the lighter steatite balls but again the maximum is a shallow one and there is only 1 or 2 per cent extra colour strength to be obtained by increasing the ball loading above 50 per cent.

All percentage ball loadings are the ratios of apparent volume of the balls to the total volume of the mill.

Times of milling

Stainers were prepared with the same formulation using both steatite and steel balls, and varying the ball milling times from two hours up to 72 hours. They were evaluated for dispersion in the usual way. The results are given in Table 18 and are also shown graphically in Fig. 6.

Table 18
Effect of milling times

Milling time (hours)	Steatite balls		Steel balls	
	K/S value	Mean particle diameter (μ)	K/S value	Mean particle diameter (μ)
2	1.084	0.430	1.200	0.390
4	1.250	0.375	1.420	0.335
8	1.480	0.320	1.835	0.265
12	1.590	0.305	2.020	0.240
16	1.690	0.285	2.140	0.225
24	1.820	0.270	2.290	0.210
30	1.860	0.260	2.310	0.210
36	1.900	0.255	2.330	0.205
48	1.970	0.245	2.360	0.205
60	2.020	0.240	2.400	0.200
66	2.070	0.235	2.410	0.200
72	2.120	0.230	2.440	0.195

The curves in Fig. 6 demonstrate that with this particular pigment (Blue GLSM) in this particular resin, the bulk of the dispersion takes place in the first eight hours' milling. For times longer than 24 hours, the colour strength and dispersion only improve very slowly with extra times of milling. For normal commercial grinding and for laboratory tests and comparisons, 24-hour ball-millings would seem to be reasonably satisfactory.
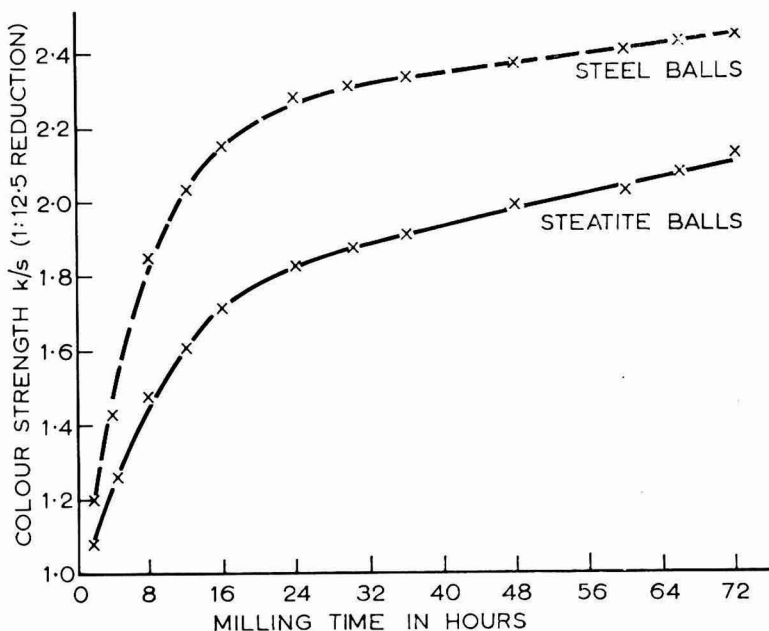
Fig. 6. Irgalite Blue GLSM. Colour strength in relation to milling time

Mill charge

Discussions with a selection of paint makers revealed that the average ball mill loading was a ball mill charge of 50 per cent apparent volume with just sufficient millbase to cover the balls.

Accordingly, stainers were made by ball milling to the following specifications, using steatite balls as the grinding media.

    (a)   50g millbase + 250g balls (55.5% apparent volume)
    (b)   80g millbase + 250g balls (55.5% apparent volume)
    (c) 100g millbase + 250g balls (55.5% apparent volume)
    (d) 100g millbase + 300g balls (66.6% apparent volume)

In (a) the mill base was insufficient to cover the balls; in (b) and (d) it just covered the balls, and in (c) it more than covered the balls.

Ball milling times were 20 hours. The stainers were evaluated in the usual way. The results are given in Table 19.

Table 19
Effect of mill charge

Mill charge				K/S value	Mean particle diameter (μ)
(a) 50g millbase + 250g balls	..	..	..	2.00	0.240
(b) 80g millbase + 250g balls	..	..	..	1.73	0.280
(c) 100g millbase + 300g balls	..	..	..	1.69	0.285
(d) 100g millbase + 300g balls	..	..	..	1.67	0.290

This table shows clearly that the best results are obtained when the mill-base is insufficient to cover the balls. It is generally accepted in the industry that such a low level of addition would give rise to extra wear on the balls and the mill lining. Certainly it would reduce the output of the mill.

The actual volume of the steatite balls used in these trials was determined by measurement. It was found to be 60 per cent of the apparent volume. This agrees with figures of 40 per cent quoted in the literature for the void volume.

The volume composition of the mill charge can accordingly be expressed as in Table 20.

Table 20
Volume composition of the mill charges

Mill charge		a	b	c	d
Actual volume of balls (%)	..	33.3	33.3	33.3	40.0
Volume of millbase (%) ..	..	16.7	26.7	33.3	33.3
Volume of air (%)	..	50.0	40.0	33.3	26.7
Ratio balls/millbase/air	..	2/1/3	1.2/1/1.5	1/1/1	1.2/1/0.8

Table 19 also shows that there is little, if any, significant difference in the efficiency of mill charges b, c and d.

Effect of viscosity

The viscosities of the medium at various resin solids contents were measured at room temperature using a No. 4 Ford Cup, before milling and before any pigment was added.

Fig. 7 shows the results graphically, flow time being plotted against percentage medium solids.

It can be seen from this graph that, at 40 per cent medium solids, the viscosity commences to increase rapidly. Fig. 3 indicated that, when milling at 40 per cent and upwards medium solids, there are significant decreases in colour strength and dispersion. It can be deduced, therefore, that once the viscosity of the medium in the mill base reaches a certain value, the efficiency of the dispersion process falls off rapidly.
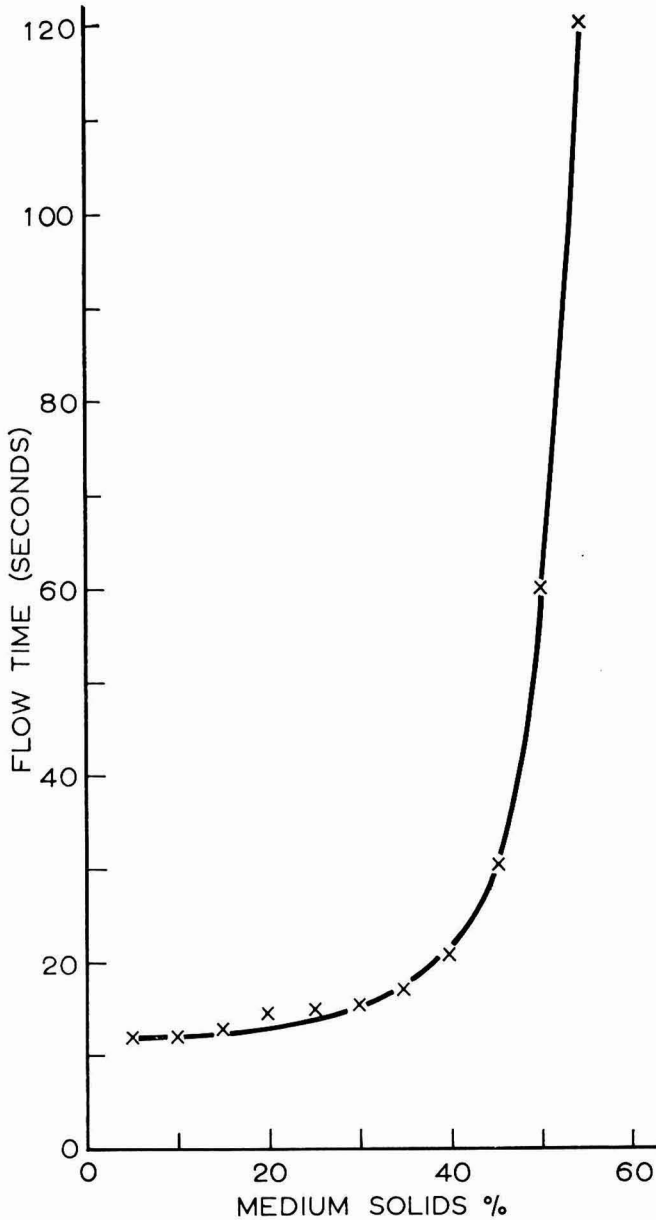
Fig. 7. Unpigmented millbase. Flow time in relation to medium solids content

Effect of grinding temperature

Using optimum medium solids and pigmentation level, stainers were made by ball milling for 20 hours at temperatures of 25°, 40°, 60° and 70°C.

Reductions of these stainers at 1:12.5 were made with a standard white paint and the resultant paints evaluated in the usual way.

Results are given in Table 21.

Table 21

Effect of temperature

Temperature	K/S value	Mean particle diameter (μ)
25°C	1.76	0.270
40°C	1.77	0.270
60°C	1.79	0.270
70°C	1.82	0.265

These results show that grinding efficiency is independent of temperature up to 70°C.

Cross checks on dispersion results

As outlined in the procedure, a certain number of the stainers were taken and their particle size distributions were measured on the disc centrifuge. From the size distribution curves, the 50 per cent weight mean diameter was read off and compared with the mean diameter obtained by the indirect method used in all the above work.

The results of this cross checking can be seen in Table 22.

Table 22

Cross checks on dispersion results in the disc centrifuge

Sample	Red 1	Red 2	Blue 1	Blue 2	Blue 3	Blue 4
K/S method ..	0.260μ	0.365μ	0.19μ	0.285μ	0.445μ	0.450μ
Direct method ..	0.285μ	0.370μ	0.17μ	0.300μ	0.425μ	0.430μ

It is felt that the agreement between the particle diameters obtained by the two methods is good enough to justify the continued use of the indirect method.

Optimum formulation

From these trials an optimum milling procedure and formulation can be built up for this particular pigment and this particular resin using ⅜in diameter steatite balls. It is interesting to compare this optimum formulation with the original starting formulation which, as already mentioned, was based on practical experience and accepted practice. This comparison is shown below in Table 23, which also gives the optimum formulations for two other pigments.

Table 23
Original and optimum formulations

		Original formulation	Optimum formulations for		
			Blue GLSM	Red M2B	Violet 6RLT
	Pigment (g) ..	20.0	20.0	25.0	25.0
	Beckosol P470 (g) ..	40.0	34.3	32.2	32.2
	White spirit (g) ..	38.8	45.7	42.8	42.8
Mill 20h add					
	Beckosol P470 (g) ..	50.0	50.0	50.0	50.0
Mill 1h add					
	Beckosol P470 (g) ..	46.4	45.6	45.6	45.6
	D4 Driers (g) ..	4.8	4.4	4.4	4.4
		200.0	200.0	200.0	200.0
Millbase					
	% pigment ..	20	20	25	25
	% medium solids ..	35.5	30	30	30
	P/B ratio	1/1.4	1/1.2	1/1.1	1/1.1
Final paint					
	% pigment ..	10	10	12.5	12
	% medium solids ..	53	50.5	·51.1	51.1
	P/B ratio ..	1/4.8	1/4.6	1/3.6	1/3.6

A comparison of the results, in terms of the colour strength and particle size reduction that are given by the original and optimum formulations, is given in Table 24.

Table 24
Comparison of results obtained by the original and optimum formulations

			Initial formulation	Optimum formulation
Blue GLSM	K/S value ..		1.72	1.72
	50% diameter ..		0.28µ	0.28µ
Red M2B	K/S value ..		0.60	0.61
	50% diameter ..		0.305µ	0.295µ
Violet 6RLT	K/S value ..		0.35	0.355
	50% diameter ..		0.165µ	0.165µ

It can be seen from Table 24, that the optimum formulations do not give any better dispersions than the original ones based on experience. The slight changes in the formulations would have some practical advantages.

In the case of the Blue GLSM, the lower medium solids should give better drainage from the mill.

In the case of the red and the violet, the higher pigmentation levels would give a bigger throughput of stainer.

These results are a striking confirmation of the soundness of the original formulations.

Effect of mill size

Having optimised the procedure, another check was made on the effect of the mill size. The optimum formulation was milled in a 1lb honey jar and in a gallon pot mill. The formulations were the same in percentage compositions, the two vessels were rotated at the same percentage critical speeds for 20 hours.

The results are given in Table 25 for Blue GLSM and Red M2B, and confirm that the efficiency is independent of the size of the mill.

Table 25
Effect of mill size

Pigment	Mill	K/S value	50% Diameter (μ)
Blue GLSM ..	1lb jar	1.70	0.280
Blue GLSM ..	1 gallon pot	1.67	0.290
Red M2B ..	1lb jar	0.620	0.285
Red M2B ..	1 gallon pot	0.610	0.290

Co-milling versus stainer technique—Blue GLSM

A direct comparison was then made between co-milling and stainer ball mill techniques.

For the stainer technique the optimum formulation was used, the milling time being 20 hours in a 1lb honey jar with 300g steatite balls. A 1:12.5 reduction was made with a standard white gloss paint containing 25 per cent TiO_2.

For the co-milling trial, the formulation was based on that of the standard white gloss paint with the addition of the Blue GLSM to give a 1:12.5 ratio of blue to white.

The corresponding films were measured on the spectrophotometer and the corresponding diameters of the blue pigments were calculated. The results are shown in Table 26.

Table 26
Comparison of co-milling and stainer addition

	K/S	50% diameter (μ)
Stainer ..	1.74	0.280
Co-milling ..	2.14	0.225

This demonstrates that co-milling gives a better dispersion and approximately 16 per cent better colour value. On the other hand, further work showed that the efficiency of the co-milling technique was dependent on the ratio of blue

to white and fell off when this ratio was reduced. The results are shown in Table 27.

Table 27

Co-milling efficiency—Blue GLSM

Reduction	K/S value	50% Diameter (μ)
1:12.5	2.14	0.225
1:25	1.01	0.240
1:50	0.46	0.265
1:100	0.22	0.280
1:200	0.10	0.300

Comparing tables 26 and 27, a revised comparison between co-milling and stainer techniques can now be made.

At a ratio of blue to white of 1:100, the efficiency of the two techniques is the same. At greater levels of blue than 1:100, the co-milling technique is more efficient. At lower levels of blue than 1:100 the co-milling technique is less efficient.

Other pigments

Some of the findings from the above work were checked using two other pigments in the same resin, Beckosol P470. The other two pigments were Violet 6RLT, a carbazole violet, CI Pigment Violet 34, and Red M2B, a manganese 2B toner, CI Pigment Red 48. The optimum formulations for these two pigments has already been given (Table 23) and also the effect of the mill size with the Red M2B (Table 25). There were no basic differences in the results for the three pigments.

Effect of speed of rotation

One finding was the effect of the speed of rotation on the milling efficiency. Unfortunately, the advent of new rollers in the laboratory meant that only four speeds of rotation were available, representing 34, 73, 76 and 114 per cent of the critical speed.

The effects of this variation in speed was examined for these two pigments in the same manner as the earlier work for the blue. Results are given in Tables 28 and 29.

Table 28

Effect of speed on milling of Red M2B

% Critical speed	K/S value	50% diameter (μ)
34	1.030	0.360
73	1.274	0.280
76	1.292	0.275
114	1.100	0.335

Table 29

Effect of speed on milling of Violet 6RLT

% Critical speed	K/S value	50% diameter (μ)
34	2.00	0.190
73	2.30	0.160
76	2.32	0.160
114	2.10	0.175

These results are shown graphically in Fig. 8 together with the earlier results for the Blue GLSM.

The graphs show that the same relationship holds good for all three pigments. As the percentage critical speed is increased from say, 70 per cent to 105 per cent, the grinding efficiency, as determined by colour strength, goes through a shallow maximum.
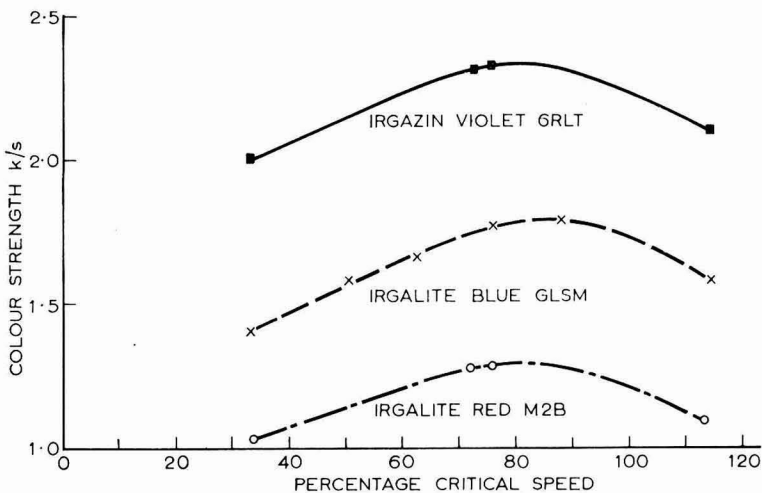
Fig. 8. Irgazin Violet 6 RLT, Irgalite Blue GLSM and Irgalite Red M2B. Colour strength in relation to percentage critical speed

Effect of grinding times

Again this experiment was repeated with the Red M2B and the Violet 6RLT using the optimum formulations. The milling times ranged from two hours to 72 hours. Standard reductions were made with the standard white paint and their K/S values determined. From the master curves of K/S versus particle sizes, the corresponding 50 per cent diameters were read off.

The results are shown graphically in Fig. 9 which plots 50 per cent diameter against milling time for the two pigments and includes the earlier results for the blue for comparison.
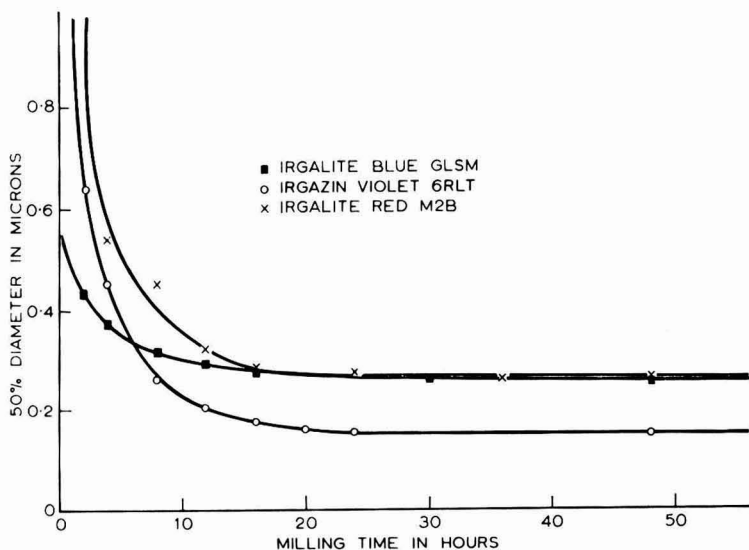
Fig. 9. Irgazin Violet 6 RLT, Irgalite Blue GLSM and Irgalite Red M2B. Particle size in relation to milling time

In terms of size reduction with time, the blue and the red are almost indentical after 16 hours' grinding.

The curve for the violet is similar but parallel, lower levels of particle size being reached.

In all three cases, after 24 hours' grinding, further size reduction takes place only very slowly.

When different pigments are compared in this way, it is important to remember that the colour strength varies with size for each pigment in a different manner, i.e. the K/S versus particle size graphs are different. Consequently, if colour strengths versus milling time graphs are plotted for the three pigments, the blue and the red are much different in behaviour, as shown in Fig. 10.

These limited experiments would seem to indicate that different pigments are affected in the same way as the Blue GLSM when the milling conditions are varied.

Co-milling versus stainer addition technique—Violet 6RLT and Red M2B

A direct comparison was made between co-milling and stainer addition techniques for the Violet 6RLT and Red M2B, using ball milling in each case. The experimental procedure was the same as that for the blue.

Again it was found that the efficiency of the co-milling process fell off as the ratio of organic pigment to white was reduced. The results are given in Table 30.
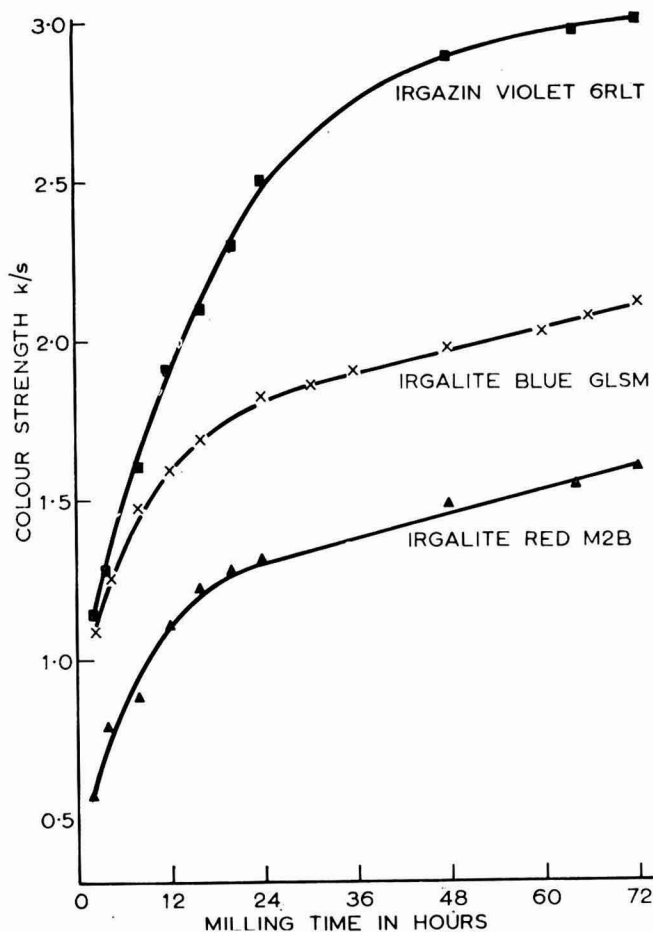
Fig. 10. Irgazin Violet 6 RLT, Irgalite Blue GLSM and Irgalite Red M2B. Colour strength in
relation to milling time

Table 30
Co-milling efficiency

Reduction	Violet 6RLT		Red M2B	
	K/S value	50% diameter (μ)	K/S value	50% diameter (μ)
1:12.5	2.230	0.16	1.310	0.275
1:25	1.010	0.18	0.615	0.295
1:50	0.480	0.20	0.300	0.300
1:100	0.220	0.23	0.145	0.305
1:200	0.115	0.22	0.070	0.325

Using the stainer technique, the result was as follows: Violet 6RLT/1 : 12.5/
2.230/0.16μ. Red M2B/1:12.5/0.620/0.290μ.

The comparison between the two techniques is slightly different from that found for the Blue GLSM.

With the Violet 6RLT, at a ratio of 1:12.5, the efficiency of the two techniques is the same.

At greater reductions than 1:12.5, the co-milling technique is less efficient. With the Red M2B, at a ratio of 1:25, the efficiency of the two techniques is the same. At greater reductions, the co-milling technique is less efficient.

Other resins

Limited experiments were done with two other resins. These were: Beckurane 79-60—a polyurethane resin; and Scopol 55NM—a vinyl-toluenated alkyd resin.

These are air-drying resins compatible with Beckosol P470. To assess the dispersion level of Blue GLSM stainers based on them, the stainers were reduced with the same standard P470 white paint to a ratio of 1:12.5, blue to white pigment. The K/S values of dry films of these reductions were measured on a spectrophotometer and the corresponding mean diameters read off from the master curve.

The blue appeared to disperse very well in the Beckurane, but only poorly in the Scopol.

Milling times

Dispersions of the Blue GLSM were prepared in the Beckurane 79-60 and the Scopol 55NM with milling times ranging from four hours to 72 hours.

Reductions at 1:12.5 were prepared with the standard white paint based on Beckosol P470 and the colour strengths of films of these reductions were measured on the spectrophotometer. From these values, the mean particle sizes were read off from the master curve.

The results are given in Table 31 and shown graphically in Fig. 11, which includes previous results obtained in Beckosol P470.

Table 31

Effect of milling times—Blue GLSM

Milling Time (h)	K/S values		50% diameter (μ)	
	Beckurane	Scopol	Beckurane	Scopol
4	1.550	0.190	0.310	> 1.0
8	1.800	0.310	0.270	,,
12	2.000	0.400	0.245	,,
16	2.225	0.450	0.215	,,
20	2.341	0.480	0.205	,,
24	2.440	0.500	0.200	,,
36	2.640	0.515	0.185	,,
48	2.740	0.530	0.180	,,
60	2.865	0.540	0.170	,,
72	2.950	0.545	0.165	,,
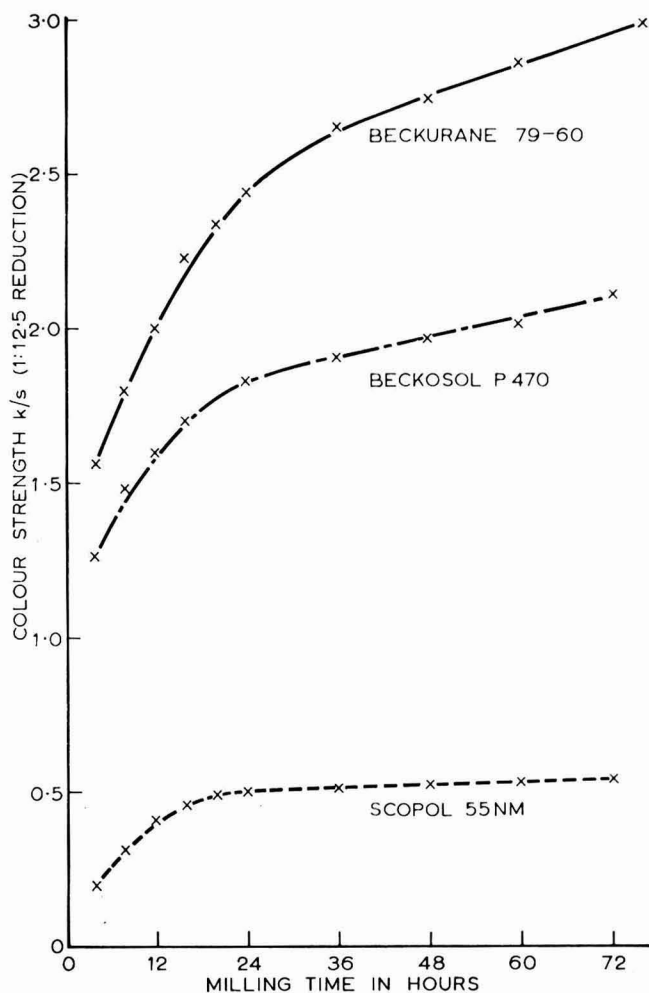
Fig. 11. Irgalite Blue GLSM. Colour strength in relation to milling times for different resins

It can be seen from this graph and the table that Beckurane 79-60 is a better dispersing medium for the Blue GLSM than the Beckosol P470, whilst the Scopol 55NM is decidedly poorer.

For all three resins, the bulk of the dispersion takes place in the first 24 hours' ball milling.

Percentage medium solids in the millbase

The effect of varying the percentage medium solids in the millbase was determined for these two resins using Blue GLSM and the same technique as before.

With the Beckurane, maximum colour strength was found at 30 per cent medium solids, and a very marked fall off when the medium solids was increased above 40 per cent.

In this respect it behaves very similarly to the Beckosol P470, but the maximum is a very shallow one indeed, over a range from 10 to 40 per cent medium solids.

With the Scopol, the results were surprising. The overall dispersion was poor, but decreased even further as the amount of resin in the millbase was increased. The results are given in Table 32.

Table 32
Scopol 55NM—Blue GLSM

% Medium solids	K/S value	50% diameter (μ)
10	0.505	> 1.0
30	0.450	,,
40	0.265	,,
55	0.120	,,

It is believed, from this work with other air-drying resins, that many of the findings for the Beckosol P470 will apply, but that this cannot be taken for granted.

Conclusions

The main conclusion from the work is that modern ball milling techniques are not far from the optimum. This does not mean that they give complete dispersion of organic pigments, far from it, but that they are using the mill in the most efficient manner.

It is believed that this work has established in detail the effect of operating variables on the grinding efficiency and these effects can be listed as follows.

The size of the mill is immaterial if the same percentage critical speed is employed.

The speed of the mill does affect the grinding efficiency. The colour strength goes through a shallow maximum as the percentage critical speed goes from 70 to 105.

Effect of millbase composition:

at a pigmentation level of 20 per cent, there is a maximum in efficiency in the region from 30 to 35 per cent medium solids,

a pigmentation level of from 15 to 20 per cent gives the best efficiency; above this the efficiency falls off.

The size of the grinding media has an effect. The smaller the size of the media, the better the dispersion. The shape of the media appears to have no effect.

Percentage ball loading: the maximum dispersion is achieved at ball loadings of from 60 to 80 per cent by apparent volume, but the maximum is a very shallow one.

Mill charge: the best results are obtained when the millbase is insufficient to cover the balls.

Milling time: after 24 hours, the reduction in particle size with further milling goes very slowly. This slow increase in dispersion may be accompanied by significant increases in colour strength dependent on the particular pigment.

Effect of viscosity: above a certain level of viscosity, the efficiency falls off very rapidly.

Effect of grinding temperatures: the grinding efficiency is independent of temperature up to 70°C.

Co-milling versus stainer techniques: at colour strengths greater than 1:100 reductions, co-milling is more efficient than stainer techniques, for the blue.

These findings have been established with a β phthalocyanine blue in one air-drying resin, Beckosol P470. It is believed that other pigments in this resin will behave similarly to the blue. If the resin is varied however, the effects may well be somewhat different.

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2. Carr, W., *JOCCA*, 1970, **53**, 884.

Discussion at the Irish Section

Mr M. O'CALLAGHAN referred to the many variables considered in the experiments. Was the same white pigment always used, and if so, which one?

Dr W. CARR replied that the white pigment had not been varied. Rutiox CR2 (at 25 per cent pigment level) had been used, and the resin for the white paint was Beckosol P470. This was constant throughout the experiments, one of the reasons being that at present there was no technique for measuring the dispersion level achieved with white pigments. The effect of the variation in the mill procedure on the dispersion level achieved with the organic pigment was all that had been considered.

Dr STOYLE congratulated Dr Carr on the excellence of his lecture, and was pleased to see from the results that the procedures both ink and paint manufacturers were following as a result of trial and error were proved to be satisfactory in theory. He asked if some clarification could be given on whether grinding efficiency increased if the size of the grinding charge was reduced below ⅛in.

Dr CARR said that he didn't know. One idea that had been brought to his attention was the use of sand as a grinding medium in a ball mill. Although this might achieve a better dispersion, problems such as filtering the sand off would arise. His work had been done in duplicate using both steel balls and steatite, and time had not been available to try any more variations.

Mr D. BARRY pointed out that, in the graph of ball size against efficiency, the ⅛in ball size appeared to give the optimum result for the milling carried out in a honey jar. Was it a matter of actual size of the grinding media or the size of the grinding media relative to the size of the ball mill that was important?

Dr CARR remarked that no experiments had been carried out with production ball mills of, for example, 200 gallon capacity. He would expect however, to achieve a better dispersion with a ⅛in diameter charge than with a larger size.

MR A. RICHARDS asked if Dr Carr had carried out any experiments with varnishes as used by printing ink manufacturers in the field of liquid inks, for example, nitro-cellulose and polyamide varnishes.

DR CARR said that he had tried, but with little success. The direct technique used a disc centrifuge. The disc was made of Perspex, because it was transparent and because it could be accurately machined. The solvents in liquid inks and stoving enamels attacked the Perspex, and thus a more suitable material for the disc would be required to examine this type of formulation. On the other hand, for offset and letter-press oil type inks, the indirect technique could be adapted very easily for measuring the degree of dispersion.

MR RICHARDS remarked that Dr Carr had appeared to condemn grinding gauges in his lecture.

DR CARR replied that he had not meant to condemn them, but they had been shown as not being suitable as an accurate measure of dispersion.

MR P. D. KELLY asked if Dr Carr inferred from his results that milling efficiency decreased with an increase in viscosity of the resin solution.

DR CARR concurred; optimum dispersion was found using 30–35 per cent medium solids. When one of 40 per cent solids, of higher viscosity, was used, the efficiency of dispersion fell off markedly.

MR D. GODDEN asked if there was any specific pigment property that would allow the assessment of optimum millbase formulations using pigments other than phthalo-cyanine blue.

DR CARR said not at this stage. Now the direct and indirect methods of accurately measuring pigment dispersion had been devised, it was hoped in the future research to find out why organic pigments reacted so differently when being dispersed, e.g. why it was more difficult to disperse a pigment in one vehicle compared to another, or why one organic pigment differed from another in the same medium.

The next stage would be to modify pigments to give the optimum dispersion at high pigmentation in all vehicles. There was obviously some relationship between a pigment and a pigment medium which controlled the ease with which a pigment dispersed, and the level to which it dispersed under a given technique, and these forces and these factors were largely unknown at the present.

MR D. SHARPE enquired if there was any reason for the particular choice of pig-ments used in the experiments.

DR CARR replied that the basic reasoning was that because the indirect technique was being used, master curves were necessary, and they were available for the pigments used. In addition, these curves were sensitive enough to give a fairly good guide to the dispersion level achieved. The direct technique could not yet be applied to "bleed-ing" pigments such as toluidine red and Fanal pigments, because under centrifugal force in the centrifuge, they bled in the spin fluid.

MR M. O'CALLAGHAN wondered if the paint used in the experiments was free of all such defects such as floating, flooding and flocculation.

MR A. KELLY, Dr Carr's associate, said that very slight signs of flotation were noted but not enough to impair the results of the experiments.

MR O'CALLAGHAN asked if, in view of flocculation troubles that were known to occur with simple formulations as used in the experiments, the paints were being kept to carry out storage checks.

DR CARR replied that storage trials had been carried out in the past for stainers, and it was found that after a period of 12 months there was a slight coarsening of the particle size, but not to a significant degree. Storage trials of the reduced paints, how-ever, had not been carried out.

DR STOYLE pointed out that when the volume of material to be ground was less than the volume of balls, it appeared that a more efficient and rapid grind was achieved. Did Dr Carr recommend this method, assuming wear was not a significant factor?

DR CARR said that the decision rested on the type of paint being made. These results were achieved with Beckosol P470, which was the basis for a decorative paint. A satisfactory level of gloss was obtained after about 24 hours' milling. If an industrial finish was being made with a different resin, and assuming the same factors held good, it might be important to obtain maximum gloss, even though it took longer and throughput was down, and some wear and tear took place in the mill. If maximum gloss was required a smaller charge would be an advantage, but with decorative paints the improvement might not be sufficient to warrant using a lower charge.

DR STOYLE remarked that, in the case of ink manufacture, the wear and tear could be a significant factor against the use of this method.

DR CARR said that he did not know if the wear was significant.

MR J. SAGE asked if Dr Carr had experimented with dispersion of the pigment in a medium by high speed stirrer prior to ball milling.

DR CARR replied that he had not, but it was on the list for investigation in the future. Consideration was also being given to whether a similar project on the study of sand milling would be of interest to paint manufacturers, because it might be that, unlike ball milling, where the experiments have shown that techniques established over the years are efficient, manufacturers might still be a long way from optimum efficiency operating techniques with sand mills.

MR D. GODDEN asked, if a paint manufacturer was short of time in his manufacturing programme, would Dr Carr recommend the use of easily dispersible pigments in ball mills?

DR CARR said that his experience of easily dispersible pigments in terms of particle size measurement indicated that they reached a certain level of dispersion fairly quickly, more rapidly than the standard pigment, but on prolonged grinding they did not disperse further. In other words, an acceptable level was achieved quickly, which answered the point.

MR O'CALLAGHAN remarked that a 24-hour milling cycle had been suggested by Dr Carr in his experiments. This length of time was not attractive to paint manufacturers, who would suggest 14 hours as a maximum period. Would he agree that, with an easily dispersible blue and titanium dioxide, the optimum colour value would be reached within a shorter period of time ?

DR CARR did not think that this would be the case. An acceptable level of colour value would be achieved in a shorter time, but this would not be the maximum colour value.

MR RICHARDS asked if Dr Carr had experimented with wetting agents and optimum colour values.

DR CARR said that he had examined Lecithin, and found that it did nothing in terms of the level of dispersion achieved. At least three other surface active agents which were sold and advertised in the literature for improving the dispersability of organic pigments had been investigated, all from reputable firms on the Continent. From the tests, the dispersion levels achieved when they were used were slightly inferior to those when they were absent.

MR BARRY enquired if Dr Carr would recommend the same techniques for an attritor mill.

DR CARR felt that it was possible, but whether the results would be parallel was not clear. He would expect them to be parallel, but had no actual evidence to support the expectation.

Kubelka-Munk theory and colour matching

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Summary

An expression for the reflectance of an infinitely thick film is derived from a modified Kubelka-Munk (K-M) reflectance function.

It is shown how the true ratio of K-M absorption and scattering coefficients can be found from measured reflectances.

The Saunderson reflectance correction has been analysed theoretically and it is shown how the use of an incorrect value for a real physical variable in a misapplied equation yields improved colour matching predictions.

Finally, experimental data on grey plastics is used to illustrate that, within the current accuracy limits of modern commercial photometers, both the Saunderson correction and the modified K-M theory give satisfactory improvements in colour matching calculations.

Further advances in colour prediction must be in the instrumental field rather than in the theoretical development of more accurate basic equations.

Keywords

Processes and methods primarily associated with manufacturing or synthesis	*Miscellaneous terms*
colour matching	Kubelka-Munk theory
	Saunderson correction

La théorie Kubelka-Munk dans le domaine du contretypage de couleurs

Résumé

On a décrit au moyens d'une équation Kubelka-Munk modifiée de réflectance (K-M), une expression pour préciser la réflectance d'un feuil infiniment épais.

On démontre comment on saurait obtenir le vrai rapport entre l'absorption K-M et les coéfficients de diffusion à partir des réflectances déterminées.

On a subi la correction de réflectance proposée par Saunderson à une analyse théorique et l'on a démontré que l'emploi d'une valeur injuste d'une réelle variable physique dans une équation dans les cas où celle-ci n'est pas absolument valable rend de meilleures prévisions sur la fiabilité du contretypage de couleurs.

Enfin, on utilise des données expérimentales à l'égard d'une série de matières plastiques grises afin de démontrer que, dedans les limites de précision actuelles des photometrès commerciaux de nos jours, la correction Saunderson et la théorie K-M modifiée donnent à la fois de bonnes améliorations des calculs dans le domaine du contretypage de couleurs.

D'autres améliorations à l'égard de la prévision de la couleur à être obtenue à partir d'un procédé de contretypage doivent se trouver dans le domaine de l'appareil plutôt que dans le développement théorique des équations de base plus precises.

Kubelka-Munk Theorie und Farbabtönen

Zusammenfassung

Ein Ausdruck für die Rückstrahlung eines unendlich dicken Films wird von einer modifizierten Kubelka—Munk (K-M) Rückstrahlungsfunktion abgeleitet.

Es wird aufgezeigt, wie aus gemessenen Rückstrahlungen das echte Verhältnis von K-M Absorption und Streungskoeffizienten gefunden werden kann.

Die Saunderson Rückstrahlungskorrektion wurde theoretisch analysiert, und es wurde gezeigt, wieso die Benutzung eines nicht korrekten Wertes als wirkliche physikalische Variable in einer falsch angewandten Gleichung verbesserte Farbabtön- Voraussagen ergeben kann.

Schliessiich werden experimentelle, auf graue Kunststoffe bezogene Wertbeenutzt, um zu il ustrieren, dass innerhalb der z.Zt. üblichen Genauigkeitsgrenzen bei modernen Photometern des Handels beide, die Saunderson Korrektur und die modifizierte K-M Theorie befriedigende Verbesserungen in Berechnungen für Farbabtönungen ergeben.

Weitere Fortschritte im Farbtonvoraussagen müssen eher auf dem Gebiet der Instrumentierung, als in der theoretischen Entwicklung genauer grundlegender Gleichungen liegen.

Теория Кубелька-Мунка и подбор цветов

Резюме

Из модифицированной функции отражаемости Кубельки-Мунка (К-М) формулируется выражение для отражаемости безграничной толстой пленки. Показано что истинное отношение коэффициентов К-М поглощения и рассеяния может быть получено из измеренных отражаемостей. Поправка отражаемости Сандерсона анализировалась теоретически и показано что применение неточного значения для истинного физического переменного в неправильно использованном уравнении, может дать более усовершенствованный прогноз для подбора красок. В заключение рассматриваются экспериментальные данные полученные с серыми пластмассами, чтобы показать что в пределах точности современных коммерческих фотометров, как поправка Сандерсона так и модифицированная теория К-М, дают удовлетворительное улучшение в расчетах подбора красок.

Дальнейший прогресс в прогнозе красок должен лежать скорее в области инструментов чем в области теоретического развития более точных основных уравнений.

Introduction

In recent years, increasingly sophisticated practical approaches to colour matching have come into use. Several of these are based on computer techniques, and it has been shown that the improved accuracy of the predictions saves process time and reduces cost. However, the full potential of computer techniques can only be realised by making corresponding improvements in other parts of the overall colour prediction process.

The success of the colour matching calculation depends on two factors, namely the accuracy of the practical measurements and the use of a theory that adequately represents the physical phenomena. The purpose of this paper is to attempt to achieve a balanced outlook regarding these two factors and to indicate to what extent current theories and experimental accuracy must be improved if useful practical advances are to be made in this field.

On the theoretical side, a modified version of Kubelka-Munk theory will be used to develop an equation which is adequate to describe practical systems. The Saunderson corrections will also be examined and will similarly be shown to be satisfactory for present day use. Experimental results will be presented confirming these conclusions. The results will also be used to illustrate the importance of accurate practical measurements of reflectance, indicating that this is the field in which future improvements need to be made.

No attempt has been made by the author to discuss the problems of describing and analysing "colour space". Some criterion must be used, however, to

determine the success, or otherwise, of any proposed theory. The one used in this paper is that the absorption coefficient, as calculated from experimental measurements, should give a linear plot against concentration of the colourant.

Theory

Modification of Kubelka-Munk (K-M) theory

Many of the practical problems associated with the use of K-M theory arise from neglect of the original postulates specified for its application. Physical effects occur in paint films that are not included in the basic theory, but which must be incorporated in any expression relating light reflecting properties to film thickness.

A major variable that is now beginning to receive the practical attention it justifies is the reflection of light scattered at the inside of the paint→air boundary. Light that penetrates into the film and is scattered back towards the source experiences a substantial reflection back into the film at the paint→air boundary. The boundary reflectance can be as much as 60 per cent of the back-scattered light, owing, mainly to total internal reflection. The Saunderson correction consists of an expression designed to eliminate this effect from measured film reflectances prior to application of the K-M theory.

The air→paint boundary is also instrumental in bringing about the other major departure of paint films from the ideal K-M system. Refraction of the incident light at the surface directs the light into the scattering medium within a cone of semi-angle 40-45° about the surface normal. This effect occurs irrespective of the initial directional characteristics of the incident light, and results in a lower total reflectance than predicted by the uncorrected K-M theory. It is the neglect of this effect that has led to the low values of the internal boundary reflectance obtained by application of the Saunderson correction [2] to experimental colour prediction data. This will be discussed in more detail shortly.

A modified form of the K-M equation relating reflectance, R, to film thickness, X, and incorporating corrections for the two effects outlined above, was introduced in a recent publication[1]. It is repeated below.

$$R = \frac{(1 - r_1) \mid (1 - ar_2) \sinh b (SX - D) + br_2 \cosh b (SX - D) \mid}{\mid (a - r_2) - r_1 (1 - ar_2) \mid \sinh bSX + (1 - r_1 r_2) b \cosh bSX} \quad \ldots \ldots (1)$$

where r_1 = internal boundary reflectance for diffuse light at the paint/air surface

r_2 = reflectance for diffuse light at the substrate

S = back-scattering coefficient for diffuse light

D = a light diffusion constant

a and b are defined by:

$$a = 1 + (K/S); \quad b = (a^2 - 1)^{0.5}$$

K = absorption coefficient for diffuse light.

The constant, D, allows for the extra penetration of the incident light into the system. Experimental determinations of D, applicable in rutile pigmented glossy systems, give a value of 0.50 independent of pigment concentration.

It is assumed in equation 1 that a correction has already been applied to allow for the Fresnel reflectance of the incident light at the air boundary.

The reflectance of an infinitely thick film can be obtained directly from equation 1. The hyperbolic functions approximate to a simple exponential, i.e. for large values of x,

$$\sinh x = \cosh x \rightarrow e^x.$$

Introduction of this approximation into equation 1 can be shown to eliminate substrate reflectance and film thickness to give:

$$R_\infty = \frac{(1 - r_1)\, e^{-bD}}{(a + b - r_1)} \quad \dots\dots\dots\dots\dots\dots\dots\dots(2)$$

This equation replaces the familiar equation derived from uncorrected K-M theory.

$$R_\infty = \frac{1}{(a + b)} = (a - b) \dots\dots\dots\dots\dots\dots\dots(3)$$

Equation 3 can be re-arranged to give:

$$K/S = (1 - R_\infty)^2/2R_\infty \quad \dots\dots\dots\dots\dots\dots\dots(4)$$

This is a very well known and extremely useful practical relationship, since it expresses the important variable K/S in terms of the experimental measurement.

Unfortunately, a similar exercise is not possible with equation 2, despite the fact that r_1 and D are constants and R_∞ is a function of K/S only. The difficulty lies with the exponential term. The simplest way of handling equation 2 is to calculate values of R_∞ for various values of K/S and present the results graphically or in tabulated form.

However, a useful relationship for computation purposes has been obtained by taking the calculation procedure one stage further. Formation of the quantity $(1 - R_\infty)^2/2R_\infty$ from the calculated values of R_∞ gives an "apparent" value of K/S which can be conveniently denoted by $(K/S)_A$. It can be shown that a simple empirical relation exists between this quantity and the original "real" value of K/S, denoted by $(K/S)_R$ and used initially to calculate R_∞ using equation 2.

The data used for this exercise are given in Table 1. Values for r_1 and D of 0.58 and 0.50 respectively, determined experimentally from white films, were used in the calculations. The quantities $(K/S)_A$ and $(K/S)_R$ are plotted against each other on logarithmic scales in Fig. 1. From this graph it can be shown that:

$$(K/S)_R = 0.160\,(K/S)_A^{1.054} \quad \dots\dots\dots\dots\dots\dots(5)$$

The agreement between this relationship and the actual results is illustrated by the values of $(K/S)_R$ calculated from equation 5 and listed in Table 1.

Table 1

Agreement between measured and calculated values of $(K/S)_R$

$(K/S)_R$	R_∞	$(K/S)_A$	$0.16 \left(\dfrac{K}{S}\right)_A^{1.054}$
0.002	0.839	0.0156	0.00198
0.005	0.761	0.0376	0.00503
0.01	0.684	0.0728	0.0101
0.02	0.593	0.140	0.0201
0.05	0.453	0.330	0.0497
0.10	0.341	0.635	0.099
0.20	0.235	1.246	0.201
0.50	0.118	3.302	0.563
1.00	0.056	7.949	1.420
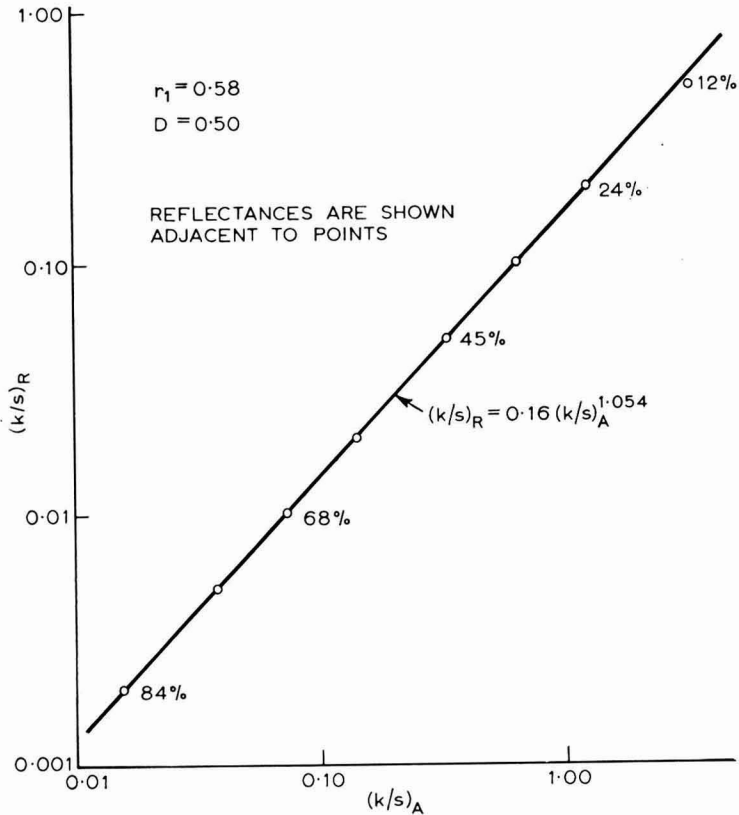
Fig. 1. Log. log plot of the real (K/S) value, $(K/S)_R$, against the apparent value, $(K/S)_A$. The solid line represents the fitted expression for the relationship

It should be emphasised that this expression is an empirical result derived from application of theory. No experimental reflectance data was used directly in its derivation. In fact, simple empirical power laws have been found independently from experimental data. Best[3] obtained a power of 1.25 and showed

this to be as effective as other methods available for improving colour prediction. It will be shown later, however, that determination of the power is very sensitive to small systematic experimental errors.

Two points emerge from Table 1. First, the simple power law agrees with the theoretical results only for reflectances greater than about 20 per cent. Secondly, the error in K/S arising from use of uncorrected K-M theory is extremely large, a factor of 6 to 8 being involved. Thus, any attempt to correlate values of K/S determined from uncorrected K-M theory with fundamental light scattering theories cannot possibly succeed.

The Saunderson correction

Saunderson[2] was one of the first to show that application of the uncorrected K-M theory to problems of colour prediction often gave poor results. He introduced a value of 0.4 for r_1, the internal reflectance for diffuse light at the paint-air boundary.

The widely quoted equation he used can be represented as follows:

$$R_M = r_F + (1 - r_F) . \frac{(1 - r_S) . R_K}{(1 - r_S . R_K)} \dots\dots\dots\dots(6)$$

where R_M = measured reflectance

   R_K = true reflectance, to be used in uncorrected K-M theory

   r_F = Fresnel reflectance of the incident light at the air boundary

   r_S = internal boundary reflectance for diffuse light.

The quantity rs is nominally equivalent to r_1, introduced earlier. However, it has been redesignated r_S here, since in practice it does not have the same value as r_1.

For simplification it will be assumed that the correction associated with r_F has been carried out separately. Equation 6 can then be inverted to give:

$$R_K = \frac{R_M}{(1 - r_S + r_S . R_M)} \dots\dots\dots\dots\dots(7)$$

Saunderson found by trial and error that a value of 0.4 for r_S produced the best colour matching predictions. More recently Bridgeman[4] found an average value of 0.400 for r_S from a rigorous statistical analysis of paint film reflectances. Both these workers compared predicted reflectances with measured values, using normal colour matching procedures. Thus there is little doubt that $r_S = 0.4$ is the optimum value for use in the application of equation 7 to practical colour matching problems.

However, both theoretically and experimentally[1], the value of r_1, supposedly the same physical quantity as r_S, has a value of 0.5—0.6. This strongly implies that r_S does not, in fact, represent the true physical quantity r_1. Bridgeman's work suggests some theoretical anomaly, since he found an inexplicable wavelength dependency for r_S.

It must be concluded that using $r_S = 0.4$ in equation 7 gives a modified reflectance, R_K, which purely by chance subsequently produces ultimate values for K/S that obey the concentration proportionality law,

$$\text{that is } \frac{K}{S} = \frac{\Sigma K_j C_j}{\Sigma S_j C_j} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Colour matching calculations depend entirely on the validity of this expression.

It is possible to calculate expected values of r_S by simulating the trial and error colour matching calculations of Saunderson. The procedure can be applied to a grossly simplified example. Consider two films having equal scattering coefficients, but different concentrations, C_1 and C_2, of non-scattering colourant. The measured reflectances, $(R_M)_1$ and $(R_M)_2$, would be processed by application of the following expressions.

$$R_K = R_M/(1 - r_S + r_S \cdot R_M)$$
$$K/S = (1 - R_K)^2/2R_K.$$

The appropriate value of r_S is the one for which

$$(K/S)_1/C_1 = (K/S)_2/C_2,$$

that is the absorption coefficient should be proportional to concentration of colourant. In fact the above equation can be solved for r_S in terms of R_M to give:

$$\frac{1}{r_S} = 1 + \left| \frac{(R_M)_2 \, C_2 \, N_1 - (R_M)_1 \, C_1 \, N_2}{C_2 \, N_1 - C_1 \, N_2} \right| \quad \ldots\ldots\ldots\ldots(9)$$

where $N = (1 - R_M)^2/2R_M \equiv (K/S)_A.$

Equation 9 can be applied to the reflectances calculated earlier from modified K-M theory and listed in Table 1. The values of R_α are the predicted practical reflectances for the given values of K/S and the concentration ratio, C_1/C_2, is merely the ratio of the corresponding K/S values.

The values of r_S found for successive pairs of reflectances in Table 1 are shown in Table 2. An average value of 0.37 applies to reflectances greater than about 40 per cent, in fair agreement with the published experimental values.

Table 2
Values of r_S found for successive pairs of reflectances in Table 1

$(K/S)_R$	R_∞	r_S
0.002	0.839	
		0.386
0.005	0.761	
		0.380
0.01	0.684	
		0.370
0.02	0.593	
		0.346
0.05	0.453	
		0.292
0.10	0.341	
		0.161
0.20	0.235	

It should be pointed out that equation 9 is extremely sensitive to small errors in reflectance and is considered impractical for regular experimental use. The rapid drop in the calculated values of r_S for low reflectances in Table 2 is attributed to this sensitivity, coupled with a steadily decreasing applicability of the modified K-M theory as the reflectance decreases.

Finally, to illustrate further the artificial nature of the Saunderson correction, the reflectance values in Table 1 have been corrected by application of equation 7, using a value of 0.40 for r_S. The corrected reflectance values have then been converted into a K/S ratio by use of equation 4.

Thus, the normal Saunderson correction has been applied to the reflectance data, giving values of K/S (denoted by $(K/S)_S$) that can be compared with the "true" values, $(K/S)_R$. The comparison is shown in Table 3.

Table 3
Comparison of $(K/S)_S$ and $(K/S)_R$

R_∞	0.839	0.761	0.684	0.593	0.453	0.341	0.235
$(K/S)_R$ ..	0.002	0.005	0.01	0.02	0.05	0.10	0.20
$(K/S)_S$ ..	0.00650	0.0163	0.0326	0.0653	0.164	0.333	0.688
Ratio ..	3.25	3.26	3.26	3.27	3.28	3.33	3.44

It is evident, as shown by the ratios, that the Saunderson correction gives a final value of K/S that is directly proportional to the real value. This is the reason for its success in improving colour predictions.

For the theoretician, however, the correction is rather misleading, since it yields values of K/S that are some three times greater than the true values. Awareness of this difficulty has previously been masked by the apparently sound experimental backing for the determination of r_S, and a lack of consideration of the physical variables existing in the practical systems to which basic theories have been applied.

The comments and calculations so far have been made almost entirely on theoretical grounds. In the next section experimental results are presented and analysed by application of modified K-M theory and the Saunderson correction.

Experimental results

The applicability of the modified K-M reflectance equation introduced earlier has not been clearly defined. In fact, assumptions have been made in its derivation that restrict its application nominally to systems with reflectances greater than about 20 per cent. The experimental work was designed to some extent, therefore, to investigate the effectiveness of the modified expression for reflectances below this level. However, the major reasons for concentrating on the low reflectance region were to investigate the practical problems associated with measuring low reflectances and to test the applicability of the Saunderson correction (equation 7) and the empirical power law presented earlier (equation 5).

Determination of the reflectance values

A series of ABS (acrilonitrile/butadiene/styrene) polymer panels pigmented with rutile TiO_2 and a vegetable black were prepared using a heated two-roll milling and hot pressing technique. The volume concentration of TiO_2 was kept constant and the concentration of vegetable black varied to give reflectances ranging from 1.4 per cent to 81 per cent.

The reflectances were measured using the green filter on a Colormaster Model V colorimeter. A correction was applied to compensate for the loss of incident light due to Fresnel reflection at the air→plastic boundary (experimental determination—4.0 per cent). The final values are listed against the concentration of vegetable black in Table 4. Concentrations are in arbitrary units, since it is only necessary to have accurate relative values in order to compare the corrections in this paper.

Table 4

Analysis of experimental results

Black concentration	Corrected reflectance (%)	Uncorrected K-M	Saunderson correction	Modified K-M
0	84.64	—	—	—
0.01	44.49	1.09	0.99	1.03
0.02	33.74	1.05	1.00	1.03
0.03	27.54	1.03	1.01	1.02
0.05	20.63	1.00	1.02	1.00
0.10	13.41	0.92	0.98	0.96
0.15	9.75	0.91	1.00	0.97
0.20	7.76	0.90	1.00	0.97
0.25	6.45	0.89	0.99	0.97
0.30	5.38	0.91	1.02	1.01
0.40	4.39	0.86	0.97	0.96
0.50	3.65	0.84	0.95	0.95
0.75	2.59	0.80	0.92	0.93
1.00	2.03	0.78	0.89	0.91
1.30	1.81	0.67	0.77	0.79
1.60	1.42	0.70	0.81	0.84

An important practical difficulty became evident during the reflectance measurements. Use of a white tile standard for calibration of the instrument at a high reflectance value was straight-forward, apart from the usual problem of defining the absolute reflectance value of the tile. However, calibration for low reflectances high-lighted an important practical difficulty, namely the elimination of stray light. The stray light level that occurs with a glossy film over the sample port can be measured adequately only by calibration of the instrument with accurately known glossy black standards. The Colormaster used in this work appeared to have a stray light level of about 0.2 per cent, which, though small compared with the reflectance of pastel shades, represents a 10 per cent error at the 2 per cent reflectance levels of the darkest samples used in this paper.

A further difficulty, associated with the samples themselves, arose. Surface defects in the films can scatter appreciable quantities of light. Since it is not practicable to achieve a polished finish equal to that of the reference panels

on routine test samples, this problem may well define the practical limit of accuracy that can be achieved with commercial colour prediction procedures.

Analysis of the results

The reflectances listed in Table 4 have been processed in three ways:

Uncorrected K-M theory was applied by converting the reflectances directly into values of $(K/S)_A$ using equation 4;

The Saunderson correction was applied, using $r_S = 0.40$ in equation 8, and the resulting reflectances converted into values of $(K/S)_S$;

The values of $(K/S)_A$ as calculated above were raised to the power 1.054, representing the modified K-M theory approach.

All three sets of final K/S values were then further processed by subtracting the "zero colourant" value and then dividing by the concentration of black. The sets were then normalised for comparative purposes by dividing throughout by the average of the first six values corresponding to the six lowest colourant concentrations. This is merely to remove the different absolute levels of specific absorption given by the three different analytical processes.

The final results, which represent absorption per unit colourant concentration scaled to unity at high reflectance values, are listed in Table 4 and plotted in Fig. 2.
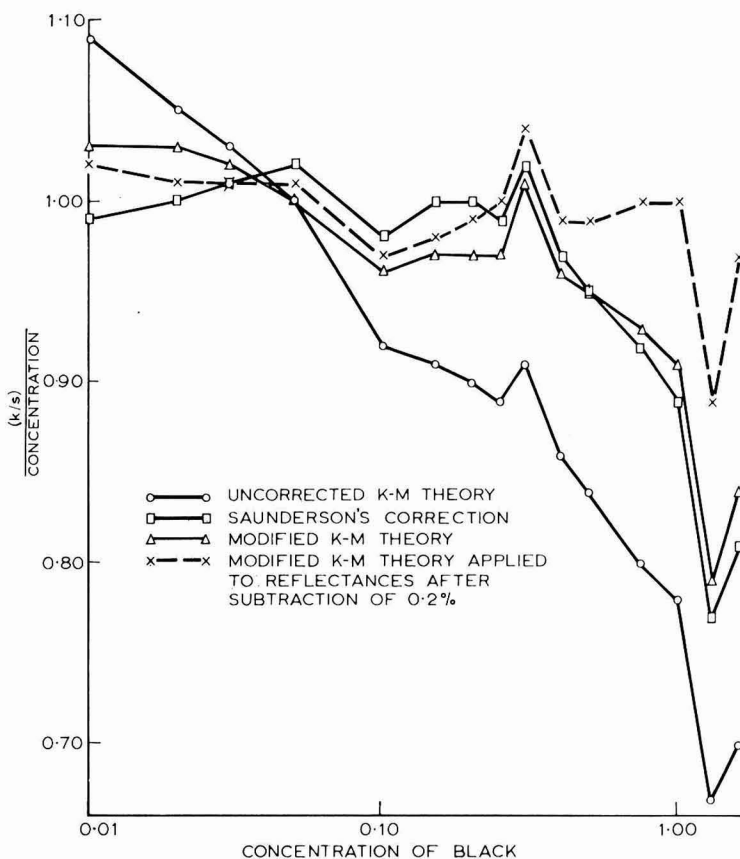

Fig. 2. Comparison of colour matching corrections

Discussion of results

Both the Saunderson correction and the power law represent considerable improvements over the uncorrected K-M theory, which is exhibiting the well known reduction of specific absorption at low reflectances. There is little to choose between the Saunderson correction and the power law, both apparently indicating a partial failure for reflectances below about 4 per cent.

However, both methods appear to apply to much lower levels of reflectance than are indicated by the theoretical limitations described earlier. Use of the function $(K/S)_A^{1.054}$ proves to be much more successful experimentally than can be satisfactorily accounted for by the theory used to derive it.

The effect of experimental error is a major factor that must be considered at low reflectance levels. This can be illustrated very effectively by use of the following simple device.

The problem of stray light was mentioned earlier, and it was indicated that a level of about 0.2 per cent existed in the Colormaster used for determining the reflectances in this work. Let it be assumed, therefore, that the experimental reflectances listed in Table 4 are too high due to the "addition" of 0.2 per cent stray light. Subtraction of this amount from the reflectances and reapplication of the 1.054 power law to the resulting K/S values leads to the dotted line shown in Fig. 2.

The marked effect of this small error, which roughly corresponds, incidentally, to the reproducibility error of the Colormaster instrument, highlights the problem of practical reflectance determination. Both the Saunderson correction and the power law procedures are quite satisfactory for use in accurate colour prediction work, provided the practical determination of reflectance is sufficiently precise. The provision and use of light scattering theories more sophisticated than those given in this paper would be pointless.

Practical procedures

Reproducibility and accuracy in routine reflectance determination is of overriding importance in colour matching work.

Accurate, reproducible reflectance values can be determined on modern equipment, provided the necessary precautions are taken. However, correction of results to absolute values is difficult and rarely carried out. A procedure for improved colour matching predictions can be suggested, based on the work described in this paper.

A series of samples such as those used in this paper is required. The reflectances are determined using the standard conditions intended for control purposes. The best power law for these conditions can then be obtained by plotting the logarithm of the resulting $(K/S)_A$ values against the logarithm of the colourant concentration and determining the gradient of the best line through the points.

This method has been applied to the reflectances listed in Table 4, and a power value of 1.081 obtained, compared with the theoretical value of 1.054 found earlier. The results in Table 5 show the comparison between these two power laws together with the application of the 1.054 law to reflectances reduced by 0.2 per cent.

Table 5

Comparison of power laws

Reflectance (%)	Normalised absorption per unit concentration		
	Modified K-M -exponent 1.054	Modified K-M -reduced reflectances -exponent 1.054	Modified K-M -exponent 1.081
44.49	1.03	1.02	0.98
33.74	1.03	1.01	0.99
27.54	1.02	1.01	1.02
20.63	1.00	1.01	1.01
13.41	0.96	0.97	0.98
9.75	0.97	0.98	1.01
7.76	0.97	0.99	1.02
6.45	0.97	1.00	1.02
5.38	1.01	1.04	1.07
4.39	0.96	0.99	1.02
3.65	0.95	0.99	1.01
2.59	0.93	1.00	1.00
2.03	0.91	1.00	0.99
1.81	0.79	0.89	0.86
1.42	0.84	0.97	0.92

It can be seen that changing the exponent by 0.027 is approximately equivalent to reducing the reflectances by 0.2 per cent. This example shows how sensitive practical determinations of the power value are to small errors in reflectance. Inevitably, this also makes comparisons between theory and practice extremely difficult, and stresses again the need for accuracy in reflectance determinations.

Conclusions

Modified K-M theory has been applied to the colour matching problems for rutile pigmented systems, indicating why uncorrected K-M theory is unsatisfactory. The success of the Saunderson correction is explained, in spite of its use of an incorrect value of a real physical variable in a misapplied correction equation. An examination of a series of experimental reflectances has shown that both the modified K-M theory and Saunderson correction are adequate for modern colour matching calculations. The major difficulty is in the practical assessment of absolute reflectance.

An approach that perhaps deals best with the current problem is the empirical determination of the power law relating the apparent value of K/S with concentration for any one particular colorimeter and its calibration standards. Progress beyond this stage is dependent on a full realisation of the physical factors affecting reflectance and their consideration when practical determinations of reflectance are made.

It would appear that, even when satisfactory practical prowess is attained, the natural localised variations of surface texture, concentration etc. in practical films and their consequent effects on reflectance will never warrant the use of more sophisticated light scattering theories than that outlined in this paper.

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The role of research on paint technology in the Australian building industry

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Summary

The advantages of carrying out investigations in coating technology at an institute devoted to building research are discussed, on the basis of research work done at the Division of Building Research, CSIRO.

Keywords

Le rôle joué dans l'industrie de construction en Australie par les recherches dans le domaine de la technologie de peintures

Résumé

On discute, au point de vue des recherches effectuées dans la Section de Building Research de la C.S.I.R.O., les avantages d'entreprendre les investigations dans le domaine de la technologie de peintures à un institut consacré aux recherches pour l'industrie de construction.

Die von der Forschung in Lacktechnologie für die Australische Bauindustrie Gespielte Rolle

Zusammenfassung

Eine Besprechung der möglichen Vorteile dadurch, dass Untersuchungen in Anstrichmitteltechnologie an einem dem Baufach gewidmeten Institut auf der Basis von in der Division of Building Research durchgeführten Forschungsarbeiten vorgenommen werden.

Роль исследований в области технологии красок, в строительной промышленности Австралии

Резюме

Обсуждаются преимущества проведения исследований и испытаний в области технологии покрытий, в Институте посвященном строительским исследованиям, на основании исследовательских работ проведенных в Отделе Строительства Организаюции Государственных Научных и Промышленных Исследований (CSIRO).

Introduction

The purpose of this article is to examine what contributions research in paint technology can make to the economy of the building industry, to show what can be achieved on the basis of work done at the Division of Building Research, and to justify the inclusion of paint investigations in the programme of an institute concerned with building technology. The views expressed are strongly

influenced by Australian conditions but those prevailing in the USA and some parts of Europe are similar and the comments may be of more general interest.

Scientific investigations in the field of decorative paint technology are at present largely carried out in four main types of organizations: by the suppliers of raw material, by paint manufacturers, by paint research institutes, and by small sections in various building research institutes.

It is pertinent to ask why research in this field should be carried out in an institute devoted to building research, since there appear to be many other places which purport to carry out research in this field. An organization dealing with constructions of buildings of all kinds certainly needs some knowledge of paint, but is it necessary to go deeper and carry out investigations which are sufficiently sophisticated to be classed as research? Would it not be sufficient to have someone who is well acquainted with paint to give advice when necessary?

A person who has no strong research background in paint technology is unlikely to make other than trivial recommendations on the use of paint. For example, if he is asked what type of paint to use in a kitchen, he might recommend a high gloss finish because it is washable, which is an important consideration in a kitchen. But if the question involves painting walls which show efflorescence, the situation is more complex. Many procedures have been recommended for such cases but they do not all have a proper foundation and many have been tried repeatedly with very indifferent success. Here a more thorough investigation is needed, and someone able to draw up a relevant research programme is essential.

Origin of the paint section at the Division of Building Research

The stimulus to start the paint section of the Division of Building Research in 1957 came from the paint industry, which at that time had experienced a great deal of trouble with the staining of surfaces decorated with flat alkyd enamels. The industry provided financial assistance to start an investigation into this defect, and established a committee to advise on problems of interest to the paint industry. After three years, the financial assistance was withdrawn on the grounds that there were no research problems of common interest to all the individual contributors.

The work subsequently carried out by the section arose from inquiries made by the public and by the building trade. These were examined and, if necessary a research project was initiated to solve the particular and related problems. As the work progressed, numerous other questions usually arose which, if judged to be sufficiently important, were also investigated.

Research projects carried out by the paint section
Staining of paint films

As already stated, this project was initiated by the paint industry. Eventually it was found that the cause of the staining was a reaction between small amounts of lead and mercury contained in the paint and the hydrogen sulphide always present in trace quantities in the air. Compounds of lead were added to the paints as driers and compounds of mercury were present as preservatives and

fungicides. As hydrogen sulphide cannot be eliminated from the air, the answer to the problem is to eliminate these metals from paint formulations.

To clarify the rather confusing observations which had been made at the Division or reported by others, it was necessary to carry out a great amount of research work in order to make some progress with the problem. Simple methods for the determination of very small quantities of lead, mercury and sulphides in paint films had to be developed, and a method had to be devised for preparing atmospheres containing small quantities of hydrogen sulphide. Work also had to be done on the optical effect of an uneven distribution of a colourant in a paint film and the solubility product of cobalt and lead sulphides had to be redetermined.[1,2,3]

Adhesion problems

Many cases of adhesion failure in paint films applied to surfaces of cement and gypsum plaster were reported. On investigation it was found that the failures were due to three causes: traces of release agents on the surface of gypsum plaster products, efflorescence, and faulty cement and gypsum plaster renderings.

Simple tests for the strength of adhesion of paint films to porous and non-porous substrates had to be developed so as to be able to study the causes of failure, the type of salt responsible for efflorescence and its mode of formation had to be established, and a quick analytical method for determining small quantities of sodium sulphate in the presence of calcium sulphate had to be developed[2].

Formulation of fungus-resistant paints

This work was initiated at the request of the Housing Commission, Victoria, which had been unable to buy suitable fungus-resistant paints and approached the Division for advice.

A survey of the literature showed that a great amount of work had been done on the formulation of fungus-resistant paints in the industrialised countries over the last 30-40 years, but progress seemed to be negligible. Many additives had been proposed but none appeared to be satisfactory in all circumstances, since opinions on the usefulness of the recommended compounds were widely divergent among the various investigators.

This confusion seemed to arise from the complexity of the problem and the difficulties encountered in assessing a fungus-resistant formulation. Two main procedures had been used for testing, a bio-assay technique, and exposure of painted panels at sites favouring profuse growth of mould. The bio-assay technique showed little correlation with the results of exposure tests, and the latter were very unsatisfactory because they were of a kind best described as "hit and miss". The panels were exposed and the growth of mould observed, but there was seldom any investigation of the behaviour of the additive used. The fundamental question as to why mould appeared was scarcely ever asked. Was it because the fungicide either disappeared from the paint film or decomposed during exposure? Was the appearance of mould due to the basic instability of the formulation or to its adaptation to a new environment? For this

reason the research at the Division was designed to discover improved procedures for assessing fungus-resistant paints, rather than to search for new mould inhibitive compounds. Proposed new additives would be of little use unless they could be properly assessed.

Development of a test for fungus resistance requires consideration of the following points:

a laboratory test for the compound in question

a test for its stability in the paint film under varying climatic conditions—every fungicide will disappear from a paint film in time, because it must be slightly soluble in order to enter the body of the developing spore, but the critical point is the rate at which it disappears from the film;

the rate at which the fungicide diffuses from the body of the paint film to the surface; and

the metabolic processes by which the development of spores is checked by fungicides and fungistats.

Only the second of these points was investigated, since a laboratory test was already available, there was no member of the staff competent to work on the metabolic processes of mould, and research into diffusion rates did not appear to be warranted until knowledge of the mechanism by which the development of spores is checked became available.

An economical method of testing fungus-resistant paints on a large scale was introduced. This does not appear to have been applied previously, probably because of the large expense entailed, and results of panel exposure tests were considered to be sufficient. The procedure is best illustrated by an example. It was desired to compare four paints, A, B, C, and D, for their resistance to fungus growth. Each wall of a house on which mould growth was known to occur was divided into a series of four strips, A, B, C, and D, and these were varied in a statistically predetermined pattern. The degree of mould growth on the strips was then observed.

In the project on fungus-resistant paints, a large amount of work had to be done on the development of quick analytical methods to determine the residual fungicides or fungistatic agents in paint films.

It would appear that, for interior conditions, no further research is necessary, since sufficient fungus-resistant paint formulations are known and further investigations would be likely to produce only marginal benefits. The same cannot be said for exterior coatings, and further work in this field could lead to significant improvements.

Details of the work on formulation of fungus-resistant paints have been published.[5,6,7]

Formulation of zinc oxide latex paints

In the previous project it was found that latex paints formulated with about 40 per cent by weight of zinc oxide showed a considerably increased fungus resistance. Such paints are difficult to formulate and tend to solidify on storage. Very little is known about the influence of various factors, such as additives, types of latex, and storage temperature, which could affect the stability of the

paint, and an investigation of these variables was therefore undertaken. Perhaps the most interesting finding was the significance of the effect of additives like calcium silicate, potassium tetraphosphate, and barium metaborate on the stability of the paint. A vinyl acetate/acrylate copolymer latex was found to be the most suitable for the formulation of zinc oxide latex paints. The conclusion was reached that probably any latex could be used, even a pva homopolymer latex, provided it was formulated with suitable plasticiser and was free of monomers and low molecular polymers.[8]

Weathering of paint films

This work originated from numerous requests by architects and the public for recommendation of paints that would be suitable for certain environmental conditions. Such a recommendation is impossible without an accelerated weathering test. Unfortunately, no satisfactory test of this type is available, which is rather surprising since this method of testing has been investigated for more than 30 years by paint technologists of all industrialised nations.

On studying the literature on this subject it became apparent that two important aspects of the problem had not received sufficient consideration.

No serious attempts seemed to have been made to separate the factors responsible for the breakdown of a paint film and to determine their separate quantitative influence. For instance, the importance of humidity has been known for many years, but no attempt to establish a quantitative relationship between relative humidity and the degree of chalking is recorded. A reliable accelerated testing method can be developed only if a great deal is known about the mechanism of the changes that take place, or at least of the variables that influence the changes and the degree to which they do so.

Insufficient attention has been given to the need for direct and quantitative measurements of changes in the properties of a paint film.

The first of the two aspects to be given special emphasis in work at the Division was development of a useful accelerated weathering test for any climate. The factors responsible for the breakdown of a paint film on weathering are the relative humidity, wetness of the paint film, the air temperature (particularly at the time the film is exposed to sunshine), and the wavelength and intensity of the incident radiation. The second aspect was the determination of the effect of components of a paint on its weathering properties. The kind of question asked is exemplified by the following:

"How is the chalking rate of a paint film influenced if a pigment which causes strong chalking, e.g. zinc oxide, is partly replaced by one which causes very little chalking?"

The main results of this work can be summarised as follows.

The ratio of the chalking rates of two paints under a particular set of conditions is not necessarily the same under a different set of conditions. It is possible that this kind of relationship also applies to other changes, e.g. in mechanical properties.

The conclusions reached regarding the changes taking place in the paint film on ageing may be considerably refined by weighing the panels before and after removing the chalk from them.

Conclusions have been reached as to the likely reactions occurring in the paint film on weathering. These are preliminary views and may need revision as new facts become known.

Details of this project have been published.[9]

Measurement of the hiding power of paint

In an effort to reduce the cost of maintenance painting for the Housing Commission, Victoria, an effort was made to develop a suitable fungus-resistant one-coat paint. In order to evaluate these formulations it was necessary to measure the hiding power of paints, but it soon became clear that most of the methods available were either based on very doubtful premises or were very time-consuming. It was decided to examine the theoretical justification for the procedures used and to develop, if possible, a single reliable procedure for determining opacity.

Results of the work on this project have been published.[10,11]

Economic benefits

The investigations described above resulted in considerable savings for the manufacturer and the user. Manufacturers in Australia should be able to save more than $100,000 per year by omitting the mercury compounds which were added in the mistaken belief that they increased fungus resistance of paints. One manufacturer whose products command approximately 10 per cent of the market is known to be saving $13,000 per year in this way.

The incidence of staining dropped dramatically after it was shown that even very small amounts of mercury and lead compounds can cause staining, and the mechanism of staining was clarified. The introduction of sodium hypochlorite, which bleaches mould stains, in place of the usual anti-mould wash also resulted in considerable savings, since in many cases the appearance of the surfaces was restored to the original colour. It is estimated that these measures save the consumer in Australia approximately $\frac{3}{4}$ million per year.

The introduction of zinc oxide latex paints saves the Housing Commission, Victoria, about $24,000 per year in redecorating costs, but the most important aspect of the work was the elimination of the numerous and embarrassing· complaints received from householders regarding mould growth in the Commission's dwelling units. The Commission was advised as to the validity of various schemes proposed by interested parties to stop mould growth. For instance, it was rightly argued that the growth of mildew could be stopped if walls and ceilings were insulated against heat losses, but this would have been very costly, and it was demonstrated that the same effect could be achieved by using the correct type of paint.

The use of a calcium chloride solution to stop efflorescence, and the restoration of weak plaster walls (which are hard to paint) with phosphoric acid, also introduced considerable savings. Prior to this suggestion, weak plaster rendering had to be removed and the wall replastered.

It is difficult to give even an approximate estimate of the savings achieved by such projects as the weathering of paint films or measurement of hiding power. The contribution of these and similar projects is mainly in the more

precise knowledge of the technology, and most technologists will agree that this is a very important aspect which nearly always leads to some economic gains.

Cost of research

The work described here has been carried out by two professional officers in the paint section of the Division, with some *ad hoc* assistance from colleagues in other sections. The cost is at present of the order of $35,000 per year or about $0.5 million in 15 years. Even if it were argued that what has been found would have been achieved by others in the next five or ten years, the ratio of benefits to outlay would still be at least ten.

However, it must be borne in mind that all of the projects were in fields which had been studied over the past 30 years or more by technologists all over the world, using superior facilities, and that, in spite of this, it was still possible to make significant progress.

Applied research in the paint industry

The reader may not be convinced of the value of research in paint technology in an institute devoted to building research, but could this type of work have been done in any of the organizations mentioned earlier? This will be discussed in some detail in the following sections.

The material supplier

A significant percentage of the raw materials used by the paint industry were not originally developed for use in coatings, and this usage forms only an additional application. It is understandable that work carried out by the supplier tends to be biased in favour of his own product, and that an independent check will provide evidence on the validity of his claims and will assist with the intelligent use of the product. Zinc oxide is a good example. For many years this compound was recommended as an additive to paint, the claims being that it would make the paint film more fungus-resistant and that it protected the binder. Recent work at the Division and elsewhere has thrown some doubts on the validity of this claim. As a fungistat it must be added in comparatively large quantities to have any effect at all, and the efficiency depends upon the type of zinc oxide. The claim that it served a protective function was based mainly on the ability of zinc oxide to absorb ultraviolet radiation. The theory is very attractive, but unfortunately it is not in agreement with the facts. Zinc oxide has its uses in paint formulations, but large amounts of money have been wasted by adding it quite unnecessarily to paint, and ultimately the cost had to be met by the consumer.

The paint manufacturer

The paint manufacturer must, of course, test the claims of the supplier, and this is not as easy as it appears. The properties of a paint film can be divided into two parts, those that can be assessed immediately, e.g. the formation of brush marks or the colour developed, and those that become apparent only after a considerable time, e.g. weatherability, dirt retention, and mould resistance. The small manufacturer will certainly find it difficult to test the second

set of properties thoroughly; the larger ones, which usually have better facilities, will make the tests and then decide on the usefulness of the product. However, even they may find the procedure to be too costly, or for various reasons the investigations may not be taken far enough. For example, the programme at the Division of Building Research on staining of alkyd films could have been discontinued after establishing that it was due to the reaction between lead in the paint and traces of hydrogen sulphide contained in the air. The investigation was, in fact, carried further by redetermining the solubility product of cobalt sulphide, which appeared to be wrong. The use of the old value could have led to the belief that staining may sometimes be due to the cobalt drier in the paint. A further step was to examine the relation between distribution of sulphide in the paint film and the strength of staining. All this knowledge has been very useful in interpreting new cases of staining when they arise.

The amount of background knowledge that should be acquired in the solution of a problem is a matter of opinion. It depends mainly on the experience and working philosophy of the investigator and the circumstances in which he is situated. In a works laboratory, the pressure to complete an investigation is very great and it will often be ended prematurely. Once it is discontinued it is very difficult to resume the work. On the other hand, it must be admitted that in a research institute the mistake may be made of continuing an investigation for so long that it becomes purely pedantic.

Paint research institutes

Paint research institutes are usually industry associations subsidised by the government, and their findings are available only to their subscribers and not to other interested parties. This is a pity, although the situation is quite understandable. Apart from this aspect, many problems connected with painting are better considered in relation to properties of the substrate. An example of this is the work on adhesion which was mentioned previously.

Building research institutes

To carry out investigations in the field of paint technology within an organization devoted to building research has economic advantages in the decoration and protection of buildings. Examples of what can be accomplished have been given in this paper.

What then are the advantages of carrying out investigations in paint technology in a building research institute? First, there is the wide range of inquiries which come from private individuals, architects and builders. Most of these are trivial, but a small number will direct attention to useful lines of investigation. Secondly, the availability of specialists in other disciplines. Detailed information on substrates can be readily obtained to any depth desired but, more importantly, if some special equipment is needed for the investigation the interest of colleagues can be aroused. For instance, X-ray analysis became important in the Divisional investigations on zinc oxide and the necessary help was obtained from other sections. The third, and possibly most important, advantage is the freedom from pressure. This is a matter of the policy of the organization and not of the type of work which is being carried

out by it, but it is especially important with paint investigations for the following reasons. Paint technology is an interdisciplinary subject, since there is scarcely any simple discipline which would apply only to the formulation of paints, and in any project it is necessary to "borrow" heavily from other disciplines. In the work on formulation of fungus-resistant paints, a thorough knowledge of analytical chemistry was essential so that suitable methods for checking the persistence of fungicides could be developed; in the work on procedures for measuring hiding power an acquaintance with applied optics was required; studies of weathering required a knowledge of catalytic reactions, and so on. The study of such topics may be regarded by some managements as too remote from subject matter and be looked on with disfavour.

[*Received 12 December 1971*

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Next month's issue

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

"Composition of water-soluble DCO alkyds," *by N. A. Ghanem, M. A. El-Azmirly and Z. H. Abd El-Latif*

"A chromatographic study of an etching primer," *by J. Bassett, B. Bush and A. T. Holder*

"Colloidal aspects of printing inks," *by W. Carr*

"Cobalt 2-ethyl hexonoate systems as accelerators for two-pack polyurethanes and their effects on storage and stability," *by R. J. Goodman and J. A. Douek*

Correspondence

Measurement of the hiding power of paints

SIR,—The above paper by Hoffmann *et al.* (*JOCCA* 1972, **55**, 292) questions the predictive value of the standard Kubelka-Munk two-constant theory and proposes an alternative theory which is more successful at low film thicknesses. One reason for the questions is that the K-M two-constant theory results in "constants", scattering coefficient S and absorption coefficient K, which depend on the film thickness and the form of the equations actually used. The alternative theory also results in non-constant values for S and K.

This alternative theory, called the H equations, makes the assumption that the intensity at a point x from the surface of a paint film is given by

$$I_o \exp - (K + S)x$$

where I_o is the incident intensity. Of this energy, a fraction Sdx is back-scattered by the layer of thickness dx and, after suffering an attenuation $\exp - Kx$, emerges from the paint/air interface. Thus the basic assumption appears to be that there is no multiple scatter in the system.

From the equations given in Appendix 1 of the paper it is evident that the reflectance of a paint film of thickness X and zero absorption, over a black substrate, is given by

$$R = (1 - \exp - SX)$$

This is a simple Lambert-Beer Law equation for such a system. It is possible to carry out an explicit analysis for this system, assuming multiple scatter to prevail, when the reflectance is given by

$$R = SX/(1 + SX)$$

which is a standard special case of the K-M two-constant theory.

The fact that these two equations are in conflict confirms that the alternative H equations are based on the (unstated) assumption of no multiple scattering in the paint system. It is commonplace that practical paint systems rely on multiple scattering, unless they are thin and of low pigment volume concentration, hence there is doubt about the validity of the H equations in practical situations. Conversely, it is to be expected that the H equations will be applicable, and better than the K-M equation, at low film thickness.

Even in the regions where the various equations can be considered as valid, from a scattering viewpoint, they are unsatisfactory in that they both produce S and K values which are functions of the film thickness. The underlying problem is that the two sets of equations ignore the refractive index discontinuity at the paint/air interface and the specular reflections which take place there. A detailed discussion of the effects of this interface is presented in *JOCCA*, 1967, **50**, 111 (quoted by Hoffmann *et al.*) where it is demonstrated that the measured scattering coefficient must decrease with increasing film thickness. Although that analysis deals with the case of a non-absorbing paint over a black substrate, an Appendix indicates how the full K-M equations were modified to take account of the reflections at the paint/air interface of an

absorbing paint over both black and white substrates, and used to calculate scattering coefficients.

Therefore, because the H equations relate only to simple scatter situations, and take no account of the reflections at the paint/air interface, they should not be regarded as an improvement on, or an alternative to, the existing K-M theory.

Yours faithfully,

W. E. CRAKER.

Organics and Pigments Division,
Laporte Industries Limited
PO Box 26, Grimsby, Lincs.
17 May 1972.

SIR,—Mr Day (*JOCCA* 1972, **55**, 632) is dubious about the value of the method for the determination of the hiding power of paintP when different laboratories are involved. It is a matter for experiments to decide whether a satisfactory standard method can be evolved on the basis of my proposal, which is well founded.

I have no experience of the procedure described by Mr Day, but I think that a method which relies on the eye as a measuring instrument is open to the objection that the sensitivity of the eye is so variable.

Mr Craker is concerned that the H equations may be regarded by some as alternatives to the equations derived by K and M for the determination of the absorption and scattering coefficients of a paint film. In fact the H equations are not more suitable for this purpose and this has been clearly stated in our paper (Hoffmann et al. *JOCCA* 1972, **55**, 292). Hence my proposal of a new method (*Hoffmann*. JOCCA 1972, **55**, 314) for the determination of hiding power. The assumption underlying this procedure has been found reasonable for a number of paints and a further investigation by a "round robin" procedure has been urged on the basis of these results.

The H equations are, however, more suitable for the determination of the reflectivity of paints than the K and M equation because, as has been shown in our paper, the right value for the reflectivity can be extrapolated from optical measurements on significantly thinner paint films than is the case by the use of the K and M equations.

Incidentally, the assumption of no back scattering in the derivation of the H equations has been already stated in a previous paper. The reference to this is given in the list of references to the paper under discussion. It is remarkable that the assumption of no back scattering leads to an equation (H equation) which is better than the K and M equations which we derived without this simplication.

Yours faithfully,

E. Hoffmann.

17 Elizabeth Street,
Mentune, Victoria 3194,
Australia,
26 June 1972

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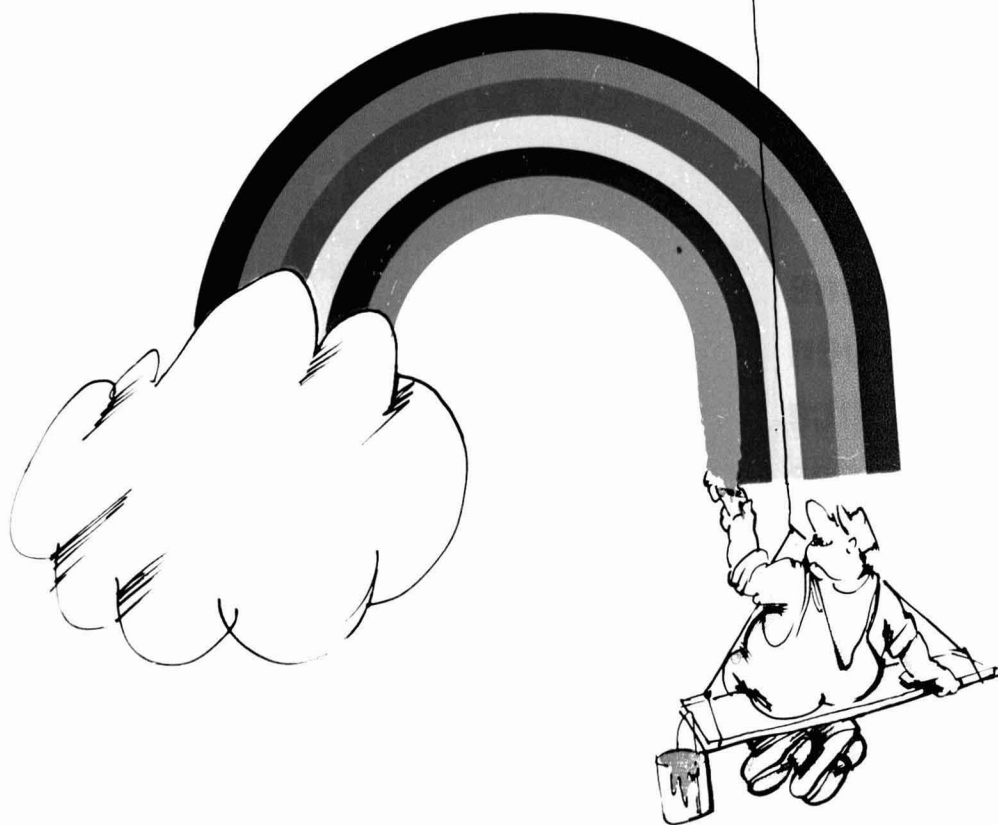
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Student Review

Paint Technology Manuals.   Part Seven: Works practice

Chapter IV. Paint manufacture
(Part II)

Paint milling machinery
Group 2: Complete dispersion mills:

> Ball mills
> Attritor mills
> Kady mills
> High speed impeller mixers—
>> Cowles
>> Torrance

Ball mills

Ball mills are an adaptation of a natural method of grinding, seen in pebbles on the sea shore. The ball mill was originally used for particle size reduction in grinding of ores, pottery and ceramic materials. Its adaptation to paint manufacture is much more recent, and for the last forty years it has been the mainstay of pigment dispersion in the industry. Ball mills are, however, now tending to be replaced by faster dispersing and more automatic equipment.

A ball mill consists of a horizontal hollow steel cylinder with either cast iron or steel ends. The cylinder can be rotated on shafts fitted into its ends and these fit into bearings on A-shaped pedestals which carry the heavy weight of the mill. Great care must be taken with the lubrication of the bearings, as wear on them means that increased power is consumed and alteration of the depth of the bearings may result in trouble with the drive gearing. This gearing can be fitted on one of the shafts, but it is now more usual for the drive to be transmitted direct to the body of the mill by girdle gear. In the latter case, the drive from the motor can be by belt or by worm gearing to a small pinion engaging with this girdle gear. Since it is necessary to stop the mill at a fairly precise position for loading and unloading purposes, a hand gear is usually fitted that is capable of making the small movements required for the final adjustment. The hand gear is so designed that, if it is not disengaged by the operator before starting the motor, it will do so automatically.

Three openings are usually provided; a rectangular opening for filling, a circular opening for emptying and a small opening at one end of the mill for releasing the pressure of the air, which expands as heat is generated during the milling operation. This last opening consists of a screwed boss attached to the end of the mill, and a long plug which screws into it, the length of the plug being sufficient to penetrate to the interior surface of the lining. In this way, the opening cannot become clogged. The other two openings consist of flanges bolted to the outside of the mill and penetrating inward to the interior surface of the lining. Into these flanges are fitted covers, the interiors of which are lined with the same material as the lining of the mill, with a packing washer which should be resistant to the solvents commonly employed in the mill. The circular cover can be substituted, during emptying, by a hollow cylinder

of the same outside dimensions; this has a number of slots cut in its inward end and a screwed boss in its outside end to take a screwed valve, so that the flow from the mill can be controlled. When in operation, the two covers are retained in position by bolts. These bolts must be handled with care because they are subjected to much use, and if they become worn or cracked leakage from the mill may occur.

The mill is lined with porcelain or steatite bricks or, for mills in which steel balls are to be used, with renewable steel wearing plates bolted through the shell. In the case of the porcelain or steatite bricks, the cylindrical walls are lined with bricks of a shape to conform with the mill surface, and these are usually moulded with male and female dovetail grooves so that they lock together. The bricks for the circular ends are rectangular and are also usually dovetailed. A mixture of Portland cement and ground pottery waste in the proportions of 1:2 or 1:3 is used to bind the bricks together. Great care is necessary in this building operation, since repair is costly if part of the lining becomes detached. The choice of lining is mainly decided by cost and expected life. Steatite gives longer life but is more costly. Lining, and repair of damaged linings, is a skilled operation, and should normally be done only by an expert.

The grinding charge for porcelain or steatite lined mills may consist of hard pebbles, porcelain balls, steatite balls, or the more recently introduced high-density balls, while steel balls are used for the steel mill.

Factors affecting efficiency of ball mill operation
To obtain the maximum output from a ball mill, the details of the operation should be understood. The grinding action is due to the rolling, tumbling, rubbing and striking action of the balls against each other and against the lining of the mill; shearing action is induced by the balls moving at different speeds throughout the mass. Consequently, a combination of attrition, impact and shear forces is operating. It follows that the more points of contact, i.e. the more balls present in a given volume of ball charge, the greater the grinding or dispersing effect. The optimum will be reached by using the smallest balls possible of equal size (compare sand and bead mills). The limiting factor in this respect is, of course, the consistency of the product being ground.

The balls must move freely under gravity; they must roll and cascade vigorously and to do this their weight must be sufficient to prevent any tendency to "float" in the paint mixture or to be carried round as an immobile mass held by adhesion of the paint layer to the inside of the mill. Obviously, the higher the specific gravity of the balls the better; in this respect steel balls are pre-eminent in that their density is nearly three times as great as that of pebbles or porcelain balls. See Table 3.

Table 3
Comparison of steel and flint balls

Material	Diameter (ins)	Wt ozs	Number per ft³ of mill space	Contacts per ft³	Grinding time ratio	Power consumption (arbituary units)
Steel ..	1	2⅜	1960	5874	1	2¼
Flint ..	1½	2⅜	580	1734	4	1

Theoretically, steel balls give an equivalent grinding effect in ¼ the time of flint balls with a power consumption only 2¼ times greater.

The general practice when using flint pebbles or porcelain balls is to charge the mill with 75-90 per cent of its normal ball volume with the smallest possible size balls and make up the balance with larger balls which are intended to act as agitators and so reduce the possible sluggishness in the smaller media (see Table 4).

Table 4

Typical charges for ball mills of various sizes

Diameter of mill Feet	Percentage and size of grinding media Small	Large
1 to 2	75%—¾ to 1in	25%—1 to 1½in
2 to 3½	75%—¾ to 1in	25%—1½ to 2in
3½ to 5½	75%—1 to 1½in	25%—1¾ to 2¼in

Note. Steel balls are usually smaller in size: from ½ to 1in diameter.

Ball charge: In order to obtain the correct cascading, the ball charge should occupy just under half the depth of the mill, or 45 per cent of the total volume of the mill. With steel balls, it is not advisable to use the full 45 per cent charge of balls unless the mill is water cooled; with uncooled steel mills the usual charge is 33-40 per cent of the mill volume.

Speed of rotation: The speed of rotation is a most important factor in mill efficiency. The speed should be great enough to carry the balls to a sufficient height to permit rapid cascading and to give relative movement throughout the ball mass, but not so great that the balls tend to be held against the wall of the mill by centrifugal action. It is convenient to express the speed of the mill as a percentage of the critical speed, this being defined as that speed which is just sufficient to cause the balls to adhere to the circumference of the mill by centrifugal action when no liquid charge is present, and being calculated from the relation:

$$\text{Critical speed in revs. per min.} = \frac{54.18}{\sqrt{R}}$$

where R is the interior radius in feet.

It was shown by R. G. Baines (*JOCCA* 1946, **29,** 182) by constructing a mill with transparent perspex ends and watching the movement of the balls at increasing speeds of rotation, that the ideal speed is 55-60 per cent of the critical speed. The charge of balls rotated with a liquid then assumes the form shown in Fig. 25. It was found that the layers of balls were moving with different relative speeds throughout the mass and no balls were ejected from the top of the rotating mass. Wear on the lining is at a minimum, particularly as a pool of liquid forms in the lower left quadrant of the mill (A) thereby cushioning the fall of the balls.
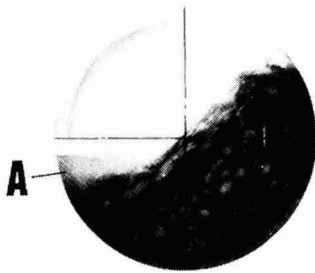
CORRECT SPEED
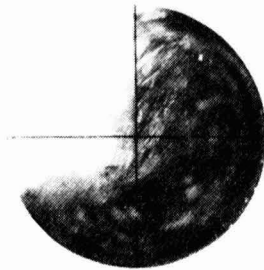
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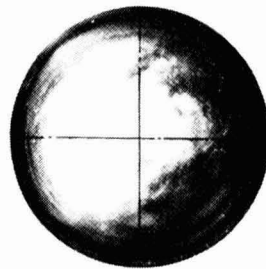
CRITICAL SPEED

Fig. 25. Effect of speed of rotation on ball milling (Courtesy of Steele & Cowlishaw Ltd.)

Volume of mill charge: The volume of the charge to be ground in a ball mill has a marked effect on the efficiency and speed of the operation. If it is too small, a pool of liquid is not formed at the point A and there is less cushioning effect as the balls cascade down the mass. This is dangerous, particularly when the

ground charge has a low viscosity, because it may result in the fracture of some of the balls and damage to the lining of the mill. The latter means that the mill must be taken out of action for an expensive relining operation, while fracture of the grinding media involves straining and refining the paint charge, followed by washing, removal of the balls and sorting through them to remove all the damaged ones and to eliminate the broken fragments before re-using them.

If the volume of the charge to be ground is too large, the grinding media tend to be separated from each other by a thick layer of the charge. Since the shear occurring in the liquid layer between the two balls is proportional to the relative speeds of the two balls and inversely proportional to the distance between them, the optimum shear will occur when the viscosity is sufficiently low to allow a reasonable difference in the velocities of the balls and both the viscosity and quantity of the charge are such that a thin layer of liquid is sheared between them.

It is now generally accepted that the optimum charge of pigment, paint medium and solvent is approximately equal in volume to the voids between the balls, but this may result in practice in considerable wear in the grinding medium and it is usual to increase the above volume by an additional amount equal to 5 per cent of the total capacity of the mill.

Theoretically, the volume of the voids between a sufficiently large number of spheres of uniform size is 26 per cent of the superficial volume occupied by them, irrespective of their diameter, and the volume of the spheres themselves is 74 per cent. When smaller diameter spheres are also present, they tend to pack in the voids between the larger ones and this leads to a decrease in the voids volume. The ball charge in a mill is seldom uniform in size nor strictly spherical in shape and the calculation giving the above volumes assumes a hexagonal packing, which would be unlikely to occur in a dynamic situation. It is usual to assume that the voids volume is 40 per cent of the apparent volume occupied by the ball charge.

Thus if the mill is loaded with balls to an apparent volume equal to 45 per cent of the mill capacity then the void volume would be 40 per cent of 45 per cent = 18 per cent of the total mill capacity. Adding the 5 per cent described above to reduce wear this gives a charge of the paint ingredients of 18 + 5 = 23 per cent of the mill volume. In cases where a high degree of dispersion is not required or where an easily dispersible pigment is in use, the charge of mill base may be increased sometimes to as high as 40 per cent of the mill volume.

Consistency of the grind charge: It is evident, from what has been said above regarding the conditions needed for efficient mill operation, that the consistency or viscosity of the mixture of pigment, resin and solvent to be ground will have an important effect on the dispersing operation.

If the viscosity is too high, the speed of the balls relative to each other will become so slow that virtually no shear exists in the fluid layer between them, and in the extreme case the whole charge may rotate with the mill as an immobile mass. On the other hand, if the charge is too mobile, increased wear and possibly fracture of the grinding media may result on account of excessive cascading. The optimum viscosity appears to be that at which the mixture of pigment

and medium, when rubbed up on a plate with a knife, just runs. By using various quantities of medium and thinners, i.e., by adjusting the solids ratio of the medium, further improvement can be obtained in the total amount of pigment dispersed at each charge of the mill. A method developed by Daniel and Schurtz to this end has rationalised the procedure. A fixed quantity of pigment is rubbed on a plate and muller with a mixture of medium and thinners of known composition until the paste just runs. The amount of liquid used and its solids are recorded. The titration is repeated with further quantities of pigment and other mixtures of medium and thinners (usually ranging from 5 per cent to 40 per cent solids in steps of 5 per cent) recording in each case the amount of liquid used to give a runnable paste with the fixed amount of pigment and the chosen solids content of the medium and thinners mixture. The graphed data give a curve of the type shown in Fig. 26. The minimum value thus found is the most efficient charge for the mill, since it represents the lowest liquid/solid ratio which gives the desired viscosity of mill paste.
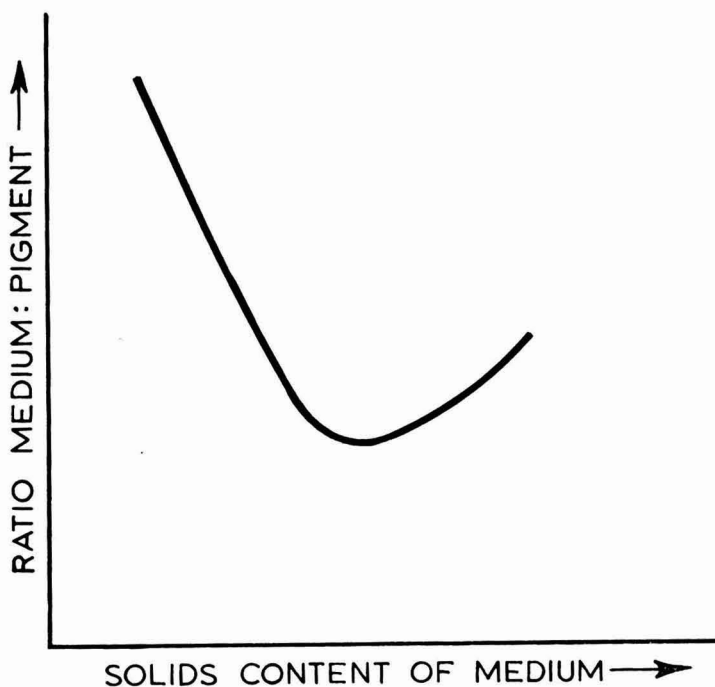
Fig. 26. Titration curve for determination of optimum ball mill charge

Consider, for example, the dispersion of titanium dioxide in a long oil length alkyd. Using the Daniel method with 20g of pigment, the minimum point on the flow point curve was obtained with 7ml of a 15 per cent solution of the alkyd in white spirit. Knowing the specific gravity of the solution, the optimum quantity of resin and solvent required to disperse a given quantity of the pigment can readily be calculated. However, it must be stressed that the use of the charge determined as above has certain drawbacks, particularly the possibility of "seeding" on thinning. This appears to be a reagglomeration

of the pigment, together with partial precipitation of part of the medium. It is therefore important that investigation should be made of initial mill runs, and, if seeding occurs, the medium/thinners ratio should be increased. Additional medium should also be added if undue thickening occurs during dispersion of the pigment; this frequently happens with organic pigments.

ICI Ltd, in the publication "Pigments for paints" 1963, quotes ball mill charges for its range of pigments dispersed in a long oil length penta alkyd and white spirit as solvent. In general, milling is carried out in a 20 per cent resin solution. It will be noted in this publication that the concentration of pigment giving maximum output varies considerably from pigment to pigment and that variation in the resin concentration, whilst giving increased efficiency in certain cases, is much less significant. This elementary discussion of the consistency of the mill base is somewhat over-simplified. In the first place, as the ball mill continues to operate, the temperature will rise and this, in general, will lead to a decrease in viscosity. It is usually a simple matter to reduce the viscosity of the charge by the addition of medium and/or solvent; to increase it would possibly need the addition of pigment in fairly large amounts. Secondly, as the milling proceeds the pigment will become more finely dispersed, the rheology of the mill base may change, its viscosity may increase and it may develop pseudoplastic or thixotropic characteristics. These last two characteristics lead to a decreasing viscosity as the rate of shear is increased, and whilst they may produce a suitably low viscosity whilst the mill is in operation, when it is stopped and the shear ceases the viscosity will rise, and this is accentuated by any simultaneous cooling. Thus difficulty may arise in discharging the mill. In such cases, discharge of the mill or dilution of the charge with additional medium immediately after the completion of milling may be essential. It is also possible that dilatancy may arise; this is an increase in viscosity with increasing shear rate and could in extreme cases lead to immobility of the charge and failure of any further dispersing action.

It is evident that, whilst the Daniel method described above is useful in determining the approximate optimum composition of the mill base, further experimentation is necessary before the mill base composition can be finalised. This is particularly important where the degree of dispersion in the mill is greater than that obtained in the Daniel test.

A great deal of work has been published upon the volume of the grind charge and its optimum consistency. Papers suggested for further reading are:

Bowman, A., *JOCCA* 1952, **35,** 314 (Dispersion of TiO_2)
Cook, H. G., *JOCCA* 1965, **48,** 17 (Dispersion of dyestuffs)
Sheppard, I. R., *JOCCA* 1964, **47,** 691 (Optimum grinding conditions)
Carr, W., *JOCCA* 1972, **55,** 663.

This last paper considers the influence of various factors of mill operation in the light of the optimum particle size distribution of the pigment in the final dispersion.

In addition, there are the two papers previously mentioned.

Baines, R. G., *JOCCA* 1946, **29,** 182 which studies the movement of the balls during grinding.

Hoogerbeets, J. G., *JOCCA* 1971, **54,** 1162—A Student Review on the efficient use of TiO$_2$, but which has also general implications.

Operating the mill

The only objective achieved by a ball mill, or any other milling machine used in paint manufacture, that could not be carried out in a simple mixer is the dispersion of the pigment. Clearly, the greater the weight of pigment dispersed per batch or per unit time the more efficient the operation. The technique of milling the greatest weight of pigment practicable in a mixture of medium and solvent of low solids content is sometimes known as "sludge" or "slush" grinding. One method of arriving at a suitable mill base composition has been described in the last section.

The volume of paint given by such a procedure will naturally depend on the pigment content of the finished paint. When this is low, as in some gloss finishes, notably black, the yield of paint obtained from a batch can be greater than the total volume of the mill in which it is made. (This involves partial dilution of the mill base in the mill, discharge and final dilution in a mixer.) At the other extreme, some highly pigmented undercoats may have to be milled with practically the whole of the medium solids present in the mill. In such cases the final volume of paint obtained from a batch may not greatly exceed the volume of the mill base ground.

These techniques involve the use of a liquid grind charge containing low medium solids and high solvent contents (so as to obtain a sufficiently low viscosity grind charge). It has been stated above that some dispersions of this type are unstable and may seed or aggregate on standing, particularly if large volumes of medium/solvent are added. This must be avoided because the aggregates do not readily redisperse on re-running the mill, and it may be necessary to refine such a paint on a single-roll mill. This results in loss of pigment and resin solids and may significantly alter the intended composition.

It is beyond the scope of this review to discuss the reasons for this instability, but it may be of interest to mention briefly one possible explanation. Most media used in paint manufacture embrace a fairly wide range of molecular size and species; during the dispersion process the lower molecular weight and more polar species of the medium become adsorbed on the pigment particles, and it is these same species which tend to stabilise the higher molecular weight species in the medium solution. Thus, when the concentration of resin solids in the liquid mill charge is low, the adsorption on the pigment may remove a high proportion of the lower molecular weight species from the solution and this in turn destabilises the high molecular weight species, which may coagulate around the pigment particles. This is particularly likely to occur if a large volume of solvent or medium and solvent is added. This is the reason why it is often necessary to dilute the mill base in two or three stages as soon as the dispersion is completed and to run the mill for a few minutes between each addition.

As no premixing is necessary, the mill merely requires a platform arranged so that loading may proceed from above, usually through the larger manhole. The easiest method of achieving this is to use a light metal funnel; the outlet fits into the manhole and the top of the funnel is supported by the platform.

Generally, the whole of the liquid portion of the charge is introduced, followed by the pigments. With highly pigmented materials or light, fluffy pigments such as carbon black, only part of the pigment is loaded. The mill is then closed, run for a short while, re-opened and a further portion of the solid material added. These operations are repeated, if necessary until all the charge has been added. This mill is then run. As the temperature of the mixture rises during the milling period, so the pressure also tends to rise; air and other gases adsorbed on the pigment are displaced; the pressure developed may become dangerously high, so the mill is stopped periodically and the air is allowed to escape through the small release valve already mentioned. Grinding is continued to the required degree of fineness. Partial thinning of the charge is then carried out by adding medium and thinners in one, two or more portions and running the mill for a short time after each addition. This is done because overthinning with medium and thinners at this stage might lead to pigment flocculation and seeding. The contents of the mill are now discharged into a finishing tank or pumped into a mixing tank, where the batch is completed.

The paint which does not drain from the mill is usually washed out with a small quantity of thinners and added to the bulk. To prepare the mill for another charge involving a change in colour, it is necessary to wash it completely with suitable thinners; if the colour change is considerable and slight contamination cannot be tolerated, the whole of the ball charge is dropped from the mill, the interior thoroughly cleaned, and the balls washed separately and returned to the mill. In any case it is desirable to carry out this procedure at regular intervals so that the mill walls can be inspected and any broken pebbles or balls removed and replaced. The cleaning of mills can be an expensive operation in solvent and labour costs and in loss of operating time. Mills are most economically operated if a mill can be allocated to a particular product and used for batch after batch without cleaning or even very complete drainage.

Where the output is not sufficiently large to enable this to be done, mills should be allocated to a particular colour range (or alternatively medium type). Failing this, some cycle of gradually deepening colours should be devised, so that thorough cleaning becomes necessary only if a change has to be made from the deepest to the lightest colour. (Sometimes it is possible to reverse the colour schedule and proceed gradually from dark to light.)

Steel mills: The use of steel lined mills with balls of the same material is confined to products where contamination with metallic iron is immaterial e.g. blacks and dark colours. The high specific gravity of steel balls compared to pebbles or porcelain balls results in more mechanical work being done during processing, i.e., the shear forces are increased; the consistency of the charge can be increased and considerably more heat is developed. Steel mills are therefore often jacketed to permit water cooling.

In a steel mill, the charge density is much higher and there is more slippage between the steel balls and the lining than between pebbles and a porcelain lining, with the result that the steel balls may not reach the height necessary for efficient cascading. This is overcome by fitting lifter bars along the inside of the mill parallel to the axis of rotation. Generally, a steel mill is capable of producing results similar to those obtained with a pebble mill, in about one third of the time.

Laboratory mills: Small porcelain pots or jars are used extensively for develop-
ment work or for making small quantities of material. A typical unit comprises
a series of 9 litre porcelain pots which fit into one or more oblong cradles in
rows of three. The pots are strapped into the cradle and this rotates longitu-
dinally, imparting the necessary turning motion to the pots. The cradles may
be 2, 3 or 4 tiers high within the same frame, the drive being effected by chain
and sprocket linkage from the prime moving cradle. The unit is efficient and
useful for small quantities only, and care in handling the pots is required, since
they can be heavy when loaded and offer a high breakage risk. A "home made,"
but extremely efficient, unit is based on six 5 litre porecelain jars which lie on
their sides on 4in rubber wheels fitted on to 2in line shafting, each jar being
supported on two parallel shafts. The shafting is built into an elevated frame
(about 2ft above ground level), usually in parallel lanes, and rubber guides are
fitted to stop the posts from "tracking" when turning. Cork bungs covered with
leather act as plugs, and there is virtually no limit to the number of pots which
can be run at one time. Again, this is extremely useful for smaller quantities of
finished product, as both types of unit allow the minimum of pot cleaning
since one pot can be kept for one colour or product.

Advantages of the ball mill

No pre-mixing equipment is required, and with careful formulation of the
charge the mill will give a high output per man/hour of labour.

The mills are frequently run overnight, require little attention and may
utilise electricity at "off-peak" rates.

The degree of dispersion obtained is controlled and repeatable.

Being totally enclosed, volatile matter losses are low and hence there is a
great advantage with media containing very volatile solvents.

The mill is adaptable to the grinding of most pigment dispersions, other than
heavy pastes, and to a wide range of pigments—hard or soft, fine or coarse.

Unskilled labour can be employed.

Disadvantages of the ball mill

The mills occupy considerable space.

The mills are difficult to clean thoroughly and lack flexibility in the size of
batch produced.

The attritor mill (e.g. Torrance—Fig. 27)

This mill has been described as a ball mill placed on end, the balls being agitated
by means of an impeller.

The machine consists of a vertical stainless steel vessel in which there is a
charge of grinding media—usually small steatite or steel balls—which is sur-
rounded by a water cooling jacket. The grinding charge is agitated by means
of an impeller on which there are a series of horizontal arms. In practice, the
ingredients for the mill base are loaded into the mill and the entire contents
agitated until a satisfactory dispersion has been obtained, after which the mill
base is discharged from the bottom of the machine. On larger machines, it
is customary to circulate the mill base during the milling cycle by pumping
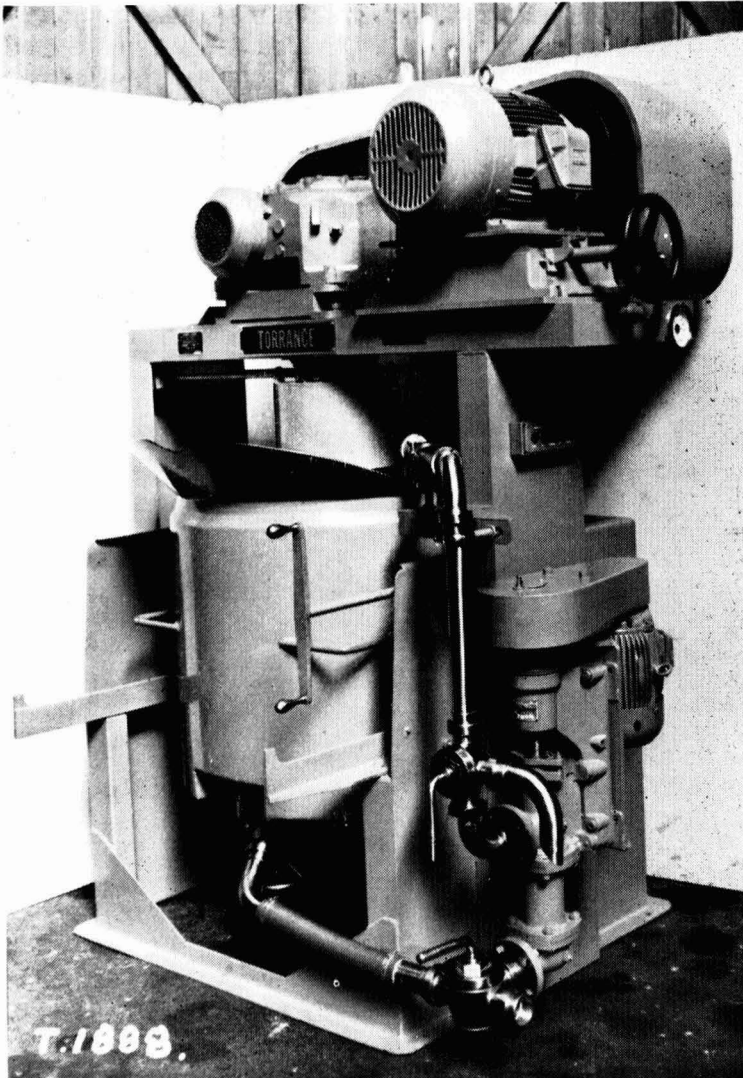
Fig. 27. Attritor mill (courtesy of Torrance & Sons Ltd.)

from the bottom of the grinding vessel back to the top of the machine. As originally designed, the attritor was essentially a batch processing machine with a short milling cycle, but it has been adapted to continuous production; in appearance and operation it then closely resembles the sand mill. Mill base formulations follow closely the principles discussed under ball mills. The most efficient dispersion is obtained with the charge just covering the grinding media, as with ball mills; the charge can be increased somewhat in mills fitted with the circulating device. As the movement of the grinding media is not dependent upon gravity, the attritor can be used with mill charge at higher consistencies than can the ball mill.

In practice, the paint vehicle, at the required non-volatile content, is charged into the mill. The agitator is started at slow speed and the pigment added slowly. When the pigment addition is completed, the agitator is switched to normal speed. The charge is stabilised by further addition of vehicle after the completion of the dispersion, and the mill discharged by gravity or by pumping. Grinding times in the attritor are claimed to be very much less than those in a ball mill of comparable size.

The Kady mill

This apparatus consists of a bowl-shaped covered vessel or tank, through the bottom of which protrudes a firmly located shaft, the lower end of the shaft carrying a series of grooves by which it can be rotated by a set of vee belts connected to the vertical shaft of a motor. The upper end of the shaft carries the kinetic dispersion unit or "head," which is situated just above the bottom of the tank. (See Fig. 28.) The capacity of the tank may vary from 72 to 800 litres according to the model.
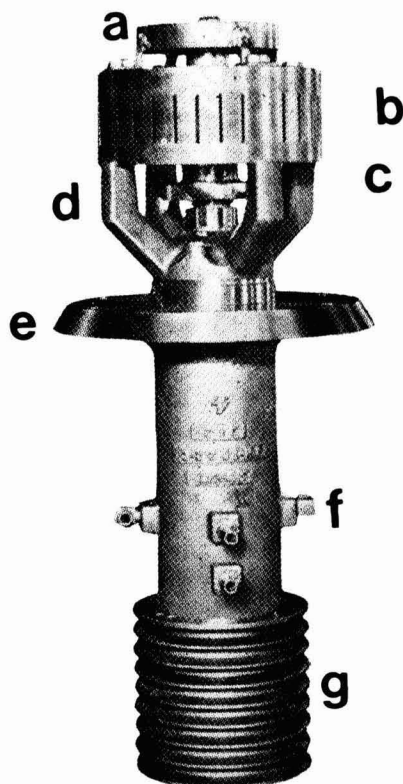
Fig. 28. Kady mill, dispersion head and drive, (a) upper shroud and propeller, (b) main dispersion head containing rotor and stator, (c) main working seal, (d) bottom feeding propeller, (e) tank bottom mounting flange, (f) bearing and seal housing, (g) driven shaft

The dispersion unit consists of a disc-shaped rotor mounted on the shaft, which carries a number of slots 0.125in wide and varying from 0.5 to 1.75in deep, according to the capacity of the apparatus. The slots in the rotor are

not radial, but are inclined at an angle to the radius; the rotor has an outside diameter of 6.5in and is rotated at between 5,200 and 6,500rpm, depending upon the capacity of the plant. There is also a laboratory model of rather different design, which operates at 16,000rpm. The rotor rotates inside a stationary closely fitting ring-shaped stator, which carries a number of radial slots of similar size to those on the rotor, and so dimensioned that the distance from the tip of the rotor to the outside of the stator is 1.0in, see Fig. 29.
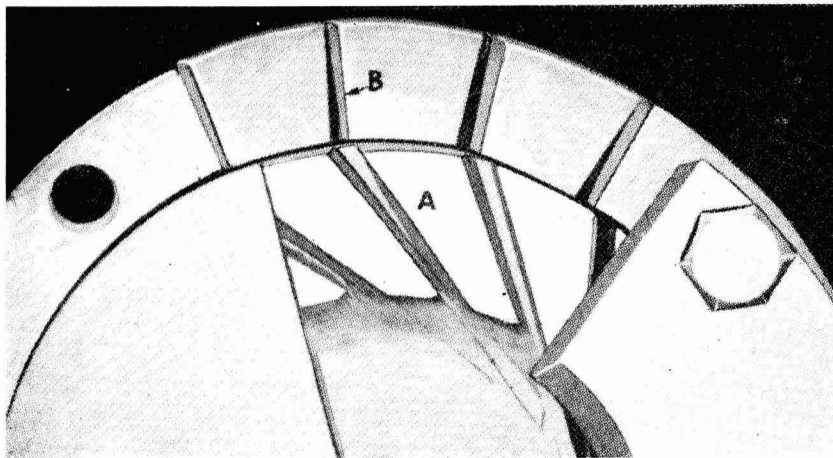
Fig. 29. Kady mill, showing dispositions of slots (A-rotor, B-stator)

In operation, the whole of the dispersion unit is immersed in and filled by any liquid contained in the tank. When the rotor is rotated, the liquid in its slots is driven by centrifugal force towards the stator, but because of the small clearance between the outside of the rotor and the inside of the stator, little flow of liquid can occur, except during the instant when the slots in these two parts coincide. In addition to the centrifugal force acting on the liquid in the rotor slot, an element of liquid situated at the outer rim of the rotor has a tangential velocity of about $1,500$ft sec,$^{-1}$ so that any liquid flowing from the rotor to the stator undergoes a very large deceleration. Any pigment aggregates carried by the liquid undergo a series of high shear stresses and are subjected to collisions with each other, with the walls of the stator slots, and a further shear when the liquid carrying them issues as a jet from the stator into the (relatively) slow moving bulk of liquid in the tank. This series of shear stresses results in the disruption of the pigment aggregates and the formation of a dispersion. However, as with the high speed dispersers to be described later, the Kady mill does not grind, that is, there is little reduction in size of the ultimate pigment particles forming the aggregates and its action is almost solely dispersion. For this reason all pigments and extenders used must be sufficiently finely ground during their manufacture for the type of paint being prepared.

Not all pigment aggregates passing through the rotor and stator follow exactly similar paths and, therefore, all are not subjected to identical stresses. There is a statistical probability that a given aggregate will pass through the dispersion head without being subjected to sufficient shear stress to disrupt

it. It is, therefore, necessary that a given pigment aggregate should pass many times through the head during the process, to ensure that the number of surviving aggregates is reduced to an acceptable level. The rate of circulation of liquid through the head is about 8,000 litres per minute, so that it becomes clear that a given element of liquid must pass through the head many times during the course of the process. Propeller blades are fitted to the shaft above and below the dispersion head, to ensure that there are no stagnant volumes in the tank from which the liquid is not passed sufficiently frequently through the head.

The high velocities and high stresses to which the liquid is submitted require the expenditure of a great deal of energy, and the apparatus needs an electric motor of 20 to 60hp, or even more for some applications. Almost all the mechanical work put into the system will finally appear as heat, and the tank holding the liquid is provided with a jacket through which cooling water is passed. The temperature reached by the charge depends on the viscosity, the density and concentration of pigment present and is generally in the region of 50—75°C.

It is evident that, if the pigment aggregates present are to be broken down rapidly, the liquid carrying them should have a low viscosity, but this does not necessarily mean that high pigment concentrations cannot be used. It is quite easy to disperse titanium dioxide at a concentration of 72—75 per cent, with not more than 10 per cent vehicle solids and the remainder solvent. For instance, 500 litres of such a slurry, containing 675 kilos of titanium dioxide, should be dispersed in 45 minutes, and yield sufficient pigment dispersion to give 1,800 litres of finished paint. Thus, although the rate of power consumption is high, the short time of operation enables the process to compare favourably with other methods on the basis of electricity costs.

The Kady mill is particularly suitable for the preparation of aqueous pigment dispersions for water-based and emulsion paints, although it must be checked that any polymer emulsion put through the mill is sufficiently stable to shear to avoid coagulation by the high mechanical stresses imposed.

The concentration of pigment that can be used and the quantity of medium required will depend on the type of pigment concerned. Compositions that tend to become "puffy" or dilatant as the pigment is dispersed are usually unsuitable and should be avoided. The development of pseudoplasticity or thixotropy is not necessarily objectionable since these structures will tend to break down under the high stresses imposed during the dispersion.

A fuller paper describing the apparatus and its use has been given by Kew (*JOCCA*, 1957, **40,** 661).

High speed dispersers (e.g. Cowles, Mastermix, Torrance)
These machines are now used for complete dispersion of certain micronised and surface treated pigments and also for pre-mixing mill bases which require subsequent dispersion, e.g. on a sand mill.

The machines comprise a vertical shaft on which is mounted a saw tooth type turbine (see Fig. 30) centred in a cylindrical vessel; the shaft is capable of rotating at high speeds and is generally driven by a variable speed drive,
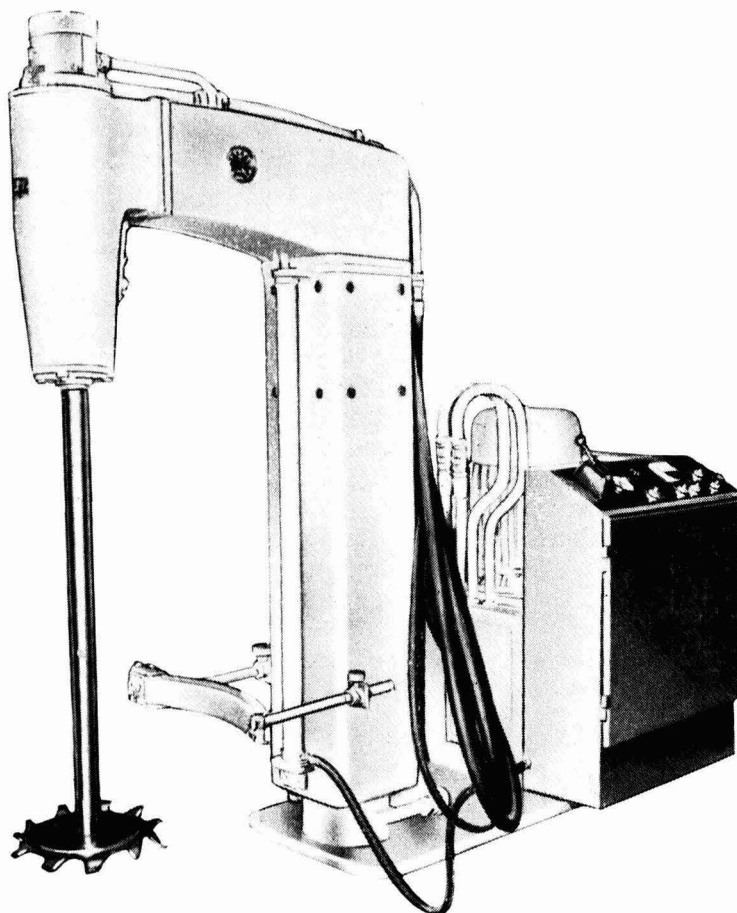
Fig. 30. High speed disperser (courtesy of Mastermix Engineering Co. Ltd.)

either by expanding pulleys and belts or variable hydraulic drive. The action of the machine is twofold; first, as the teeth of the turbine rotate at high speed, there is a rapid fluctuation of pressure build up and collapse from the leading to trailing edge of the tooth; this has the effect of rapidly removing air from the surface of the pigment leading to a rapid wetting process. The second effect is that of shear between the tip of the blade and the material, which results in dispersion of the pigment. It follows that, in order to develop this shear and obtain good results, it is necessary to keep the viscosity of the mill base as high as practicable. When formulating the millbase, allowance must be made for a fall in viscosity resulting from the substantial temperature rise which occurs during operation.

For optimum results, the peripheral speed of the turbine during milling should be between 3,000 and 4,000ft per minute; hence the larger the turbine the lower the shaft speed. It is also of importance to carry out the operation in a container of suitable dimensions in order to promote the correct flow conditions in the mix and to enable dispersion to take place. If D is the diameter

of the turbine, the following conditions should be adhered to:

vessel diameter between $2D$ and $3D$
batch level $2D$
distance of turbine from bottom of vessel $0.6D$.

The remaining factors for efficient dispersion are the composition of the mill base and the consistency of the charge. A useful description of the design and principles of high speed dispersers has been given by Daniel, F. K., *JOCCA* 1971, **54**, 84. See also Dowling, D. G., *JOCCA* 1961, **44**, 188.

As pointed out above, the mill base should be viscous yet flowable. Experience has shown that the vehicle solids should be 25-45 per cent and the viscosity of the vehicle 1.5-2 poise. The amount of pigment will be slightly lower than the oil absorption figure, as determined by the Gardner-Coleman method, would indicate, and must be determined by experiment. A useful starting point can be calculated by the Guggenheim equation (see *Off. Dig.* 1958, **30**, 792 and Hoogerbeets, J. G., *JOCCA* 1971, **54**, 1162). Alternatively, a pigment volume concentration of 42-46 per cent may be used as starting point. The consistency to be aimed at in practice is one where at maximum speed a "rolling doughnut" type of circulation is induced by the impeller blade (see Fig. 31). No splashing should be evident and the centre of the impeller should be just covered, the shaft being clearly visible in the vortex. The whole mass will then be in rapid circulation. On the other hand, if the vortex appears conical in shape, it is an indication that the consistency is too low.
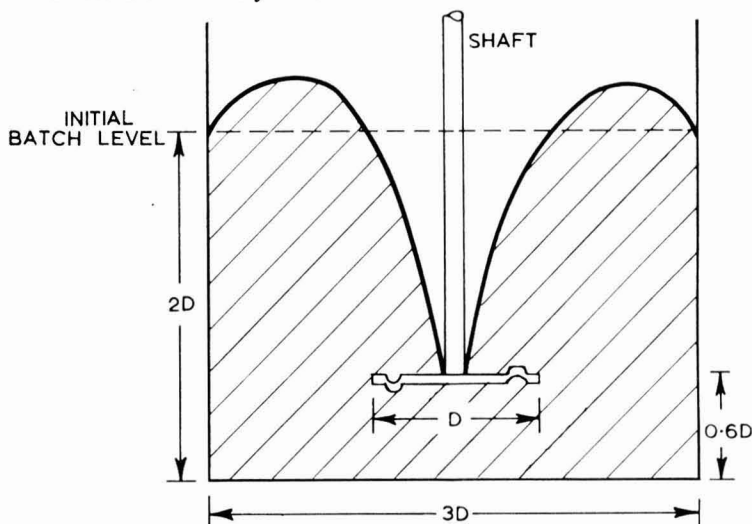
Fig. 31. Ideal circulation for high speed disperser

Working procedure

Charge the medium/solvent mixture into the container, lower the turbine until it is fairly close to the bottom of the vessel, start the motor at its slowest speed and add the pigments gradually at a rate consistent with their penetration into the vehicle. In general, pigments and extenders should be added in decreasing order of their oil absorptions. Too rapid addition of pigment will lead to lumping and sticking to the side of the container.

When all the pigment has been added, the machine is stopped and the turbine raised out of the mix; the shaft and sides of the vessel are scraped down and finally washed well with a little solvent. This is to ensure that any stray particles of pigment are incorporated before the dispersion phase itself is started. The turbine is then lowered back to the dispersing position, the speed gradually increased to the maximum and maintained for 15-20 minutes. If optimum dispersion has not been reached at this stage, further running will generally effect little improvement. The speed is then reduced to the minimum and the remaining medium and thinners slowly added (see "colloidal shock" under ball milling above). With a number of readily dispersible pigments—i.e., micronised or surface treated, complete dispersion will be obtained. If the charge is a premix for a sand or other mill, the last stage is omitted and the mill base pumped to the second mill to be used.

Double shaft dispersers (See Fig. 32)
With the normal high speed disperser, difficulties sometimes arise when large batches need to be made, particularly if the material tends to be highly viscous
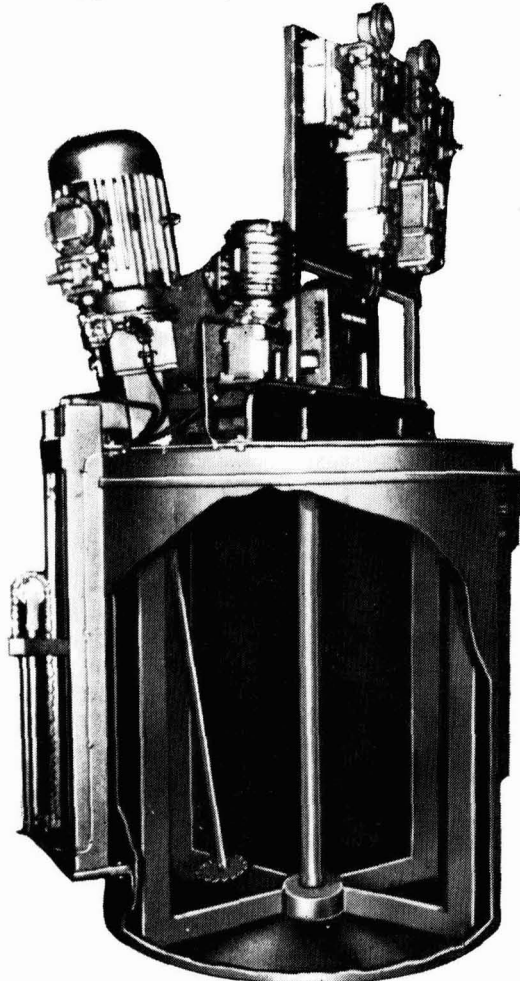
Fig. 32. Double shaft disperser (Courtesy of Mastermix Engineering Co. Ltd.)

or thixotropic in nature. It then becomes difficult to circulate the mill base efficiently, resulting in "dead spots," particularly around the edge of the container at both top and bottom. To overcome this, the double shaft disperser has been developed, in which a slow speed agitator blade is used to maintain a positive circulation of the charge, whilst a high speed disperser is operated between the slow speed shaft and the vessel, thus obviating "dead spots." By this means, it has been found possible to manufacture very large batches of dispersions, 4,500 litres being by no means uncommon. It is particularly useful for the manufacture of emulsion paints, but large batches of primers and undercoats may also be prepared.

Information Received

Chemviron Limited (formerly Pittsburgh Activated Carbon Ltd), has opened a new UK office to service the Northern industrial/municipal complex, and to provide closer support for Scandinavian operations. Based in Oldham, the new office will offer the full range of *Chemviron* products and services in water treatment, and industrial process chemicals and systems.

A new range of melamine pigment dispersions for use in stoving finishes has been introduced by **International Colloids Ltd.** Known as *Product Group M*, the dispersions are available in matched shades as well as the usual standard colours; their formulation is aimed at maximum gloss and colour stability.

The Paintmakers Association of Great Britain Limited has recently issued an announcement regarding the new BS 4800 : 1972 "Paint colours for building purposes". In its preparation, "correlations" or "near equivalents" to colours in BS 2660 : 1955 have been specified by comparison of the current BSI issue of BS 2660 with the new BS 4800 colours. The PA wishes it to be widely known that when BS2660 was introduced, it was not considered necessary to maintain complete spectrophotometric data. CIE trichromatic colour coordinates for all the colours were published in Supplement 1 to the standard, but successive printings of the cards were matched to master cards visually rather than instrumentally, leading to some difficulties caused by metamerism between different printings.

In the case of BS 4800, at the request of the PA, the BSI has made arrangements with the **Paint Research Association** for complete spectrophotometric measurements to be made and recorded of each of its 86 colours, so that permanent standards will be available throughout its existence.

Brolac Gloss and *Brolac PEP* will be available in all colours in the new BS 4800 during January 1973, **Berger Paints** has recently announced. Colours in the BS 2660 range will be available until 31 March 1973. Berger has also issued a redesigned technical manual, supplied to specifiers and trade users. A new concise, clear format has been used to give detailed specifications for application to new and traditional surfaces, with a cross reference index system. Important extracts from the Building Regulations Act 1965 and the Factories Act 1961 are also included.

Carson Paripan Ltd has diversified its activities into more general decorative products with the introduction of a range of light switches. The *Carsons Colourswitch* incorporates a clip-on perspex front under which a piece of wallpaper or painted card to match the wall behind can be placed. It is the first of the new range, more products in which are expected to follow in the near future.

Full details of the conditions at its Italian exposure site have recently been issued by **Centro di Esposizione agli Agenti Naturali (CEAN).** Day by day figures of temperature, relative humidity, rainfall and hours and intensity of sunlight are given for the month of March, and the range of exposure testing services offered by the company is outlined.

Degussa has announced that, in response to increasing demand, a further production unit for carbon black/plastics concentrates has been installed and started up at its Cologne works, thus more than doubling its capacity for these products.

A new technical bulletin issued by **Nopco Hess Limited** deals with *Nopcosant C* pigment dispersant, a recent addition to the company's range of liquid dispersants for latex systems. The bulletin, "*Nopcosant C* pigment dispersant for latex paints, pastes and adhesives," is published by the Nopco Chemical Division of Diamond Shamrock Chemical Company; copies are available from Nopco Hess Limited.

A new, improved quality brilliant white emulsion paint has been introduced by **Hadfields (Merton) Ltd.** The new paint has been reformulated to give increased opacity and covering power, and improved application properties, while maintaining its price at the same level as that of the previous formula.

Russell Finex Limited has published a specification chart of the stainless steel, nylon and polyester meshes provided for its mesh supply and remeshing service for machines of any manufacture. All standard width meshes can be supplied to any length.

A plant for the production of a range of glycol ethers has recently been commissioned by **ICI Ltd.**, Petrochemicals Division. A total of nine products based on ethoxol, the monoethyl ether of ethylene glycol, are being produced. The solvents are recommended for use in the paint and printing ink industries, and their high stability, miscibility, and strong solvency are stressed.

A new range of cross-linked polystyrene gels for non-aqueous gel permeation chromatography has been introduced by **Applied Research Laboratories Limited.** Known as the *ARgeL* range, the gels are available packed in $\frac{3}{8}$in stainless steel columns in lengths of 2, 3 or 4 feet, $\frac{1}{2}$ metre or 1 metre, which range should fit all commercially available GPC instruments.

Rohm and Haas Company, and **Lennig Chemicals Ltd.,** its British subsidiary, have announced the start up of a new methyl methacrylate monomer plant at Seal Sands, Teesside. The plant, which was constructed to meet an increasing market for acrylic sheet and moulding powder, has a production capacity of 27,000 tons per year, and will also manufacture methacrylic acid and other methacrylate esters.

Another new plant with a capacity of 50,000 tons per year of acrylate monomer is scheduled for commission at Seal Sands later this year.

Tioxide International Limited has recently published "*Tioxide* pigments in airdrying gloss paints", a two part treatise on this subject. Part one discusses the composition, formulation and preparation of airdrying gloss paints, while part two compares different grades of *Tioxide* and suggests the most suitable for use in different types of finish. At the same time, Tioxide has issued an up to date list of its publications, together with those of its associate company, **Titanium Intermediates Limited.**

It has recently been announced that **Cole Polymers Limited** has been appointed as distributor to the paint trade of *Methocel* synthetic thickener for latex and emulsion paints. This product is manufactured by **Dow Chemical Company Limited.**

The American **Torit Corporation** has now formed a wholly-owned UK subsidiary—**Torit Limited**—which will be responsible for the sales and marketing of the entire *Torit* range of dust collection and welding fume extraction equipment throughout the United Kingdom.

Three new pigments for paint and printing inks have been introduced by **Sandoz Ltd.** Copper phthalocyanine types, the new pigments, *Sandorin Blue BNK, Green 8GLS* and *Green 3 GLS*, are claimed to exhibit high colour value, pure shades, excellent light and weather fastness, and good all round fastness. In addition, *Sandorin Blue BNK* is said to be non-crystallising and completely stable to aromatic solvents and to have good rheological properties, while the two *Sandorin Greens* are practically non-flocculating and with similar stability and rheological properties. Sandoz has also introduced *Savinyl Pink 6 BLS*, a new dyestuff suitable for gravure and flexographic inks.

Owing to recent local building schemes and land acquisition, **Cornbrook Resin Company Limited** has ceased manufacture of resins and closed its Wardle, Rochdale factory. In order to minimise any problems caused to regular customers of long standing, arrangements have been made that certain rosin modified resins and metallic resinates should be available from **Leon Frenkel Ltd.,** and novolacs and resoles from **Blackburn & Oliver Ltd.**

A new booklet on formaldehyde has been issued by **Joseph Crosfield & Sons Ltd.** The booklet is in three sections: manufacture and properties; established applications; methods of analysis, health hazards etc. Copies are available from Crosfield on request.

Annual Report of the Council for 1971

Adopted at the Tenth Annual General Meeting held at Wax Chandlers' Hall, Gresham Street, London, EC2V 7AB on 7 June 1972.

General

By far the most significant event of the year has been the introduction of an optional Professional Grade for Ordinary Members of the Association. This is a development which has long been under consideration by Council, but very great difficulties lay in its achievement since it had been felt that it might have become necessary to alter the whole character and even the name of the Association and that this would have met with criticism, particularly amongst members of long standing. However, a way has been found whereby the desire of Members to obtain an educational identity with the industries covered by the Association, similar to that in many other industries, can be achieved without in any way amending the Memorandum and Articles of the Association, or its name, and full details were published in the September issue of the *Journal*. At the same time, Council asked the overseas Sections of the Association in South Africa and New Zealand to set up sub-committees which would be able to advise on comparable examinations and qualifications in those countries.

Council is pleased to report that by the end of the year wide-spread support from the membership for the scheme had clearly shown the necessity for its introduction. Council regards the institution of the Professional Grade as an event of singular importance and significance in that the Association has, for many years, offered other facilities and services such as are available to the members of few learned societies and, although it had been very strong in its activities in the field of technical education, it had never been able to offer certification, which the new scheme allows to Ordinary Members who comply with the regulations.

The scheme was first announced in the September issue of the *Journal* and the Professional Grade Committee met in November to consider the applications received and subsequently held *viva voce* examinations and considered dissertations submitted. At the end of the year the position of those applications received by 10 November 1971 was as follows:

	Applications received	Applications transferred between grades	Successful, as first list in January 1972 Journal	Awaiting fulfilment of regulations	Not accepted
Fellowship	74	*less* 13	57	—	4
Associateship	46	*add* 13			
		less 1	44	9	5
Licentiateship	7	*add* 1	2	6	—
	127		103	15	9

In common with all other organisations in the United Kingdom, the Association suffered through the postal strike in the early part of the year. It was fortunate that the Association had had to accept a booking to hold the Exhibition in June at the Empire Hall, Olympia since, had it been held in April as in 1970, it would not have been possible to have sent out copies of the Official Guide in February. The postal strike also affected attendance at the Association's Conference, since publicity on this function overseas was severely delayed, but the Association did not suffer as badly as might have been expected because members found ways of getting their applications to the Association's office. A Council Meeting held in February provided an opportunity for the distribution and receipt of a considerable amount of correspondence to and from the Sections!

The Association's Biennial Conference was held at the Palace Hotel, Torquay 4-8 May and was attended by nearly 280 Members, non-members, guests and their ladies. The theme of the Conference was "Surface properties and appearance" and during the four Technical Sessions on the Wednesday morning, Thursday morning and afternoon and the Friday morning, eleven papers were presented. On the Wednesday afternoon, for the first time, a Management Session, at which three papers were presented, was included in the Conference programme, simultaneous with the holding of the three Workshop Sessions, the subjects of which were "How will pollution control affect the paint industry?": "Is the gloss emulsion paint a myth?": "Powder coatings—a threat to stoving enamels?". All these sessions provoked lively and informative discussions and the papers presented at the Conference, together with the discussions which took place, were published in the September, October, November and December issues of the *Journal*.

The usual social functions and activities were held, details of which appeared, with photographs, in the Conference Diary in the July issue of the *Journal*.

The Ninth Annual General Meeting of the Incorporated Association took place on Friday 7 May at the Palace Hotel, Torquay, Devon when Mr A. W. Blenkinsop was elected President. The following Vice-Presidents were elected:

> Dr S. H. Bell
> Mr I. S. Moll
> Mr C. H. Morris
> Mr F. Schollick
> Mr N. H. Seymour
> Mr L. H. Silver
> Mr T. Whitfield

The Honorary Officers were elected as follows:

Honorary Secretary	Mr D. S. Newton
Honorary Treasurer	Mr F. Cooper
Honorary Editor	Mr S. R. Finn
Honorary Research and Development Officer	Mr A. R. H. Tawn

The report of the Auditors on the scrutiny of the postal votes was received and it was announced that the following members had been elected to the Council for the years 1971-73:

> Mr A. T. S. Rudram
> Dr V. T. Crowl
> Mr D. J. Morris

Following the adoption of the Annual Report of the Council for 1970 at the Annual General Meeting, the President (Mr A. S. Fraser) presented the Jordan Award to the winner of the 1970 competition, Mr J. R. Groom. A report appears later under the Jordan Award Committee's Report.

Votes of thanks to the Retiring President, Council Members and Honorary Officers were carried with acclamation.

The Twenty-Third Technical Exhibition took place at the Empire Hall, Olympia, London, W14, 21-25 June. A report appears later under the Exhibition Committee's Report and a review of the Exhibition appeared in the August issue of the *Journal*.

In a year during which the Association has held a Conference, no Section symposia have taken place, but all Sections have completed very comprehensive programmes of technical meetings and other functions, including special events for Student Groups. In January, the London Section held a Conversazione at the Polytechnic of the South Bank on the subject "Surface coatings; their use and abuse for painting structural steel". This was a well attended and successful function.

In August the two New Zealand Sections (Auckland and Wellington) held their joint Convention at Wairakei and this marked the twenty-first year of activities of the Association in New Zealand. The Convention included not only a full programme of technical sessions and social events, but also a display of the latest materials, equipment and technology from manufacturers supplying the paint, varnish, printing ink and allied industries. A report of the Convention was published in the December issue of the *Journal*.

The South African Section's representative on Council (Dr A. Lowe) was able to visit South Africa during the course of a business visit overseas in the summer and at the October meeting of Council was glad to report on the continued success of the Section there.

On the evening of 6 October, Members of Council had the pleasure of receiving five Past Presidents and five Past Honorary Officers at the Reunion Dinner at Wax Chandlers' Hall. After Dinner the President gave the customary review of the Association's activities and followed this with a short talk on how he saw the future of the petrochemical industry. A full report and photograph appeared in the December issue of the *Journal*.

At the Annual Meeting of the Federation of Societies for Paint Technology held in Detroit in October, Dr D. A. Plant presented a paper on behalf of the Association entitled "Hiding power of coloured pigments".

During the year the Director & Secretary has been pleased to help members when they visited the Association's offices and from overseas was particularly glad to meet Mr K. M. Engelbert (Honorary Treasurer of the South African Section) and also Mr F. Schollick (Vice-President) formerly attached to the South African Section and now resident in London.

At the Torquay Conference, the Association was honoured to welcome the Presidents of the Federation of Scandinavian Paint and Varnish Technologists (Mr A. O. Brantsaeter), the Federation d'Associations de Techniciens des Industries, Vernis, Emaux et Encres d'Imprimerie de l'Europe Continentale (Dr M. Bono) and the Federation of Societies for Paint Technology (Mr S. L. Davidson) as well as the Executive Secretary of the Federation of Societies for Paint Technology (Mr R. W. Matlack).

Council was saddened to learn of the death on 2 January of the London Section Chairman in office, Mr J. E. Pooley. An obituary notice appeared in the March issue of the Journal. Other Sections which have suffered the loss of office holders during the year are Manchester and West Riding. Manchester Section suffered the loss of their Honorary Treasurer, Dr T. I. Kyle, in April and their Honorary Auditor, Mr F. A. Walker, in May. Obituary notices appeared in the September and July issues respectively of the *Journal*. On 1 May Mr D. T. Young, Honorary Social Secretary of the West Riding Section was killed in a motor accident. An obituary notice appeared in the July issue of the *Journal*.

The Council wishes to place on record its sincere appreciation of the outstanding service rendered to the Association by the Director & Secretary, Mr R. H. Hamblin, and the members of his staff.

Membership of the Association

There were 264 elections during the year compared with 242 in 1970, which can be regarded as satisfactory for a year which saw many changes in the industries covered by the Association.

As forecast in the last Annual Report, the introduction of the Professional Grade has stimulated recruitment to the Association, but since this scheme was only introduced in September the full effect will not be felt until 1972.

Section	Ordinary	Associate	Honorary	Student	Total
Bristol	79	17	—	7	103
Hull	66	6	—	4	76
Irish	48	21	—	5	74
London (including Southern Branch)	615	85	5	10	715
Manchester	347	57	2	18	424
Midlands (including Trent Valley Branch)	171	28	1	4	204
Newcastle	137	11	—	10	158
Scottish (including Eastern Branch)	107	29	—	32	168
Thames Valley	109	15	—	10	134
West Riding	59	18	—	15	92
Auckland	52	39	—	2	93
Wellington	61	29	—	—	90
South African	212	46	—	12	270
General Overseas	338	27	2	—	367
Total 1971	2,401	428	10	129	2,968
Total 1970	2,464	446	10	118	3,038
Net increase/decrease during 1971	−63	−18	—	+11	−70

The Council

During the calendar year the Council has met four times, the average attendance being 26. All meetings were held in London.

Committees of the Council

The Committees of Council met as set forth below:

Exhibition Committee	2
Finance Committee	2
Jordan Award Committee	1
President's Advisory Committee	4
Professional Grade Committee	2
Publications Committee	1

Exhibition Committee

Chairman—The Honorary Treasurer, Mr F. Cooper

The Twenty-Third Annual Technical Exhibition was held at the Empire Hall, Olympia, London from 21-25 June. For many years, the Association has held its annual Exhibitions of raw materials and equipment for the paint, printing ink, colour and allied industries in March or April, but it had not proved possible to obtain such a booking for the new venue—this being the second occasion on which the Exhibition had been held at Olympia—and concern had been expressed lest the attendance at the largest Exhibition yet organised by the Association, including exhibitors from twelve overseas countries as far afield as Australia and Canada, would suffer. In the event, however, the total attendance registered at the turnstiles of 14,500 maintained that of the previous year, there being the same number of overseas countries (38) represented in the Visitors' Book at the Information Centre as in 1970.

On the opening day, a large number of Members, exhibitors and visitors attended an Exhibition Luncheon at the Savoy Hotel, London, WC2 when the Guest of Honour was the Secretary of State for Education and Science, The Rt. Hon. Margaret Thatcher, PC, MP. In his Address of Welcome the President of the Association, Mr A. W. Blenkinsop, said that this occasion was one of many "firsts". It was the first time that the Exhibition had been as late in the year as June, which meant that it followed the Conference Annual General Meeting at which, by custom, the President was elected; thus this was his first official appearance as President. This was also the first time that the Guest of Honour had been a lady and in welcoming the Guest of Honour, he reminded guests that Mrs Thatcher had spent four years in chemical research in industry before being called to the Bar and that before her marriage, she had replied on behalf of the ladies at a dinner held by the London Section in 1951. Another first was that this was the first Association Exhibition at which over 200 companies were mentioned in the Official Guide; 18 of the 120 stands were occupied by companies that had never shown at OCCA before and a further 32 had not exhibited in 1970.

Referring to educational activities, Mr Blenkinsop stated that for many years the Association had been particularly interested in students in the industries, having published the "Introduction to paint technology," sales of which had now exceeded 15,000 copies, and the Paint Technology Manuals, Part 7 of which entitled "Works practice" was to be published as a part work in the 1972 volume of the *Journal*, under Student Reviews.

In order to strengthen the technical training already being undertaken in the industries, both in the United Kingdom and overseas, the Association was now to offer an optional Professional Grade to its Ordinary Members. The President felt that it was particularly apposite that he was able to mention this scheme for the first time in the presence of the Secretary of State for Education.

In replying, Mrs Thatcher gave an outline of her ideas on education in industry. She felt it was important that there should be adequate research facilities available to industry; a trained "research capacity" should be maintained at the universities which could be called upon to solve problems of a fundamental nature. Of no less importance were the polytechnics, which could aid in the solution of problems which, although more practical, required academic expertise equal to that necessary in more basic studies.

Mrs Thatcher apologised for the fact that she would not be able to open the Exhibition at Olympia, owing to an unexpected commitment in the House of Commons, but hoped that it would be as successful as previous Exhibitions.

The theme of the Technical Education Stand was "Colour and colour matching". A special leaflet was provided covering the concept of colour and how the eye sees it, and describing the basis of instrumental methods of colour measurement. Displays on the stand illustrated points from the leaflet and visitors were able to undergo a shortened version of the colour aptitude test.

A review of the Exhibition appeared in the August issue of the *Journal* and the Exhibition Committee is particularly grateful to Mr R. Wood (Assistant Editor) who collated the repotts and comments received from a team of some 36 reporters.

Finance Committee

Chairman—The Honorary Treasurer, Mr F. Cooper

Although the surplus achieved in the year is satisfactory, it became clear by the autumn that the subsequent year was likely to be a most difficult one owing to the economic climate prevailing in the chemical industry, both at home and abroad. The policy of keeping as much money as possible on short-term loan with local authorities was continued so that at the end of the year this amount could be used at short notice, if necessary, during 1972.

During the year it was also necessary to write-down the Rolls Royce Stock to a nominal £10.

The market value of the Association's investments at the end of the year showed that government securities stood at £35 above their purchase price and the other quoted investments stood at £15,083 above their purchase value.

Jordan Award Committee

Chairman—The Honorary Research and Development Officer, Mr A. R. H. Tawn

The Committee appointed by Council to consider the applications received for the Jordan Award met in January and decided to award the prize to Mr J. R. Groom for his paper "Milling—a printing ink variable" which he presented to the West Riding Section (to which Mr Groom is attached) in December 1970 and which was published in the March 1971 issue of the *Journal*. As indicated in the general part of this Report, the then President presented the certificate and cheque for £100 to Mr Groom at the Annual General Meeting in Torquay on 7 May. Details of the presentation, with a photograph, appeared in the July issue of the *Journal*.

President's Advisory Committee

Chairman—The President

It will be recalled that, in the Report for 1968, reference was made to the setting up of the President's Advisory Committee comprising the Honorary Officers of the Association together with three Section Chairmen, normally in their second year of office. For the 1971-72 session Mr A. W. Blenkinsop invited the Chairmen of the Hull Section (Mr N. F. Lythgoe), the Manchester Section (Dr F. M. Smith) and the Midlands Section (Mr H. J. Griffiths) to serve on this Committee.

Liaison Committee

Chairman—The President

An exchange of information, as discussed at the meeting of the Liaison Committee held during the course of the Association's Conference in 1969 (referred to in the Report for that year), has taken place and, as indicated in the general part of this Report, the Presidents of the four societies (Federation d'Associations de Techniciens des Industries, Vernis, Emaux et Encres d'Imprimerie de l'Europe Continentale, Federation of Societies for Paint Technology, Federation of Scandinavian Paint and Varnish Technologists and Oil and Colour Chemists' Association) met at the Association's Conference in Torquay in May and discussed matters of common interest.

Light Fastness Committee

At its meeting in June, Council received a letter from Dr S. H. Bell (Chairman of the Light

Fastness Committee) questioning the wisdom of retaining this Committee. Its original purpose had been achieved and in recent years it had been kept in being only to maintain a watching brief on developments, with little chance of further active work being initiated. In view of these comments, therefore, Council thanked the members concerned for their services and agreed that the Committee be disbanded forthwith.

Publications Committee

Chairman—The Honorary Editor, Mr S. R. Finn

During 1971, forty-nine papers were published, compared with fifty-three in 1970 and forty-five in 1969. The overall size of the Journal was 1,222 pages, compared with 1,132 and 1,212 in 1970 and 1969 respectively. The number of pages covered by "Transactions and Communications" was 829 (67.9 per cent) compared with 740 pages (65.4 per cent) in 1970 and 750 pages (61.9 per cent) in 1969. In 1968 the percentage of these papers was 60.1 per cent so that there has been an increasing trend over the last four years towards more technical papers.

The papers from the Symposium organised by the Scottish Section appeared in full at the beginning of 1971, and were followed by the paper from the London Section's European Liaison Lecture and three papers from the joint meeting of the London Section with the Colloid and Surface Chemistry Group of the Society of Chemical Industry held in November 1970. Commencing with the September issue, thirteen papers presented at the Torquay Conference were published in full. This year has, therefore, been notable for the number of papers originating from conferences. The Foundation Lecture given in 1970 by Sir Paul Chambers was also published in full in the January 1971 issue.

It has not yet been possible to publish the papers from the Convention on Electrodeposition held by the South African Section and mentioned in last year's Report. It is hoped that it may still be possible to do so.

There was some increase in the correspondence with the Honorary Editor (12 letters) after a decline to only seven letters in 1970.

The number of books reviewed during the year fell to fourteen compared with eighteen in the previous year. The standard again was well maintained and the Committee wishes to thank all those members who have carried out this work. The Honorary Editor also wishes to express his thanks to the Honorary Publications Officers for the large number of "Section Proceedings" produced during the year.

The "Student Review" section contained ten papers this year, but nine of these were reports of the activities of Sections on behalf of students. The only full scale "Student Review" originated from a lecture given to the Irish Section and was published in this category with the Section's and the author's consent.

Following the acceptance of SI Units by various kindred industries, an Editorial was published in the April issue describing the system and listing the relevant units, both for the convenience of authors and readers and as an internal source of reference. At this time authors were recommended to use SI Units, but it was subsequently decided to make their use obligatory as from 1 January 1975, and an Editorial stating this will appear in January 1972.

It was not found possible to publish Volume 7 of the Paint Technology Manuals as a complete volume, as was intended when last year's report was written. It was decided by Council that the volume will be serialised and published in the Journal as "Student Reviews" in the twelve issues for 1972. This work is well in hand and the first part will appear in the January number. Sales of the first six volumes of the Manuals continue at a satisfactory level. Some volumes are out of stock and reprints are under consideration during 1972.

The Resins, Drying Oils, Varnishes and Paints Report for 1970, reprinted from the Annual Reports of the Society of Chemical Industry, was published in November and the authors have been invited to prepare the Report for 1971.

Again, a large number of papers have been submitted from direct sources, twelve originating from overseas and seven from home sources. This represents 24.5 per cent and 14.3 per cent respectively, or a total of 38.4 per cent of the "Transactions and Communications."

Survey of published papers:

Section	1969	1970	1971
Bristol	1	—	—
Hull	1	1	—
Irish	—	—	1
London	6	2	6
Manchester	2	13	1
Midlands	—	5	—
Newcastle	—	1	—
New Zealand	—	—	—
Scottish	—	—	6
South African	3	—	—
Thames Valley	—	1	—
West Riding	—	—	2
Direct			
United Kingdom	9	15	7
Overseas	14	15	12
Conference	9	—	13
Foundation Lecture	—	—	1*
	45	53	49

*1970 Foundation Lecture

Working Party on Education, Training and Qualifications

As indicated in the 1970 Report, Council was presented at the end of that year with a comprehensive document setting out the steps and procedure necessary for implementing the institution of an optional Professional Grade for Ordinary Members of the Association.

This was adopted at the Council meeting in January 1971 and the Chairman (Dr H. W. Keenan) and members concerned were thanked for the services they had rendered. It was agreed that the implementation of the Professional Grade be undertaken by the Professional Grade Committee, while aspects of training and education could be referred to the Technical Education Committee.

Professional Grade Committee

Chairman—The President

Following the dissolution of the Working Party on Education, Training and Qualifications and for the purpose of administering the optional Professional Grade for Ordinary Members of the Association, Council at its meeting in February set up the Professional Grade Committee and the following members accepted the invitation to serve thereon:

> The President (Chairman)
> Immediate Past President (or President Designate)
> Mr T. W. J. Apperley
> Dr S. H. Bell
> Mr H. J. Clarke
> Mr R. R. Coupe
> Mr S. R. Finn
> Dr H. W. Keenan
> Mr A. McLean
> Dr W. M. Morgans
> Mr A. T. S. Rudram
> Dr F. M. Smith
> Mr A. R. H. Tawn
> Mr C. J. A. Taylor

At its first meeting in May, the Committee agreed upon the announcement concerning the institution of the Professional Grade, which was duly published in the September issue of the *Journal,* together with an application form. Initial reaction to this announcement is referred to in the general part of this Report.

In November the Committee met again to consider the applications which had by then been received for admission to the Professional Grade, and the first list of Fellows, Associates and Licentiates is to be published in the January 1972 issue of the *Journal*.

The Committee also considered the position of Members attached to the three overseas Sections of the Association in South Africa and New Zealand and agreed upon guide lines for the sub-committees set up in these three Sections to deal with applications. Consideration was also given to the procedure for dealing with applications received from Members attached to the General Overseas Section.

With regard to viva voce examinations, the procedure for these was considered by the Committee as well as guide lines for those required to submit dissertations, and this information was published in the December issue of the *Journal*.

Technical Education Committee

Chairman—The President

When considering the appointment of its Committees in June, Council was reminded that this Committee had not met for some time but had been retained, under the Chairmanship of Dr H. W. Keenan, with only the President, Immediate Past President (or President Designate) and two Honorary Officers. Since the Working Party on Education Training and Qualifications had been disbanded following the setting up of the Professional Grade Committee, however, it was felt that the question of training and education could now best be dealt with by the Technical Education Committee. For the purpose of liaison between this Committee and the Professional Grade Committee it was considered advisable for the President to act as Chairman to both and the following members have agreed to serve on the Technical Education Committee:

Immediate Past President (or President Designate)
Honorary Secretary
Honorary Editor
Mr. H. Bray
Mr N. J. P. Buchanan
Mr J. E. Mitchell
Mr A. R. H. Tawn
Mr H. C. Worsdall

Technical Committee

Chairman—The Honorary Research and Development Officer, Mr A. R. H. Tawn

Following the reconstitution of this Committee in 1968 (referred to in the Report for that year), Council agreed in July 1969 that the appointment of the Committee should be considered each year and, in fact, no such Committee was set up in 1969 or 1970.

In June 1971, however, Council was reminded that although one of the functions of the Technical Committee was to co-ordinate the choice of subject for the Association's Conferences and Section Symposia during non-conference years, much of this work could be done by post. Similarly the recommendation to Council of suitable names for appointment as Association representatives on British Standards Institution Committees could be undertaken by post. Nevertheless there remained a whole field which it was felt was increasingly important, such as the concept of the technical, management and workshop sessions at the Association's Conference and any future technical activities, particularly in relation to other European technical and scientific organisations. For this purpose, therefore, the Technical Committee was reconstituted and the following members have agreed to serve thereon:

The President
The Immediate Past President (or President Designate)
Mr T. R. Bullett
Mr G. H. Hutchinson
Mr A. T. S. Rudram
Dr F. M. Smith
Dr G. Swann

Working Party on Forward Thinking

In view of the fact that the purpose for setting up this Working Party had been achieved and their work either completed or passed to other Committees. it was agreed by Council at its meeting in June that it be disbanded and the appreciation of the Council for the duties undertaken by this Working Party was conveyed to the members concerned.

Representation on other organisations

The Association was represented on other organisations, as follows:

Technical Training Board for the Printing Ink and Roller Making Industry: Mr R. M. W. W. Wilson and Mr N. Locke.

Paint Apprenticeship Council: Dr H. W. Keenan and Mr G. Copping.

The Parliamentary and Scientific Committee: The President and the Director & Secretary.

The British National Committee for Chemistry: Mr A. R. H. Tawn.

City and Guilds Advisory Committee No. 9—Technology of Pigments, Paints, Varnishes and Lacquers: Dr J. G. Gillan.

East Ham Technical College Advisory Committee: Mr R. M. W. W. Wilson.

Association of Exhibition Organisers: The Director & Secretary.

Programme Liaison Committee: The Honorary Programmes Officer of the London Section and the Director & Secretary.

The Paintmakers Association Training and Technical Education Committee: The Honorary Secretary and the Director & Secretary.

The Society of Dyers and Colourists Terms and Definitions Committee: Dr J. Toole and Mr A. E. Honiball.

The Society of Dyers and Colourists Review of Coloration Progress Committee: Mr H. D. Brearley.

The Colour Group (Great Britain): Mr R. Smith.

Institution of Corrosion Technology Education Committee: Dr J. B. Harrison and Mr D. S. Newton.

British Standards Institution:

PVC	Pigments, Paints and Varnishes Industry Committee	Dr J. B. Harrison
PVC/1	Pigments	Mr A. S. Lewis
PVC/1/9	Black Pigments	Mr J. S. Marsh
PVC/1/11	Extenders	Mr S. A. Ray
PVC/1/18	Zinc Dust Pigments	Mr D. S. Newton
PVC/3	Oils, Varnishes, Putty etc.	Mr G. H. Hutchinson
PVC/3/5	Test Methods for Paint Media	Mr S. R. Finn
PVC/4 and PVC/4/1	Lac	Dr B. S. Gidvani
PVC/6	Cement Paints	Mr W. O. Nutt
PVC/8	Plastic Wood	Mr V. P. Gellay
PVC/10	Test Methods for Paints	Mr A. N. McKelvie
PVC/14	Colours for Paints	Mr A. B. Lock
PVC/15	Water Paints and Distempers	Mr T. W. Wilkinson
PVC/16	Ready Mixed Paints	Mr G. A. Newell
PVC/19	Bituminous Paint	Dr H. B. Footner
PVC/20	Calcium Plumbate Priming Paints	Mr A. G. Walker
PVC/23	Zinc Rich Paints	Dr D. Atherton
PVC/24	Water Thinned Priming Paints	Mr J. H. Sparrow
PVC/25	Organic Finishes for Aluminium Windows	Dr J. B. Ley
LGE/9	Artificial Daylight for Colour Matching	Miss O. Rawland
C/17	Viscosity	Mr A. N. McKelvie
C/17/2	Revision of BS.188 (Drafting)	Mr A. N. McKelvie
CHE/43	Test Sieves	Mr M. J. F. Meason
CHE/50	Test Methods for Powder Properties	Mr D. S. Newton

CIC/4	Solvents and Allied Products	Dr L. A. O'Neill
OFFA/6	Glycerine	Mr S. R. Finn
OFFA/7	Sampling Oilseeds, Oils and Fats	Mr N. F. Lythgoe
OFFA/12	Vegetable Oils	Mr N. F. Lythgoe
OFFA/24	Analysis of Oilseeds, Oils and Fats	Mr N. F. Lythgoe
ELE/16/53/6	Varnishes	Mr J. McGowan
ACE/44	Aircraft Finishes	Mr J. B. G. Lewin
BLCP/18	Code of Practice: Painting	Mr P. J. Gay
M/36	Artists' Materials	Mr J. A. L. Hawkey
RDE/25	Road Marking Compounds	Mr T. R. Bullett
OC/20/4/12	Chemistry and Chemical Technology	Mr J. Orpwood

Reports from the above representatives may be seen by members at the Association's offices.

The Association was also represented on overseas organisations as follows:

South African Bureau of Standards' Specifications:

SABS 515	Decorative Paints, non-aqueous solvent base, interior use	Mr H. I. Bossman Mr N. A. Brown Mr K. M. Englebert Mr A. H. Meyling
SABS 630	Decorative High Gloss Enamel—non-aqueous solvent base, exterior and interior use	Mr H. I. Bossman Mr N. A. Brown Mr K. M. Englebert Mr A. H. Meyling
SABS 631	Decorative Oil Gloss Paint—non-aqueous solvent base, exterior and interior use	Mr H. I. Bossman Mr N. A. Brown Mr K. M. Englebert Mr A. H. Meyling
SABS 663	Primer and Enamel Paint for Hospital Furniture	Mr A. H. Meyling
SABS 681	Undercoats for Paints	Mr K. R. Hart
SABS 683	Roof Paints	Mr K. M. Englebert
SABS 801	Epoxy Tar Paints	Mr P. A. Draper
SABS 912	Calcium Plumbate Primer	Mr M. P. Greef

Science and Education Advisory Committee, Natal College of Advanced Technical Education: Mr K. R. McDonald, Mr K. M. Englebert.

Science and Education Advisory Committee, Witwatersrand College of Advanced Technical Education: Mr H. H. Aschenburg, Mr P. A. J. Gate.

Council of the National Association of Scientific and Technical Societies: Mr L. F. Saunders.

Standards Association of New Zealand—Paints and Coatings Sectional Committee: Mr T. W. Slinn.

APPENDIX

Report of the Council in accordance with the Companies Act 1967

1. The Council presents herewith the audited accounts of the Association for the year ended 31 December 1971.

2. *Results*

   The results for the year and the appropriation thereof are set out in the Income and Expenditure Account on pages 753-754.

3. *Principal Activities of the Association*

The Association has continued in its work of furthering the development of the science
and technology of the oil and colour industries.

4. *Changes in fixed assets*

The movement in fixed assets during the year is set out in the table on page 754. There were
no significant changes during the year.

5. *The Council*

The following were members of Council at 31 December 1971:

A. W. Blenkinsop	
A. S. Fraser	
D. S. Newton, AMCT, CGIA, FInstCorrT, FIMF	
F. Cooper, BSc	
S. R. Finn, BSc, FRIC	
A. R. H. Tawn, FRIC, FInstPet, FIMF	
S. H. Bell, PhD, DIC, ARCS, FRIC	
I. S. Moll, BSc	
C. H. Morris	
F. Schollick, BSc, FRIC	
N. H. Seymour	elected 7 May 1971
L. H. Silver	
T. Whitfield	elected 7 May 1971
V. T. Crowl, BSc, PhD, DIC, FRIC, ARCS	elected 7 May 1971
A. G. Holt, BSc, BPharm	
J. E. Mitchell, BSc, FRIC	
D. J. Morris	elected 7 May 1971
A. T. S. Rudram	elected 7 May 1971
H. R. Touchin, BSc, FRIC	elected 3 June 1971
P. L. Gollop, ARIC	
J. R. Taylor, BSc, FRIC	
N. F. Lythgoe, FRIC	
F. D. Robinson, BSc	
F. D. H. Sharp	
Miss P. Magee	elected 19 March 1971
D. E. Eddowes, BSc	
H. R. Hamburg, PhD	elected 14 January 1971
F. M. Smith, BSc, PhD, ARIC	
S. Duckworth, ARIC	
H. J. Griffiths, ACT	
D. E. Hopper, ACT	elected 23 April 1971
A. A. Duell, ARIC	
K. F. Baxter	elected 1 April 1971
R. G. Gardiner	
E. M. Burns	
B. Jacob	
W. H. Tatton, ARIC	elected 15 April 1971
Mrs K. Driver	
D. Morris	elected 2 September 1971
O. E. Rutledge	
F. Sowerbutts, BScTech	
L. F. Saunders	
A. Lowe, MSc, PhD	
M. D. Thompson	elected 1 March 1971
G. Willison, FRIC	
D. A. Kalwig	

(co-opted as President of the Oil and Colour Chemists' Association Australia)

In addition, the following were members of Council at 1 January 1971 and served during the year; the date shown after each name denotes when service on Council terminated:

A. H. McEwan	(7 May 1971)
W. J. McWaters	(7 May 1971)
I. C. R. Bews, BSc, ARIC	(7 May 1971)
R. N. Wheeler, BA, ARIC	(7 May 1971)
H. C. Worsdall	(7 May 1971)
D. M. James, BSc, FRIC	(8 April 1971)
S. McWade	(19 March 1971)
J. E. Pooley, BSc, ARIC	(2 January 1971)
R. F. Hill, BSc, ARIC, ACT, API	(23 April 1971)
D. H. Tate	(1 April 1971)
K. R. W. Chitty	(15 April 1971)
L. J. Watkinson, MSc, PhD, ARIC	(6 April 1971)
J. N. McKean	(elected 6 April 1971, resigned 2 September 1971)
T. W. Slinn	(1 March 1971)
D. M. D. Stewart, BSc, ARACI	(3 June 1971)

6. *Auditors*

The auditors, Cooper Brothers & Co., will continue in office in accordance with Section 159(2) of the Companies Act, 1948.

By Order of the Council

ROBERT HAMBLIN
Director & Secretary

3 January 1972

Oil and Colour Chemists' Association

BALANCE SHEET as at 31 December 1971

1970 £	£		£	£
		ACCUMULATED FUND—		
		Balance at 31 December		
42,860		1970	52,997	
10,137		*Add* Surplus for the year ..	6,876	
52,997				59,873
		CURRENT LIABILITIES—		
		Creditors and Accrued		
5,647		Liabilities	3,759	
15,664		Receipts in Advance ..	29,172	
		Provision for Technical		
573		Activities	214	
		Provision for Paint Tech-		
411		nology Manuals ..	445	
22,295				33,590

1970 £	£		£	£
		FIXED ASSETS—		
		Furniture, Fittings, Car		
		and Office Machines		
	8,473	at cost	8,578	
		Less Accumulated		
	5,121	Depreciation	5,953	
3,352				2,625
		QUOTED INVESTMENTS—		
		British Government Secur-		
		ities at cost (Market		
	13,208	Value £11,743) ..	11,708	
		Other investments at cost		
		less £1,334 written off		
	27,497	(Market Value £41,688)	26,605	
		UNQUOTED INVESTMENTS—		
		Local Authorities Short		
	10,000	Term Loans	22,000	
50,705				60,313
		CURRENT ASSETS—		
		STOCK OF UNSOLD PUB-		
	515	LICATIONS—At cost ..	399	
		PAPER—Stock in hand at		
	705	cost	1,540	
		DEBTORS AND PAYMENTS		
	15,938	IN ADVANCE	14,725	
		Cash and Bank Balances		
		in United Kingdom		
	4,077	and Overseas Sections	13,861	
21,235				30,525

A. W. BLENKINSOP
President
F. COOPER
Hon. Treasurer
R. H. HAMBLIN
Director and Secretary

£75,292	£93,463	£75,292	£93,463

REPORT OF THE AUDITORS TO THE MEMBERS

Annual accounts submitted by the United Kingdom and Overseas Sections have been incorporated in these accounts, but the assets, liabilities and expenditure included therein have not been verified by us. Moreover, it has not been possible to obtain final accounts from the Irish and Auckland Sections and therefore estimated figures, based on the half year accounts, have been included. With these reservations in our opinion the accounts set out on pages 752 to 755 give a true and fair view of the Association's affairs at 31 December 1971, and of its results for the year ended on that date and comply with the Companies Acts 1948 and 1967.

COOPER BROTHERS & CO.
London, 11 February 1972   Chartered Accountants.

INCOME & EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31 DECEMBER 1971

INCOME

1970 £	£	£		£	1971 £	£
			Membership and General Income—			
		14,236	Subscriptions	14,367		
		—	Professional Grade Certification fees ..	694		
		118	Entrance fees	139		
		570	Sundry publications	574		
		3,314	Investment income	3,734		
		281	Surplus on redemption of investments ..	349		
		259	Profit on sale of equipment	16		
	18,778				19,873	
			Journal Receipts—			
		13,235	Advertising	11,655		
		10,298	Sales	11,168		
		2,298	Capitation fees OCCA Australia ..	2,246		
		1,413	Reprints	1,075		
	27,244				26,144	
	54,854		Exhibition receipts	67,007		
100,876						113,024

EXPENDITURE

1970 £	£	£		£	£	£
			Membership and General Expenses—			
		8,470	Administrative expenses (Note 4) ..	8,996		
		9,398	Journal	9,672		
		3,453	Postage, printing and stationery ..	4,873		
		961	Publications	1,074		
		1,256	Section expenditure (Note 5)	2,807		
		—	Past Presidents' dinner	277		
		394	Dinner Dance and Foundation Lecture	—		
		100	Provision for Paint Technology Manuals	100		
		—	Torquay Conference	280		
		207	Section and Past Chairmen's Badges	1		
		2,108	General expenses, including accountancy charge	1,741		
		—	Rolls-Royce stock at cost written down to a value of £10	1,334		
	26,347				31,155	
			Journal expenses—			
		8,470	Administrative expenses (Note 4) ..	8,996		
		11,485	Printing and publication	11,822		
		983	Reprints	740		
		1,510	Postage and stationery	2,056		
		490	General expenses	795		
	22,938				24,409	
			Exhibition expenses—			
		32,495	Direct expenses	40,793		
		8,469	Administrative expenses (Note 4) ..	8,996		
		490	General expenses	795		
	41,454				50,584	
90,739						106,148
£10,137			Surplus for the year			£6,876

NOTES ON THE ACCOUNTS

1. *Fixed Assets*

		£	£
Cost			
At 1 January 1971	.. ..	8,473	
Additions ..	.. ..	140	
		8,613	
Less Disposals	.. ..	35	
			8,578
Depreciation			
At 1 January 1971	.. ..	5,121	
Charged to Income and Expenditure Account	.. ..	867	
		5,988	
Less Disposals	.. ..	35	
			5,953
Net book value at 31 December 1971	.. ..		£2,625

2. *Foreign Currencies*

Overseas Section income, expenditure, assets and liabilities have been converted to Sterling at the following rates:

New Zealand $2.14
South Africa   Rands 1.71

3. The Ethel Behrens Fund and the Jordan Award Fund have not been incorporated in the Association's Income and Expenditure Account and Balance Sheet but have been shown as separate accounts.

4. *Administration Expenses*

Administration expenses have been equally apportioned between the three main headings of expenditure in the Income and Expenditure Account on the basis of staff time involved. These expenses are:

1970 £		1971 £
19,019	Salaries	20,604
577	Temporary staff	581
732	Welfare	699
3,805	Rent, rates, lighting, telephone	3,787
263	Audit fee	350
100	Provision for dilapidations	100
913	Provision for depreciation	867
£25,409		£26,988

	The charge to each heading is therefore:	
£8,470	Membership	£8,996
£8,470	Journal	£8,996
£8,469	Exhibition	£8,996

5. *Section Expenditure*

The Section expenditure is as follows:

1970 £		1971 £
15	Bristol	65
46	Hull	92
2	Irish (estimated)	329
401	London	467
	(Southern Branch £39)	
347	Manchester	346
178	Midlands	217
	(Trent Valley Branch £18)	
124	Newcastle	134
(332)	Scottish	195
	(Eastern Branch £73)	
132	Thames Valley	126
33	West Riding	60
90	Auckland (estimated)	107
78	Wellington	64
142	South African	327
£1,256		£2,529
—	Un 'erestimated overseas expenditure in the previous year	278
£1,256		£2,807

Ethel Behrens Fund

INCOME & EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31 DECEMBER 1971

1970 £	Expenditure	1971 £	1970 £	Income	1971 £
56	Income Tax on Investment Interest ..	54	135	Interest on Investments (gross)	135
103	FATIPEC Congress travelling expenses	—			
—	Surplus for the year	81	24	Deficit for the year	—
159		135	159		135

BALANCE SHEET as at 31 December 1971

1970 £	Liabilities	1971 £	1970 £	Assets	1971 £
2,549	Accumulated Fund 1 January 1971 ..	2,525	2,442	British Government Securities at cost ..	2,442
—	Add Surplus for the year..	81		(Market Value £2,318)	
(24)	Less Deficit for the year	—	83	Balance at Bankers	164
2,525		2,606	2,525		2,606

Jordan Award Fund

INCOME & EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31 DECEMBER 1971

1970 £	Expenditure	1971 £	1970 £	Income	1971 £
—	Award	100	66	Interest on Investments (gross)	65
10	Printing	15			
56	Surplus for the year	—	—	Deficit for the year	50
66		115	66		115

BALANCE SHEET as at 31 December 1971

1970 £	Liabilities	1971 £	1970 £	Assets	1971 £
1,089	Accumulated Fund 1 January 1971 ..	1,145	1,000	British Government Securities at cost ..	1,000
—	Less Deficit for the year	(50)		(Market Value £1,018)	
56	Add Surplus for the year..	—	145	Balance at Bankers	95
1,145		1,095	1,145		1,095

Proceedings of the Annual General Meeting

The Tenth Annual General Meeting of the Incorporated Association was held on 7 June 1972 at 6.30 p.m., at Wax Chandlers' Hall, Gresham Street, London, EC2V 7AB, with the President (Mr A. W. Blenkinsop) in the Chair.

The notice convening the meeting was read.

Apologies
Apologies for absence were received from Mr W. J. Arnot, Mr E. M. Burns, Mr S. Duckworth, Mr R. G. Gardiner, Mr D. E. Hopper, Mr A. B. Lock, Mr J. E. Mitchell, Mr S. A. Ray and Mr A. T. S. Rudram.

Minutes
The President asked the meeting to take as read the Minutes of the Ninth Annual General Meeting held on 7 May 1971, as printed and circulated in JOCCA pp. 679-683 inclusive, July 1971. There being no comments the adoption of the Minutes was put to the Meeting and carried unanimously. The President then signed the Minutes.

Report of the Auditors to the Members
The Report of the Auditors to the Members was read.

Annual Report of the Council for 1971
Mr D. S. Newton (Honorary Secretary) moved the adoption of the Annual Report of the Council and the Statement of Accounts for 1971.

Mr F. Cooper (Honorary Treasurer) seconded the adoption of the Annual Report of the Council and the Statement of Accounts for 1971.

There being no comments or questions on the Annual Report of the Council and Statement of Accounts, these were formally adopted by the meeting.

Appointment of President Designate
The President stated that, as indicated on the Agenda, Mr L. H. Silver had been appointed by Council (in accordance with Article 65(A)) as President Designate of the Association for the forthcoming session.

Mr Silver thanked members for the honour bestowed upon him and undertook to follow the excellent example set by former Presidents of the Association.

Election of Vice-Presidents of the Association
The President read the nominations of the Council, as printed on the Agenda, and asked the meeting to accept them *en bloc*. This was agreed. The following were then elected as Vice-Presidents:

(*a*) Vice-Presidents who have not been President:

(*i*) Mr R. G. Gardiner

(*ii*) Mr A. B. Lock

(*iii*) Mr K. R. McDonald

(*iv*) Mr N. H. Seymour

(*v*) Mr R. N. Wheeler

(*vi*) Mr T. Whitfield

(*b*) Vice-President who has been President:

Dr H. W. Keenan

Mr L. H. Silver, President Designate

Election of Honorary Officers of the Association

It was unanimously agreed to elect the Honorary Officers as follows:

Honorary Secretary	Mr D. S. Newton
Honorary Treasurer	Mr F. Cooper
Honorary Editor	Mr S. R. Finn
Honorary Research and Development Officer ..	Mr A. R. H. Tawn

Announcement of Election of three Elective Members to Council 1972-74

The President read the following letter which had been received from the Auditors:

We have scrutinised the voting papers for the three elected members of the Council received from the members in the United Kingdom and General Overseas Sections, and certify that the votes cast, including those notified by telex from the South African Section, show that the following obtained the largest number of votes:

H. C. Worsdall	*H. G. Clayton*	*L. J. Brooke*

Six voting papers were rejected as not being in order.

London,	*Cooper Brothers & Co.,*
25 May 1972.	*Chartered Accountants.*

The President then declared the three members listed elected to Council.

Chairmen of Sections for the coming session

The names of the Section Chairmen for the coming year were given as follows:

Auckland	..	..	..	..	..	Mr O. E. Rutledge
Bristol	..	..	..	..	..	Mr P. L. Gollop
Hull ..	..	..	..	..	..	Mr F. D. Robinson
Irish ..	..	..	..	..	..	Mr F. D. H. Sharp
London	..	..	..	..	..	Mr D. E. Eddowes
Manchester	..	..	..	..	..	Mr S. Duckworth
Midlands	..	..	..	..	..	Mr A. S. Gay
Newcastle	..	..	..	..	..	Mr A. A. Duell
Scottish	..	..	..	..	..	Mr E. M. Burns
South African	..	..	..	..	Mr K. R. McDonald
Thames Valley	..	..	..	..	Mr W. H. Tatton
Wellington ..	..	..	..	..	Mr M. D. Thomson
West Riding ..	..	..	..	..	Mrs K. Driver

Reappointment of Auditors and fixing the remuneration thereof

It was proposed by Mr F. Schollick that Cooper Brothers & Company (Chartered Accountants) be reappointed Auditors of the Association and that their fee be £350. This was seconded by Mr A. S. Gay and carried unanimously.

Vote of thanks to retiring Council Members

The President called upon Mr D. J. Silsby to propose a vote of thanks to the members retiring from Council.

Mr Silsby drew attention to the fact that sixteen members had just retired from positions on Council and he was well aware of the time and effort service thereon involved. Since Mr A. S. Fraser's term as Immediate Past President had now ended, after many years service to the Association at both Section and national level, Mr Silsby took the opportunity of thanking Mr Fraser for the work he had undertaken on behalf of the Association. Each of the other Members of Council now retiring had contributed in his own way to the work of the Council and thus the activities of the Association. To them all, members of the Association were grateful for their service on Council, and Mr Silsby asked the meeting to express their gratitude in the usual manner to all the retiring Council Members.

This was carried with acclamation.

Vote of thanks to the Honorary Officers of the Association

Dr S. H. Bell indicated that during his term of office as President of the Association he had been anxious that the Honorary Officers should work as a team and be concerned with all the activities of the Association. He was well aware of the work undertaken by the Honorary Officers and the brief reports which they gave at each Council Meeting by no means illustrated their concern with the affairs of the Association. It therefore gave him much pleasure to propose this vote of thanks to the Honorary Officers and on behalf of the members he hoped they would continue to serve the interests of the Association.

This was carried with acclamation.

Vote of thanks to Chairman of the Meeting

The Director & Secretary called upon Mr A. S. Fraser to move a vote of thanks to the President as Chairman of the meeting.

Mr Fraser drew attention to the fact that the contents of the Annual Report of the Council for 1971 showed that the Association had many ideas and had achieved a high level of efficiency during Mr Blenkinsop's first year in office as President and

he congratulated Mr Blenkinsop for the way in which he conducted this meeting. He also took the opportunity of wishing Mr Blenkinsop every success and good health in his second year as President of the Association.

The vote of thanks was carried with acclamation.

Other competent business

On behalf of the meeting, Mr F. D. H. Sharp proposed a vote of thanks to Mr R. H. Hamblin (Director and Secretary) and his staff for the work they had carried out on behalf of the Association during the year. This was supported by the President and carried with acclamation.

There being no other competent business, the President declared the meeting closed at 6.50 p.m.

After a short break for refreshments, the Members reassembled to hear Mr C. G. Todd, past-master and clerk of the Worshipful Company of Wax Chandlers, who gave a fascinating description of the company and some of its treasures.

Optional Professional Grade for Ordinary Members

Since the last list, published in the July issue of the *Journal*, a further 40 Ordinary Members have been admitted to the Grade, 12 as Fellows and 28 as Associates.

A full list is given below.

Fellows

Archer, Harold (*Manchester*)
Ashworth, Norman (*Manchester*)
Bourne, John Robert (*Midlands—Trent Valley Branch*)
Butcher, George Alfred (*Midlands*)
Cole, Derek (*General Overseas—Australia*)
Fillingham, Thomas Alan (*Hull*)
Hutchinson, Geoffrey Herbert (*Scottish—Eastern Branch*)
Kinsman, Roy Granville (*London*)
Ley, John Barry (*London*)
Newton, Dennis Sydney (*Bristol*)
Nutt, William Owen (*London*)
Willis, Gervase Hewitson (*Manchester*)

Associates

Barnes, Peter James (*London*)
Bowerman, David Francis (*Manchester*)
Chebsey, Maurice (*Manchester*)
Coates, John Allen (*Manchester*)
Cunnington, Robin Roy Carol (*London*)
Dunn, Paul Alan (*London*)
Ghosh, Sunil Kumar (*General Overseas—India*)
Green, Brian James (*London*)
Heffer, Victor George (*Manchester*)
Hill, Raymond Forsyth (*Scottish*)
Holt, Clifford (*Manchester*)
Howes, Edward John (*London*)
Humphrey, Thomas Lawson Myles (*Scottish*)
Langley, Robert (*Scottish*)
Lawton, Cyril Victor (*Midlands*)
McDonald, Kenneth Roy (*South African*)
McKay, Robert Bruce (*Scottish*)
McKean, James Newlands (*General Overseas—Hong Kong*)
Moore, Ronald Henry (*West Riding*)
Pemberton, Joseph James (*London*)
Pessall, Robert George (*Midlands*)
Rackham, John Michael (*Newcastle*)
Sharpe, David (*Hull*)
Shirt, John Michael (*West Riding*)
Speding, George (*London—Southern Branch*)
Sreeves, John Ernest (*Midlands*)
Stone, James Bryan (*London*)
Talwalkar, Vinayak Sakharam (*Manchester*)

A table giving statistical information on applications and admissions up to 8 June is set out below.

	Applications received	Applications transferred between grades	Successful	Awaiting fulfilment of regulations	Not accepted
1. Fellowship ..	144	*less* 26	107	—	11
2. Associateship ..	145	*add* 26			
		less 3	138	17	13
3. Licentiateship ..	14	*add* 3	3	14	—
	303		248	31	24

Ordinary Members submitting applications are reminded that it is of the utmost importance to include dates of appointments, clearly demonstrating that the appropriate regulations, as published in *JOCCA*, 1971, **54**, 916, have been satisfied.

To assist the Committee in its deliberations, full details of responsibilities of appointments should be attached to the applications, showing to whom the applicant is responsible and those members of staff who are directly responsible to him.

All members considering application for the Professional Grade are reminded that sponsors will not be required until October 1972.

Technical Exhibition

As announced in the July issue of the *Journal*, OCCA 25 (the OCCA Silver Jubilee Exhibition) will take place at the Empire Hall, Olympia, London, from 21-24 May 1973.

International character

The Exhibition, long known as the forum for technical display and discussion for personnel in the paint, printing ink, colour and allied manufacturing industries and the industries serving them, attracts visitors from nearly 40 overseas countries each year. To further the Exhibition's international character, it is widely advertised in technical journals at home and in 15 overseas countries. Interpreters are available without charge, and information leaflets in six languages (English, French, German, Italian, Spanish and Russian) are widely distributed both direct to firms and to individuals in many countries.

Hours of opening

The hours of opening have been changed on this occasion and are as follows:

Monday 21 May	12.00-18.00 hrs
Tuesday 22 May	09.30-18.00 hrs
Wednesday 23 May	09.30-18.00 hrs
Thursday 24 May	09.30-18.00 hrs

Visitors will thus be able to spend 6 hours at the Exhibition on the Monday and $8\frac{1}{2}$ hours on each of the other three days.

Exhibition Dinner

In response to requests from Exhibitors, on this occasion there will be an Exhibition Dinner on the Monday evening, in place of the Luncheon which has previously preceded the Opening. Details of the Dinner will be given later and an application form will be included in each copy of the *Official Guide*.

Official Guide

One of the unique features at this Exhibition is the planning of the *Official Guide* to the Exhibition, which is prepared many weeks in advance so that visitors may plan their itineraries before

the Exhibition. The Guide is sent to all Members of the Association and to members of allied bodies in Europe and other overseas countries; it is also despatched to a mailing list which has been compiled over many years, and which includes individuals throughout the world.

Invitation to Exhibit

Any company interested in exhibiting at the Silver Jubilee Exhibition should apply to the Director & Secretary at the Association's offices as soon as possible; **the closing date for applications is 2 October 1972.** The Invitation to Exhibit has already been forwarded to all potential exhibitors known to the Association, and further copies are available from the Association's offices upon request.

Foundation Lecture 1972

Sir James Tait to present 1972 Lecture

The Council is honoured to announce that the 1972 Foundation Lecture will be given by the Vice-Chancellor of the City University, Sir James Tait, LLD, PhD, BSc, CEng, FIEE, FIMechE, who has chosen for his subject "The city—a technological university. Are tradition and technology compatible?".

The Lecture will be given at Painters' Hall, Little Trinity Lane, London EC4, on Tuesday 3 October 1972 at 7.15 p.m. and will be preceded by a short service at St Vedast-alias-Foster, Foster Lane, London EC2, at 6.15 p.m. This is the church at which the commemorative service took place on the occasion of the Association's fiftieth anniversary celebrations in 1968.

Following the Association's usual custom, the Foundation Lecture will be followed by an informal dinner at the Painters' Hall.

Full details and forms of application for tickets will be sent to members in due course.

London Section

Ladies' Night

The Ladies' Night of the London Section is this year to be held at an earlier date than previously. The function will take place on Friday 6 October, at 7.00 for 7.45 p.m., at the Cafe Royal, London. Dancing will follow the dinner, and will continue until 1.00 a.m. Those wishing to attend should make early application for tickets to the Hon. Secretary of the Section, Mr R. H. E. Munn, Cray Valley Products Ltd., St. Mary Cray, Orpington, Kent.

West Riding Section

Primers

A symposium on the subject of primers is to be held in Leeds in September 1973, sponsored by the West Riding Section. Suitable papers are now being invited for submission on subjects concerned with the formulation, production or use of primers under surface coatings. Films with or without papers may also be submitted. The symposium will be of international standing and papers from overseas are welcomed. Submissions with a short synopsis should be sent to the Hon. Secretary, Mr D. H. du Rieu, Quentsplass Ltd., Wetherby, Yorkshire LS23 7BZ.

Programme Liaison Committee

This committee comprises representatives of each of the following societies:

Institution of the Rubber Industry

Oil and Colour Chemists Association

Plastics Institute

Chemical Society

Society of Chemical Industry—Plastics and Polymer Group

Society of Dyers and Colourists.

The British Plastics Federation, the Institution of Mechanical Engineers and the Rubber and Plastics Research Organisation are kept informed on a "corresponding" basis.

Major meetings or conferences on polymer or related subjects and other functions planned by these societies are given below and will be in London unless otherwise stated. The list also includes certain major events being organised by non-member societies but with whom the PI maintains close contact.

1972

July

3-7 International symposium: NMR spectroscopy (Guildford)   (CS)

12 Symposium: Corrosion in the chemical industry   (CS-InDiv)

10-12 Annual General Meeting (Leeds) (SCI)

17-21 IUPAC 7th International symposium: Reactivity of solids (Bristol)

25-27 International symposium: Organic chemistry of the excited state (Reading)   (CS)

September

10-14 IUPAC International symposium on macromolecules (Aberdeen)

10-15 "School for industry" in automation and control techniques (Bradford)   (SoDAC)

12-14 2nd International plastic pipes symposium (Southampton)   (BPF)

18-20 Industrial Sub-committee's special discussion: Solid-solid interface (Nottingham)   (CS-FaDiv)

21 Conference: Urethanes in the automobile industry (Solihull or Sutton Coldfield)   (IRI-UGrp)

26-28 Joint Autumn meetings (Nottingham)   (CS)

27 Symposium: Reinforced plastics—recent advances in the marine field (Southampton)   (PI-RPGp)

October

3 Council meeting and Foundation Lecture   (OCCA)

3/4 Symposium: New flexible polymers and crosslinks   (SCI-P&PGp/IRI)

5/6 Conference: Testing of polymers for service (Buxton)   (IoP/PI/etc)

10-12 8th International reinforced plastics conference (Brighton)   (BPF)

Oct. Conference: Degradable polymers and plastics   (PI-MCo)

November

19 Symposium: Plastics in packaging (Liverpool)   (PI-IRI/MerSn)

7 Conference: Novel engineering uses of rubber   (IRI-EGp)

9 Conference: European Economic Community   (IRI-CGp)

14 Symposium: Aspects of molecular structure   (CS-FaDiv)

29/30 PINTEC '72—Profit from science (PI-MCo)

December

1 Symposium: Design (Manchester) (PI-NWSn)

6 Lecture: Molecular complexes (CS-AnDiv)

Dec. Conference: Effect of environment on rubber (Birmingham) (IRI-EGp)

1973

January

4 Symposium: Manufacture and applications of polystyrenes (Cardiff) (PI-SWSn)

8-10 5th Cranfield conference on designing to avoid mechanical failure (PI-DCo)

16 Meeting: Effect of entry into the EEC upon the UK chemical and plastics industry (SCI-P&PGp)

24 Symposium: Implications of pollution for the coatings industry (OCCA-LSn)

24/25 Symposium: Heterophase polymerisation (SCI-P&PGp)

February

2 Symposium: Flammability and its control (SoDAC)

21 Conference: Plastics in bearings (Solihull) (PI-MCo)

March

6 Seminar: Injection moulding (Cardiff) (PI-SWSn)

8 Symposium (CS-PeDiv)

15 Symposium (CS-FaDiv)

26-29 2nd Churchill conference: Yield, deformation and fracture of polymers (Cambridge) (PI/IoP/etc)

26-30 Joint Annual meetings (Swansea) (CS)

Mar. Symposium: The future of motor car coatings (OCCA-LSn/IMFin)

Mar./ Symposium: Reinforced thermo-

April Setting materials—application and performance (PI-DCo)

April

11/12 Conference: New techniques in extrusion and injection moulding (Manchester) (PI-MCo/NWSn)

13 Annual General Meeting (SoDAC)

5/6 Conference: Reinforced plastics in aerospace applications (PI-RPGp)

April/ Conference: Rubber—metal bonding

May (IRI-EngGp)

May

7-11 Joint conference in Montreal (SPE/PI)

21-24 Technical Exhibition at Olympia (OCCA)

22/23 Conference: Plastics and paper (PI-MCo)

31 Building Education conference (PI-B&CGp)

June

18-20 Conference: Plastics industries in a developing world (PI-CGp)

19-23 Biennial conference: Towards 2000 (Eastbourne) (OCCA)

20-29 INTERPLAS

26 Dinner at the Connaught Rooms (PI)

July 3rd International symposium: Synthesis in organic chemistry (Oxford) (CS)

September

10-14 IUPAC International symposium on macromolecules (Aberdeen) (CS/PI/SCI/IRI/IoPhys)

19-21 Symposium: Technical and economic challenge of Europe (Brighton) (SoDAC)

Sept. Conference: New and improved resin systems (PI-RPGp)

October

23-25 Conference: Plastics packaging and our society (PI-PGp)

November

7-9 Foundation Lecture and Annual National Conference: Tyres (Stratford-on-Avon) (IRI-MSn)

27/28 Conference: Plastics in furniture II (PI-MCo)

1974

February

19/20 Conference: Carbon fibres II (PI-RPGp)

Spring

Conference: Finishing and decoration of plastics mouldings (Solihull) (PI-MCo)

April

1-5 Annual conference (CS/RIC)

May Foundation lecture and Annual National Conference: Processing and processibility (Buxton) (IRI-ManSn)

Summer

> Conference: Plastics in telecommunications/cables (PI-MCo)

November

> Conference: Plastics in leisure (PI-MCo)

1975

May Foundation Lecture and Annual National Conference (IRI)

1976

May Foundation Lecture and Annual National Conference (Leicester) (IRI)

1977

May International Rubber Conference (IRI)

News of Members

Mr R. G. Ficken, an Ordinary Member attached to the London Section, has been appointed manager of the newly formed special products group of Lennig Chemicals Ltd. Mr Ficken will continue as a member of the special task force responsible for the co-ordination of start-up activities at the company's extensive acrylic monomer facilities at Teesside, but will also be entirely responsible for the sales and marketing of acrylic monomers, products used in the sealant industry, and all other chemical intermediates.

Mr L. W. Robson, an Ordinary Member attached to the London Section, has retired from the Chairmanship of Titanium Intermediates Ltd. as from 30 June, after 26 years' service with the British Titan Group.

Dr A. Bowman, an Ordinary Member attached to the Newcastle Section, retired from the board of directors of British Titan Ltd. on 30 June, for reasons of ill-health. Dr Bowman, who has been with the group for 26 years, four of which were as technical director, also retired from his positions on the boards of a number of other companies in the British Titan Group.

Mr W. S. Crisp, an Ordinary Member attached to the London Section, has been appointed industrial marketing manager of Berger Paints. In this position, which is newly created, Mr Crisp will be responsible for the recommendation and implementation of marketing plans for the company's general industrial automotive, and can and coil coating divisions.

Mr K. Burrell, an Associate Member attached to the London Section, has resigned his position as director of Burrell & Co. Ltd., after 60 years with the company, including 37 years as chairman.

External wall finishes symposium

A one-day symposium on external wall finishes, organised jointly by the road and building materials group of the Society of Chemical Industry and the Agrement Board, is to be held in London on 15 February 1973. Full details will be available next month; those interested should contact the Assistant Secretary, SCI, 14 Belgrave Square, London SW1X 8PS.

FSPT Keynote Address

"A golden anniversary—prelude to a golden age" will be the title of the Keynote Lecture to be delivered by Dr H. J. Kiefer, director of R&D, Coatings and Resins Group, Glidden-Durkee Div. of SCM Corp., to the 50th Annual Meeting of the Federation of Societies for Paint Technology, at Chalfonte-Haddon Hall, Atlantic City, from 24-28 October.

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

EKERMANS, BRIAN, PO Box 8692, Hoechst SA (Pty) Ltd., Johannesburg, Transvaal, South Africa.   *(South African)*

KAEPPEL, PETER, 168 Bodenstein Street, Krugersdorp, Transvaal, South Africa.
                                                                 (South African)

KELLY, PETER GRAEME, 260 The Boulevard, East Ivanhoe, 3079, Victoria, Australia.
                                                                     (Overseas)

POTTER, JOHN ALLEN, MA, FSDC, 5 Manor Crescent, Tytherington, Macclesfield, Cheshire.   *(Manchester)*

RICHARDS, ALAN LIONEL, API, LRIC, 1 Bentfold Drive, Bury, Lancs.   *(Manchester)*

ROSE, TERENCE DAVID, 1 Falkirk Drive, Breightmet, Bolton, Lancs.   *(Manchester)*

VOGL, JOHN JULIUS, BSc, c/o Rolfes Ltd., PO Box 8001, Elandsfontein, Transvaal, South Africa.   *(Manchester)*

WATERS, JAMES, BSc, Rolfes Ltd., PO Box 8001, Elandsfontein, Transvaal, South Africa.   *(South African)*

Associate Members

BOTHA, BERYL JOAN, 32 Kellon Court, Ross Street, Amanzimtoti, Natal, South Africa.
                                                                 (South African)

STUBEN, EKKEHART, PO Box 8692, Johannesburg, South Africa.   *(South African)*

WILSON, KLAUS DIETER, c/o Hoechst Chemical South Africa (Pty) Ltd., PO Box 8692, Johannesburg, South Africa.   *(South African)*

Section programmes for 1972-73 session

Main Association events

1972

Tuesday 3 October

Foundation Lecture: "The city—a technological university. Are tradition and technology compatible?" by Sir James Tait, to be held at the Painters Hall, Little Trinity Lane, London EC4 at 7.15 p.m., preceded by a short service at the parish church of St. Vedast alias Foster, Foster Lane, London EC2 at 6.15 p.m.

1973

Monday 21-Thursday 24 May

OCCA 25 Silver Jubilee Technical Exhibition, to be held at the Empire Hall, Olympia, London W14.

Tuesday 19-Saturday 23 June

Biennial Conference "Towards 2000," to be held at the Grand Hotel, Eastbourne, Sussex.

Friday 22 June

Annual General Meeting, to be held at the Grand Hotel, Eastbourne, Sussex at 2.30 p.m.

Bristol

All meetings will be held at the Royal Hotel, Bristol, at 7.15 p.m., unless otherwise stated.

1972

Friday 29 September

Ladies' Evening "Design and colour in fabrics" by Mr I. M. Willis of Treforest Silk Printers Ltd.

Friday 27 October

Joint meeting with the Birmingham PVL Club "Systems of appraisal" by Mr N. R. Felstead and Mr C. Sibley of Berger, Jenson and Nicholson Ltd., to be held at the Hawthorns Hotel, Bristol.

Friday 24 November

"The paint industry and the Common Market" by Mr D. E. Eddowes of Polymers, Paint and Colour Journal.

Friday 8 December

Joint meeting with the Institute of Metal Finishing, South West Branch. "The economics of powder coating" by Mr R. Mansell of Dunlop Ltd.

1973

Friday 26 January

"Gravure printing," speaker to be announced.

Friday 23 February

"Modern dispersion techniques" by Mr I. Berg of Berger Paints Ltd., to be held at the Angel Hotel, Cardiff.

Friday 30 March

Informal Debate: "The customer is always right".

Friday 6 April

Annual Dinner Dance, to be held at the Mayfair Suite, Bristol Entertainments Centre.

Friday 27 April

Annual General Meeting.

Hull

All meetings will be held at the Queens Hotel, George Street, Hull, at 7.00 p.m., unless otherwise stated.

1972

Monday 2 October

"Plastic coated steel" by Mr J. Land of Dufay Plastics Ltd.

Thursday 12 October

Annual Dinner Dance, to be held at the Hotel Eden, Hull.

Monday 6 November

"Stainless and low alloy steels" by Mr J. E. Truman of Firth Brown Ltd., to be held at the Haven Inn, Barrow Haven, Lincolnshire.

Monday 4 December

"Photodegradation of epoxy resins" by Professor G. Scott of the University of Aston in Birmingham.

1973

Monday 8 January

"Is the paint industry on the move?" by Mr D. E. Eddowes of Polymers Paint and Colour Journal.

Monday 5 February

"Are emulsion paints good enough?" by Mr J. Cruden of Harco Ltd.

Monday 5 March

Ladies' Evening: "Contemporary textiles" by Professor C. S. Whewell of the University of Leeds.

Irish

All meetings will be held at the Clarence Hotel, Dublin, at 8.00 p.m., unless otherwise stated.

1972

Friday 15 September

"The uses of carbon black in paint and printing ink" by Mr F. Muller-Focken of Degussa Wolfgang.

Friday 20 October

To be announced.

Friday 3 November

Annual Dinner Dance, to be held at the Royal Starlight Hotel, Bray.

Friday 17 November

"Developments in ink technology" by Mr G. H. Hutchinson of A. B. Fleming & Co. Ltd.

Friday 8 December

Ladies' Night: Film show and social evening.

1973

Friday 19 January

"Marketing in the context of the small firm" by Mr Rock of the Irish Management Institute.

Friday 16 February

"Organic pigments for the paint industry" by Mr H. Biffar of Fabwerke Hoechst AG.

Friday 16 March

"Modern developments in packaging" by Mr E. G. O. Ridgewell of the Irish Packaging Institute.

Friday 20 April

Annual General Meeting, followed by an open forum discussion.

London

All meetings will be held at the Polytechnic of the South Bank at 7.00 p.m., unless otherwise stated.

1972

Friday 6 October

Annual Dinner Dance, to be held at the Café Royal, London W1.

Wednesday 11 October

"Permeability properties of surface coatings towards ions" by Dr J. D. Murray of the Quality Assurance Directorate (Materials).

Wednesday 8 November

European Liaison Lecture: "Painting concrete" by Mr B. Lindberg of the Scandinavian Paint and Printing Ink Research Institute.

Wednesday 6 December

Ladies' Invitation Evening: "Colour in decoration" by Mr D. C. Mason of ICI Ltd., Paints Division. Time and venue to be announced.

Monday 11 December

"Zeta potential, its use and abuse" by Dr A. L. Smith of Liverpool Polytechnic, to be held at 14 Belgrave Square, London, SW1, at 6.0 p.m.

1973

Wednesday 10 January

"The inkmaker and heat transfer inks" by Mr D. W. Woods of Coates Brothers Inks Ltd.

Wednesday 24 January

Whole day symposium: "Implications of pollution for the coatings industry," to be held at Thameside Polytechnic, Woolwich Arsenal. Further details to be announced.

Monday 5 February

"Zinc phosphate, its history, development and future" by Mr M. Rendu of Imperial Smelting Corporation (Alloys) Ltd., to be held at East Ham Technical College.

Wednesday 7 March

"Some aspects of colorimetry, particularly fibre optics" by Mr D. Irish of the Paint Research Association.

March

Joint Symposium with the Organic Finishing Group of the Institute of Metal Finishing: "The future of motor car coatings". Full details to be announced.

Manchester

All meetings will be held at the Manchester Literary and Philosophical Society, 36 George Street, Manchester 1, at 6.30 p.m., unless otherwise stated.

1972

Tuesday 19 — Wednesday 20 September

Symposium "Paint performance and the microbiological environment" to be held at the University of Manchester Institute of Science and Technology.

Friday 13 October

"New developments in clear coatings for exterior wood" by Dr R. Miller of Timber Laboratories.

Friday 20 October

Annual Dinner Dance, to be held at the Piccadilly Hotel, Piccadilly Plaza, Manchester 1.

Friday 10 November

"The scanning electron microscope" by Mr R. J. Williams of BP Chemicals (UK) Ltd., to be held at the Bolton Institute of Technology, Deane Road, Bolton.

Wednesday 13 December

"Water pollution control: objectives and methods" by Mr F. Buckley of the Lancashire River Board, to be held at the Royal Institution, Colquitt Street, Liverpool 1.

1973

Friday 12 January

"Design is where you find it—a talk on the psychology of colour and design" by Mr E. Pond of WPM Ltd.

Friday 9 February

"Technological forecasting and its potential in the surface coating industries" by Mr H. Jones.

Wednesday 7 March

"Recent trends in the development of organic pigments" by Dr E. R. Inman of CIBA-GEIGY (UK) Ltd., to be held at the Royal Institution, Liverpool.

Friday 13 April

Annual General Meeting, to be held at the Lancashire County Cricket Club, Old Trafford, Manchester.

Student Lectures

All meetings will be held at the Manchester Literary and Philosophical Society, at 4.30 p.m., unless otherwise stated.

1972

Wednesday 11 October

"Corrosion theory for the paint technologist" by Dr J. Wolstenholme of Flintshire College of Technology.

1973

Wednesday 17 January

"Solvents in paints and printing inks" by Mr C. J. Nunn of Shell Research Ltd.

Wednesday 14 February

"Synthetic stoving finishes" by Mr D. Pountain of WPM Ltd., Paint Division.

Wednesday 14 March

"Pigment dispersion" by Mr G. R. Robson of ICI Ltd., Organics Division.

Midlands

All meetings will be held at the Birmingham Chamber of Commerce and Industry, 75 Harborne Road, Birmingham 15, at 6.30 p.m., unless otherwise stated.

1972

Friday 15 September

Ladies' Evening, to be held at the Westbourne Suite, Botanical Gardens, at 7.00 p.m.

Friday 22 September

"Alpha-olefines—new monomers for surface coatings" by Mr K. B. Gilkes of British Paints & Chemicals, Resinous Chemicals Division.

Friday 20 October

"Colour passing—visual or instrumental?" by Mr K. McLaren of ICI Ltd., Dyestuffs Division.

Friday 17 November

"New technology furnace blacks as channel black replacements" by Mr N. Scott of Cabot Carbon Ltd.

1973

Friday 19 January

Annual Dinner Lecture: "Purchasing in the paint industry" by Mr D. F. Brocklehurst of BJN Group Supplies Ltd.

Friday 16 February

"Dispersymers—non-aqueous dispersion finishes. Novel finishes for the industrial and automotive fields" by Mr R. L. Baylis of ICI Ltd., Paints Division.

Friday 16 March

Annual J. Newton Friend Lecture: "Some great English potters" by Mr C. E. L. Franklin of Royal Doulton Tableware Ltd., to be held at 7.30 p.m.

Friday 13 April

Annual General Meeting.

Trent Valley Branch

All meetings will be held at the British Rail School of Transport, London Road, Derby, at 7.00 p.m.

1972

Thursday 12 October

"Powder coatings" by Mr M. Cotton of Shell Research Ltd.

Thursday 9 November

"Durability testing" by Mr E. Oakley of Tioxide International Ltd.

Thursday 7 December

"Wallpaper manufacture" by Mr S. Duckworth of WPM Ltd.

1973

Thursday 8 February

"Vinyl resins" by Mr D. J. Silsby of Bakelite Xylonite Ltd.

Thursday 8 March

"The origin and extraction of natural colours and minerals" by Mr E. Hare of Via Gellia Colour Co. Ltd.

Thursday 5 April

Annual General Meeting, followed by "Steel in fashion" by Mrs Colleran of the British Steel Corporation.

Newcastle

All meetings will be held in the Royal Turks Head Hotel, Grey Street, Newcastle upon Tyne, at 6.30 p.m., unless otherwise stated.

1972

Thursday 5 October

"The money game" by Mr S. M. Jennings of Thomas De La Rue & Co. Ltd.

Thursday 2 November

"Polymeric prognostications" by Mr A. R. H. Tawn of Cray Valley Products Ltd.

Thursday 7 December

"Pollution control" by Mr G. Turner of ICI Ltd., HOC Division.

1973

Thursday 4 January

"Business planning: only a numbers game?" by Mr J. A. Willey of Berger Jenson & Nicholson Ltd.

Thursday 1 February

"Polyurethane systems in the marine industry" by Dr F. Blomeyer of Bayer AG.

Friday 23 February

Ladies' night.

Thursday 1 March

"The evolution of alkyd resins" by Mr T. I. Price of BP Chemicals (UK) Ltd.

Thursday 5 April

Annual General Meeting, time and venue to be announced.

Scottish

All meetings will be held at the St. Enoch Hotel, Glasgow, at 6.00 p.m., unless otherwise stated.

1972

Thursday 12 October

"A lifetime in the chemical industry" by Mr J. Miller.

Thursday 9 November

"Trends in major printing processes—role of pigments" by Mr P. Raymond of CIBA-GEIGY (UK) Ltd.

Thursday 14 December

Joint meeting with Society of Dyers and Colourists—Scottish Region: "Industrial relations 1972" by Mr J. F. Shaw of the Department of Employment and Productivity.

1973

Friday 12 January

Annual Dinner Dance, to be held at the Central Hotel, Glasgow.

Wednesday 17 January

Joint meeting with BPBMA, Technical Section in Falkirk. "Adhesives," speaker and venue to be announced.

Thursday 8 February

"Powder coatings" by Mr D. W. Brooker of Shell Research Ltd.

Thursday 8 March

"Research and innovation at the Paint RA." Dr S. H. Bell of the Paint Research Association.

Eastern Branch

All meetings will be held in the Carlton Hotel, North Bridge, Edinburgh, at 7.30 p.m., unless otherwise stated.

1972

Wednesday 11 October

"Leonardo da Vinci and his times" by Mr J. C. Patek of A. B. Fleming & Co. Ltd.

Saturday 21 October

Joint meeting with Scottish Section Student Group: "Aqueous pigment dispersions" by Mr A. Gray and Mr J. T. Hunt of CIBA-GEIGY (UK) Ltd., venue to be announced.

Tuesday 7 November

Joint meeting with the BPBMA, Northern Section: "Marketing in the paper industry" by a lecturer to be arranged by the BPBMA. To be held at the Tree Tops Hotel, Aberdeen at 7.00 p.m.

Wednesday 20 December

Joint meeting with BPBMA: "Adhesives for paper and board in packaging" by Mr D. L. G. Childs of Harlow Chemical Co. Ltd., to be held at the Carlton Hotel, Edinburgh.

1973

Wednesday 17 January

"Modern analytical techniques" by Mr P. S. Nisbet of A. B. Fleming & Co. Ltd.

Friday 2 February

Annual Burns Supper, to be held at the Royal Mile Centre, Edinburgh.

Wednesday 21 February

"Testing of raw materials for paint and varnish" by a lecturer from ICI Ltd.

Wednesday 21 March

Annual General Meeting, followed by films provided by ICI Ltd.

Wednesday 18 April

"Restoration and conservation" by Mr R. L. Snowdon of the Restoration Centre, Department of the Environment. If possible this meeting will be held at a site where work is under way.

Student Group

All meetings will be held at the St. Enoch Hotel, Glasgow, at 10.00 a.m. unless otherwise stated.

1972

Saturday 14 October

"Corrosion and its costs" by Mr G. Scott of Federated Paints Ltd.

Saturday 28 October

Joint meeting and skittles match with the Eastern Branch—venue to be announced.

Saturday 11 November

"Future advantages from North Sea oil" by Mr R. C. Campbell of The Scottish Council, Department of Development and Industry.

Saturday 16 December

Joint Meeting with the Eastern Branch. Works Visit to the Linwood Plant of Chrysler Scotland Ltd. with a lecture.

on "Automotive finishes" by Mr J. McQuade of Chrysler Scotland Ltd.

1973

Saturday 20 January

"Pigments for plastics" by Mr S. T. Bebbington of ICI Ltd.

Saturday 10 February

"Selection of PVA emulsions for water-based paints" by Mr D. Wallace of Vinyl Products Ltd.

Saturday 10 March

Short talk and film on "Pollution" by Mr A. Jones of The Scottish Council, Department of Development and Industry, followed by the Annual General Meeting.

Thames Valley

All meetings will be held at the Beech Tree Hotel, Maxwell Road, Beaconsfield, Buckinghamshire, at 7.00 p.m.

1972

Thursday 28 September

"Adhesives" by Dr Fletcher of Croda Polymers Ltd.

Thursday 26 October

"Colour measurement and control with the fibe optics colorimeter" by Mr D. Irish of the Paint Research Association.

Thursday 23 November

"Car painting requirements of the future" by Mr W. Dabbs of Pressed Steel Fisher Ltd.

1973

Thursday 25 January

"Recent aspects of anti-corrosive pigments" by Mr M. Rendu of Imperial Smelting Corporation (Alloys) Ltd.

Friday 9 February

Buffet Dance, to be held at the "Great Fosters", Egham.

Thursday 22 February

Details to be announced.

Thursday 22 March

"Recent developments in the painting and decoration of metal containers" by Mr A. D. Lott of Metal Box Co. Ltd.

Thursday 12 April

Annual General Meeting, followed by a talk by a speaker from HM Customs and Excise.

Student Group

All meetings will be held in the main Lecture Theatre, Slough College, at 4.00 p.m.

1972

Thursday 5 October

"Wood preservation" by Mr B. A. Richardson.

Thursday 2 November

"Corrosion: the vulture of metallurgy and the skeleton in the chemical cupboard." Dr M. Clark of Sir John Cass College.

Thursday 7 December

"Powder coatings" by Mr Chellingsworth of Ault & Wyborg Industrial Finishes.

1973

Thursday 11 January

"Marine coatings," speaker to be arranged.

Thursday 8 February

Works visit, to be arranged. Leaving Slough College car park at 1.00 p.m.

Thursday 8 March

"Glass reinforced plastics," speaker to be arranged.

Thursday 3 May

"Corrosion inhibitive pigments," speaker to be arranged.

West Riding

All meetings will be held at the Griffin Hotel, Leeds, at 7.30 p.m.

1972

Tuesday 12 September

"Micronised iron oxide pigments" by Mr W. Schleusser of Bayer AG.

Tuesday 10 October

"Powder coatings," speaker to be arranged.

Tuesday 14 November

"Anaerobic acrylics" by Dr Leen of Borden Chemical Co. (UK) Ltd.

Friday 24 November

Annual Dinner and Dance, to be held at the Crown Hotel, Harrogate.

Tuesday 12 December

Chairman's Lecture, "Wood our oldest friend" by Mrs K. Driver.

1973

Tuesday 9 January

"High speed milling" by Mr D. W. Wilkinson of August's Ltd.

Tuesday 13 February

"Functional extenders in emulsion Paint" by Mr S. E. Maskery of Crosfield Chemicals Ltd.

Tuesday 13 March

"Microbiology" by Mr W. R. Springle of the Paint Research Station.

Tuesday 10 April

Annual General Meeting. 21st Anniversary.

May

Luncheon Lecture.

The programme for the Southen Branch of the London Section has not been received at the time of going to press. It is hoped that it will appear in the September issue.

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.

Friday 4 August

West Riding Section: Annual Golf Tournament, to be held at Wetherby Golf Club.

Tuesday 12 September

West Riding Section: "Micronised iron oxide pigments" by Mr W. Schleusser of Bayer AG. To be held at the Griffin Hotel, Leeds, at 7.30 p.m.

Friday 15 September

Midlands Section: Ladies' Evening. To be held at the Westbourne Suite, Botanical Gardens, at 7.00 p.m.

Irish Section: "The uses of carbon black in paint and printing ink" by Dr F. Muller-Focken of Degussa, to be held at the Clarence Hotel, Dublin, at 8.00 p.m.

Tuesday 19 — Wednesday 20 September

Manchester Section: Symposium "Paint performance and the microbiological environment". To be held at the

University of Manchester Institute of Science and Technology.

Friday 22 September

Midlands Section: "Alpha-olefines— new monomers for surface coatings" by Mr K. B. Gilkes of British Paints and Chemicals (Resinous Chemicals Division) to be held at the Birmingham Chamber of Commerce and Industry, 75 Harborne Road, Birmingham, at 6.30 p.m.

Thursday 28 September

Thames Valley Section: "Adhesives" by Dr Fletcher of Croda Polymers Ltd., to be held at the Beech Tree Hotel, Maxwell Road, Beaconsfield, Bucks, at 7.00 p.m.

Friday 29 September

Bristol Section: Ladies' Evening. "Design and colour in fabrics" by Mr I. W. Willis of Treforest Silk Printers Ltd., to be held at the Royal Hotel, Bristol, at 7.15 p.m.

CLASSIFIED ADVERTISEMENTS

Classified Advertisements are charged at the rate of 50p per line. Advertisements for Situations Wanted are charged at 12½p per line. A box number is charged at 5p. They should be sent to the Director & Secretary, Oil & Colour Chemists' Association, Wax Chandlers' Hall, Gresham Street, London, EC2V 7AB. Telephone: 01-606 1439.

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