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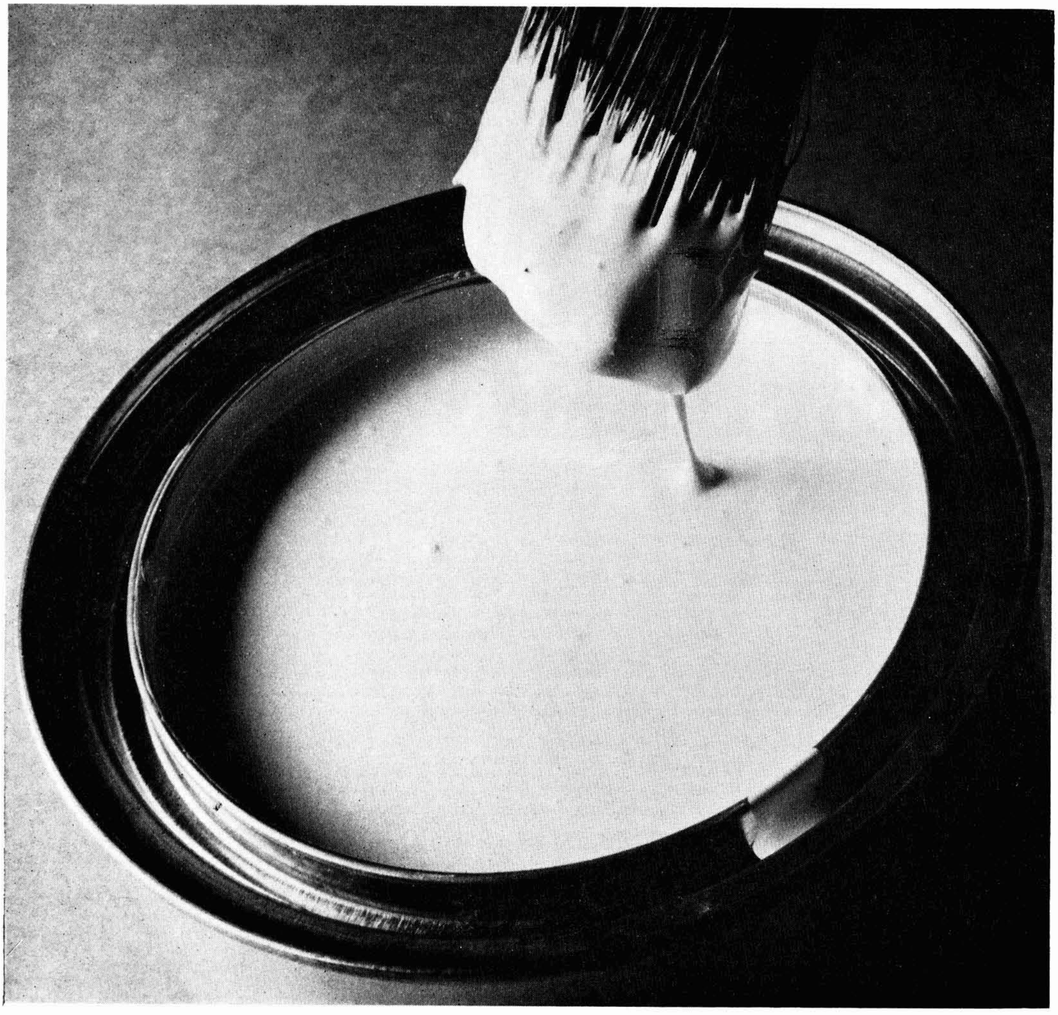

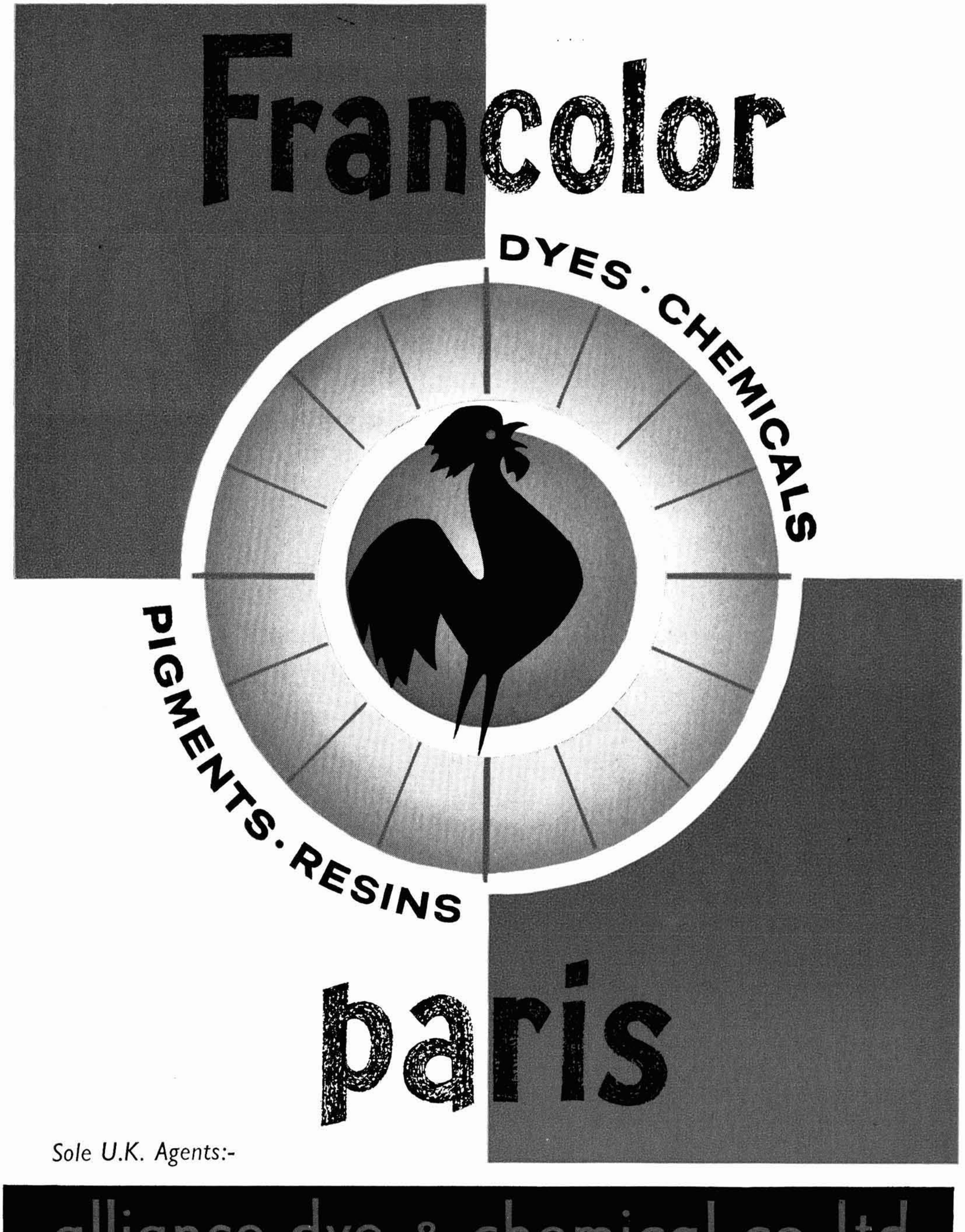
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Transactions and Communications

Testing of surface coatings by the customer*

By D. A. Bayliss

Central Electricity Generating Board, Scientific Services Department, Gravesend, Kent

Summary

The policy behind the paint testing methods used in the CEGB Protective Coatings Testing Laboratory is described. The need for comparative evaluation of proprietary materials to be carried out under conditions as close as possible to those occurring in practice is emphasised. The problem of paint application on large scale projects and the use of painting specifications, independent inspection and guarantees are discussed.

In some instances it has been necessary to develop special materials for CEGB use, and this is illustrated by the examples of a coating for nuclear fuel transport containers and paints for the maintenance of transmission towers.

Keywords

Types and classes of structures or surfaces to be coated

steel

Processes and methods primarily associated with analysis, measurement or testing

inspection

testing

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

exterior durability

Specifications, standards and regulations

specifications

Les essais sur revêtements de surface effectués par le client

Résumé

On décrit les objectifs des méthodes d'essai pour peintures que l'on utilise au Protective Coatings Testing Laboratory du CEGB. On souligne la nécessite d'effectuer les évaluations comparatives des produits de marque sous les conditions autant semblables que possible à celles qui regnet dans la pratique. On discute le problème de l'application de peintures aux chantiers de construction à grande échelle et également l'emploi des normes de peinturage, les services de contrôle indépendants, et les garantis.

En certains cas il a été nécessaire de mettre au point des produits spéciaux pour l'usage du CEGB, et on indique en faisant appel aux exemples d'un revêtement destiné à être appliqué aux récipients pour le transport des combustibles nucléaires et aussi des peintures pour l'entretien des pylons de transmission.

Prüfung von Anstrichmitteln durch den Kunden

Zusammenfassung

Die Richtlinien, welche die Lackprüfmethoden des Protective Coatings Testing Laboratory des CEGB (Central Electricity Generating Board) bestimmen, werden beschrieben. Es wird unterstrichen, dass es für vergleichende Bewertung von nicht nach Liefervorschriften erzeugten Materialien erforderlich ist, diese so nahe wie möglich unter den bei der praktischen Anwendung vorkommenden Bedingungen vorzunehmen. Besprochen wird das Problem des Anstreichens von Projekten grosser Dimensionen und der Anwendung von Vorschriften für das Auftragen, der unabhängigen Inspektion und der Garantien.

In manchen Fällen war es nötig für den CEGB Spezialprodukte zu entwickeln. Dies wird an den Beispielen eines Anstrichmittels für Behälter für den Transport von Kernbetriebstoff und von Beschichtungen für die Instandhaltung von Transmissionstürmen erläutert.

Introduction

The Central Electricity Generating Board currently operates about 170 power stations, 980 sub-stations and 16 000 route kilometres of high-voltage overhead lines carried on about 55 000 transmission towers. Other CEGB establishments include: the offices at headquarters, the three main research laboratories; the accommodation of the Construction Division, and the offices, workshops, stores and Scientific Services laboratories of the five regions.

The provision of paint and protective coatings to meet the diverse needs of this extensive organisation is clearly a matter of importance. Currently there is an annual expenditure of approx £1.5 million on paint materials alone and excluding the cost of application.

It was to help satisfy the technical and commercial needs of a large customer that in 1960 the CEGB established a "Protective Coatings Testing Laboratory". The members of this small group are unique within the CEGB in that they are occupied solely with coatings and coating problems, although the term coatings is now taken in a wider sense than just paints and includes metal and plastic coatings. This centre of specialist knowledge is used by all sections of the CEGB and to some extent by the Area Boards, South of Scotland Electricity Board and electricity supply industries throughout the world.

It was never intended that the Protective Coatings Testing Laboratory should provide a comprehensive technical service on paints and painting for all users within the Board. Instead, it was accepted that it would be necessary to rely on the help of technical and sales representatives from paint manufacturers to give technical advice, estimates, colour, consultancy and so forth, to the responsible engineers. This applies particularly to specifications for maintenance painting for which a site visit is inevitable.

Customer specified or proprietary products

The requirement for service and responsibility beyond the mere supply of paint materials was one of the reasons why

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the CEGB opted for proprietary products rather than their own paint specifications. There is also the difficulty of writing a "watertight" specification than can ensure the supply of top quality products rather than just "adequate" products. Even if there were no real difference between the two, human nature is such that engineers and painters are much more ready to accept without question the contents of a brand-named tin of paint rather than one labelled as a specification material. When the branded products are widely advertised, then this, as intended, also has a considerable influence.

Selection of materials

For both technical and commercial reasons the Board, over the years, has reduced the number of suppliers of conventional paints from at least 70 to below 10. A paint testing procedure provides the basis for the technical selection. Basically there are two different procedures that can be adopted, which could be called "specification testing" and "comparative testing". In specification testing, single samples are tested according to a standard procedure and to within defined limits. This is the procedure generally adopted, since the reproducibility and repeatability of the methods is generally well established and, therefore, the results can be repeated in any other laboratory. The CEGB, however, decided to adopt comparative testing, in which a number of different samples of paint are compared simultaneously in respect of the relevant properties, including application characteristics and operational performance. There are two main advantages of this method: firstly, the result from any test can be placed in an order of merit, so that materials selected are at the top of their class; and secondly, although standard methods can still be used, it is also possible to change certain parameters, such as the ambient conditions during application, method of application and the state of the substrate when painted. This is particularly important in an industry such as CEGB, where painting must invariably be subordinate to operational factors.

With comparative testing, no material can be tested in isolation; it must be included in a suitably sized batch which also includes control samples from previous batches. Providing that all samples in one testing batch are prepared and treated in an identical manner—for example, they must all be painted by the same operator at the same time and under identical conditions—then the conditions of preparation can be varied and adapted to meet specific circumstances which relate, as closely as possible, to reality. For example, it is difficult to make a reproducible specification test that: includes rusted steel specimens; is applied under ambient conditions less perfect than in a temperature and humidity controlled laboratory; allows for different application techniques; allows for the application of a "natural" film thickness by any one operator. This latter point is important because there is a growing gap between the technique used by the skilled craftsman or laboratory technician and by the type of labour used on industrial work.

Painting specifications generally state the ideal conditions for paint application, but due to a combination of the vagaries of the British weather and the economic need to keep the labour force fully occupied, painting is often carried out in much less than ideal conditions. Comparative testing makes it possible to test the tolerances of different paints to such abuses. It allows, for example, the exposure of newly painted samples to conditions of slight condensation, which occur so often on structures during their construction.

Test specimens can be of any shape and in any condition, providing that they are uniform throughout the batch tested. In this respect, any steel used in a paint testing batch should be obtained from the same manufacturing batch since, for example, quite small differences in copper content could make a significant difference to corrosion resistance and, therefore, to the performance of a covering paint system. Pieces of angle iron and features, like bolt heads and so forth, can also be included in the test specimen.

In recent years valuable work has been carried out by the Sub-Committee of the Advisory Council of Materials on the correlation of accelerated weathering with outdoor exposure. If the necessary time and money are available, however, natural weathering, at a relevant (but severe) site, is preferred.

The CEGB paint testing investigations have shown that exposure for a cycle comprising two summers at Dungeness or Brighton Power Station sites, which have clean but aggressively marine atmospheres, and high sunshine rates, is sufficient to show up significant differences in performances of materials. Admittedly, the poorer materials tested at these sites would last much longer in more northern and more industrial surroundings, but it is considered that the relative performance of paints would be the same.

The orientation of exposure specimens is of importance. The traditional exposure at an angle of 45° facing south gives the maximum exposure to ultraviolet radiation, but is the least corrosive aspect. Panels exposed vertically facing north stay wet longest (particularly if they are also sheltered from drying winds; this often happens with buildings, but does not often occur with paint exposure racks). Such panels also retain their gloss and colour but fail by corrosion blistering. Generally, these aspects can be met by using larger sample specimens and shapes more complicated than flat panels.

To assist in the interpretation of results and in order to categorise proprietary paint systems, manufacturers are asked to submit outline formulations and unique reference numbers of their products. When appropriate, approval is given for the formulation as tested, but any subsequent changes in formulation are automatically approved, providing that the manufacturers inform the Board of the details and reasons for the change. This is necessary to ensure that any "finger-printing" quality control tests do not reject the material as non-standard. If it is felt necessary, the new material is included in the next testing cycle. This procedure ensures that there is no hindrance to development within the paint industry. It is considered that no manufacturer would jeopardise his commercial position on such an exclusive "approved list" by deliberately degrading his products.

Paints must, of necessity, be a compromise of properties, many of which are in opposition, for example: durability and easy obliteration, flow and edge coverage, colour matching and colour fastness, high film build and economy, quick drying and long term durability, slow drying and overcoatability. Different users require the emphasis to be placed on different properties; for example, in a power station the ability to withstand difficult application conditions is more important than a high class decorative finish, whereas for a prestige office building the reverse could be true. Reasons for maintenance painting also differ and at a power station, for example, repainting would usually be carried out in order to restore a clean appearance rather than because the paint had failed or corrosion was occurring. Comparative testing allows for emphasis on any particular property required by the customer.

Many factors of durability and application must be taken into account when evaluating a given paint. Comparative testing not only allows the inclusion with ease of tests for a whole range of properties, but also several different methods of determining any one property. Laboratory test methods sometimes give different results, with different materials under different conditions. For example, the relative performance of metal primers could differ between salt spray exposure and natural outdoor weathering. Comparative testing, without its strictly defined and published limits, can make allowances for the inherent characteristics of different materials and take other factors into account. The extent to which this is carried depends largely upon the importance of the material to the user. For example, with the CEGB evaluation of proprietory gloss paints, 125 different quality characteristics were taken into account in order to define any one manufacturer's product.

It is considered by the author that over seven two-year testing cycles there has never been any difficulty in establishing the relative character and quality of an individual proprietary material. It is noteworthy that although the tests are carried out under anonymous labels, materials from the same sources generally behave consistently. Comparative testing in this way does highlight that, contrary to some manufacturers' opinions, there are significant differences in performance between different brands of paint.

Paint application

Having ensured that the CEGB uses top quality paint materials, it is less easy to ensure that such materials are used correctly. This applies particularly to structural steel painting. Although engineers and architects may claim to be aware of the importance of good surface preparation and paint application, the majority still ascribe a failure to the brand of paint used rather than to the indifferent efforts of the paint applicator. With their name at stake, it is surprising that paint manufacturers do not find some means of exerting more control over the finished article, for example, by offering the client the names of independent paint inspection firms who are familiar with their products and have access to their technical staff and whose inspectors are individually approved by them.

Guarantees

Experience has shown that guarantees of performance for general paintwork are difficult to formulate and evoke. This is because failure of paint films is usually progressive and the point at which they become "unacceptable" is difficult to define. Furthermore, some types of paint failure are more undesirable than others, since they require extensive preparation before repainting. Recompense under guarantees cannot take account of the increasing cost of labour and materials nor of the inconvenience and difficulty of access in an operational environment, such as a power station, as opposed to a new construction.

Any attempt to define guarantees more rigorously is counter-productive, since it inhibits the paint applicator to such a degree that he is hardly prepared to paint in anything but in ideal conditions. For a power station under construction, painting the steelwork, even at a cost of £0.5 million, must be subordinate to the commissioning programme. In practice, therefore, any guarantee would have to be waived to permit painting under marginally unsuitable conditions. In addition, for a large and protracted painting operation there is always a difficulty in recording comprehensively the times of painting of individual areas; this is even more difficult if isolated areas not subject to the guarantee have also to be identified.

Furthermore, even obvious and spectacular paint failures, occurring shortly after application, are often limited to a small part of a comparatively large area. Patch painting can often satisfy the technical requirements of a guarantee but not the decorative aspect. In addition, any areas of mechanical damage, for example as a result of vandalism, may be considered to invalidate a guarantee on what might have been considered a failed paint system.

Guarantees can be used, however, on specialist applications, such as tank linings, where the paint supplier has full responsibility for a "package deal" and has complete control over all aspects. It is generally intended that such coatings will last in excess of ten years, but such a period of guarantee would be unrealistic and uneconomic because, for safety's sake, any manufacturer would have to allow for at least one repainting during that period. Any period of guarantee less than ten years could suggest that such a life would be acceptable. Instead, it is a reasonable assumption that any failure due to bad application will become obvious quite quickly under operational conditions. The guarantee for a tank lining would read, therefore, something like: "the treated surfaces are to be inspected at a time not less than 12 months and not more than 24 after the coating is under operational conditions, and the Contractor will at that time be responsible for the full repair of any visible defects, excluding those from mechanical damage or by filling with liquids other than specified".

Inspection

For non-specialist painting work the CEGB relies on its own Specifications and Codes of Practice, the use of approved materials and full time inspection of painting. The inspection of painting on a large contract is too often the part-time work of an assistant engineer, who probably has other more demanding interests. The use of independent paint inspection firms can help, but the reliability of an inspection firm or (which is even more important) of individual inspectors, is difficult to establish.

Paint inspection is hard, unpleasant, unpopular and sometimes dangerous work. A paint inspector is subject to considerable pressure from the painters, who see him as a threat to their wage packet and from management on both sides who are worried about the progress of building schedules. On industrial work it is almost impossible to comply exactly with the requirements for ideal painting conditions, as laid down in Specifications and Codes of Practice. Brush-hands soon learn that most conventional paints are so tolerant that they will withstand a great deal of abuse without any obvious defects in the short term. Very little information is available to the inspector on the long term effects of variations in ambient conditions during paint application and it is hoped to make this the subject of a programme of investigational work within the CEGB in the near future.

Problems special to the CEGB

Most painting requirements within the CEGB can be met by the use of standard paint systems and there is no need to add to that proliferation of paint types that inconveniences the manufacturer and bewilders the user. In a few instances, however, special formulations are required to meet certain unique conditions and this can be illustrated by two contrasting examples.

Coatings for nuclear fuel transport containers

Nuclear fuel elements are transported to and from nuclear power stations in containers approximately 1.5m square weighing 50 tonnes. Many of the containers are loaded and unloaded under water. This water is part of the radio-active system within the power station and, therefore, the containers must be decontaminated, by washing to a safe level, before transport by road and rail.

Originally the containers were coated with an epoxy system which would normally have been considered durable for many years under the conditions of intermittent water immersion and atmospheric exposure. In fact, as the coatings aged, although they still appeared satisfactory to the eye, it became increasingly difficult to remove the radio-activity. In some instances it was necessary to wash the coatings for several days in order to achieve what had previously been possible in a few hours.

The cause proved to be a combination of two factors; firstly, minute degradation of the surface reduced the efficiency of the washing process used for decontamination and, secondly, the pigments and the resins used both varied in their ability to retain radio-activity. For example, the presence of Hansa yellow pigment used to provide the yellow "ionising radiation" hazard warning colour, gave a worse performance than white pigmentation alone. In some cases, there was a conflict of requirements, for example, anatase titanium dioxide had less radio-active pick-up than the rutile grade. After investigating a wide range of pigments and media, the following system was chosen.

For the firsι and second coats, an epoxy priming system using a bisphenol-A based solid epoxide (Epikote 1001 from Shell Chemicals Limited) is employed. The pigmentation is achieved with rutile titanium dioxide and zinc chromate in a 10:1 ratio and at a total pigment volume concentration of 15 per cent.

The third and fourth coats are finishing coats based on a modified non-drying alkyd (Plastakyd DX32 with Cardura E from Plastanol Limited) with isocyanate curing agent (Desomadur N from Bayer Chemicals Limited). Rutile titanium dioxide is the only pigment used and is also at a pigment volume concentration of 15 per cent.

The complete system is known as "CEGB 6" and it has proved very satisfactory in service with the CEGB and AEA over the last five years. It is also being used in Japan and Italy, where nuclear power stations similar to the ones in this country are operated.

Paints for transmission towers

Protection of bolted angle iron, transmission tower structures seems a fairly conventional problem. It is not surprising, therefore, that many manufacturers and suppliers claim to have the ideal material for this potentially lucrative job. In the majority of cases, however, they are guilty of putting the "theoretical" aspects of their materials' durability before the"reality" of this particular application.

In order to maintain electricity supplies at all times to the consumer, it is nearly always necessary to leave one section of a transmission line electrically "alive". This means that for safety reasons alone, no scaffolding, cranes, hoists etc can be used. The only method of painting is by "monkey climbing" over the structure. It was difficult enough to find men prepared to do this for the 132kV towers where the average height is 30m; it is extremely difficult for the new 400kV towers, which are at least 30m higher. The difficulty can be imagined of painting the underneath, or far ends, of the cross arms, at such a height. On the larger designs of the 400kV tower, there are approximately 1700m^2 of surface to be painted with approximately another 100m^2 of angles, back to back and approximately 2.5cm apart. There is also the problem of access to the individual towers because almost invariably they are in the middle of a ploughed field or one where crops are growing and not close to any road or even a footpath.

It is fortunate that the original designers of the transmission system were sufficiently far-sighted to use hot dipped galvanised steelwork. After weathering, this had made a good base for painting with only the minimum of surface preparation. No case is known to the author where tower paints have failed by flaking or loss of adhesion. The method of painting is usually by striker brush with a 1m-long handle. The technique used is a throwing and scrubbing action and, therefore, the paint used must give a continuous film when so applied and with the minimum of drag on the arm. Given the chance, the brush-hand will thin any paint down to the consistency of water, and this not only reduces the film thickness but also increases the risk of splashing.

A large proportion of the transmission system was erected 20 to 30 years ago and is simultaneously reaching the point where painting is necessary. This, coupled with the shortage of time in which individual lines can be taken out of service, means that painting has to be carried out from early to late in the year. The paint is certainly applied in extremes of temperature and although every effort is made to ensure that it is not applied in wet weather or on to a wet surface, it can be imagined that in the traditional English summer of "showers and bright periods", the brush hands are not disposed to climb up and down the towers or wait patiently for the right conditions.

Good supervision and inspection is the only answer to the problem, but so many of the difficulties which apply to the painters also apply to inspectors and supervisors. The main job is to prevent thinning and to ensure complete coverage of each coat. This latter point cannot be observed from the ground and is one of several reasons why paints applied must be through-dry overnight. In particular, there should be no fat edges left on the horizontal angle sections which can cause a climber to slip.

In addition, there are certain requirements for the paint material itself. It should contain only white spirit or a similar liquid as solvent, because as the painter's face is very close to the surface and any induced nausea or giddiness could be dangerous. Similarly, since the painters inevitably get their hands and face covered in paint, it must not be toxic or otherwise hazardous. It must contain no lead or other pigments which could poison animals or crops. On this last point, the danger lies not with animals chewing exposed steelwork but by eating crops (or grass) accidentally splashed with paint. It also illustrates the need to remove used paint tins from the site for these might otherwise be licked clean (for the oil content of the paint) by cattle. The CEGB insists that tower paints must comply with BS 4310:1968 "Permissible limit of lead in low-lead paints and similar materials", so that there is no risk to animals.

It has always been accepted that the only way finally to evaluate a tower paint system is with a full scale, and closely observed, field trial. Since submissions from manufacturers of materials for this application are so frequent and field trials so expensive, however, a preliminary sorting-out procedure was required. In the early days some wrong materials were selected for trial simply because the standard laboratory tests, methods of application and ambient conditions during the application, were so far removed from practice. Eventually four tests were developed which constituted a suitable preliminary hurdle.

Measurement of viscosity on the finishing coats is carried out using an ICI cone and plate viscometer with a range from 0 to 1.0 N s m^{-2} (0 to 10 poise), but with facilities to by-pass the temperature control. Measurements of both initial and final viscosity after 15 secs are recorded at both 3°C and 20°C. It has been found that the optimum range at both temperatures is 0.25 to 0.4 N s m^{-2}. A well bodied structure rather than thixotropy is required.

Film continuity is assessed by applying the paint to a 100 × 30cm sheet of transparent glazed paper, using a striker brush and an imitation of the tower painter's method. The paper is then viewed against a standard X-ray viewing light box so that the opaque area can be expressed as a percentage of the total panel area. For successful materials, this gives a value in excess of 90 per cent as a completely opaque area. Since the application in the field often produces quite thick films, the samples are also subjected to a sag test using the Sheen sag testing gauge on mild steel panels at 20°C and 3°C. A successful material should be satisfactory at a 200μm film thickness.

Touch-dry and hard-dry times are determined at 20°C, 10°C and 3°C. The film must be hard-dry in less than 24 hours at 3°C.

In the CEGB tower paint systems now used, all the finishing coats are pigmented with micaceous iron oxide and a small amount of aluminium pigment to give a non-reflective, weathered and galvanised appearance, known as "CEGB Tower Grey". The undercoats are black pigmented micaceous iron oxide to give the maximum contrast between coats. The media used differs in composition between manufacturers and is therefore confidential. In the past, the pigment of the priming system was based on zinc chromate, but this material is being replaced by zinc phosphate.

Conclusions

The use of a comparative testing procedure has enabled the CEGB to identify those paint manufacturers able consistently to supply top quality paints and technical service to all its user points. In only a few cases is it necessary to deviate from manufacturer's standard products to formulate materials for special purposes, such as for use in radioactive areas, or for unusual applications, such as the painting of transmission towers.

Acknowledgments

The author wishes gratefully to acknowledge the assistance over the years of his colleague Mr M. J. Baillieu and to thank Mr W. J. Prior, Director-General of the South Eastern Region of the CEGB, for permission to publish this paper.

[*Received 20 March 1975*

Discussion at Scarborough Conference

MR E. L. FRENCH said that he was surprised that the Generating Board had reduced its "approved list" from seventy companies to approximately ten and he asked whether this was purely for reasons of cost. Secondly, he agreed in principal with the idea of an approved list for paint suppliers, but thought that it was also time for companies to draw up approved lists of applicators and for the applicators themselves to be trained by the suppliers and given a certificate of approval in a similar manner to the way in which paint applicators in the motor industry visited the paint suppliers for training.

MR BAYLISS replied that so far as he was aware, no company was taken off their approved list for reasons of cost. Generally, the smaller firms were eliminated because of their inability to supply a sufficiently wide range of products of the quality required. On the second point, Mr Bayliss agreed with everything that had been said although no practical solution had been found up to the present time. There was a different philosophy among paint applicators compared with the supplying industry, and he was not sure what was the answer to this.

MR A. B. LOCK asked what steps the CEGB took to ensure that the paints actually used were the same as those tested, particularly in relation to the problems imposed on the manufacturers by raw material shortages. There was also the desire by the manufacturers to change formulations to introduce improvements in properties.

MR BAYLISS answered that he did not believe that manufacturers would supply samples different from the paints which might eventually be used since there would be no gain in this for the manufacturer—although steps were taken to ensure that this did not occur. Once an approved product was actually being used, any changes in formulation were usually accepted by the Generating Board in order not to hold up technical developments, although they usually tested the new material at some later stage.

The author also remarked that not too much reliance was placed upon accelerated weathering and it was considered preferable to test the paints for at least two summers of natural weathering at a severe "test" site in the South of England.

MR A. N. MCKELVIE commented that the author had put the cost of protection to the CEGB as £10 000 000 per year, of which £1.5 million per year was the cost of the paint alone. He wondered whether Mr Bayliss could give a split of the difference (£8.5 million per year) into surface preparation, application, access and so forth, and if possible some typical examples for different types of jobs.

MR BAYLISS said that he could not give such a breakdown and the figures would obviously vary depending on the type of structure being painted. For transmission towers, for example, the paint cost approximately £50 000 per year and that cost approximately £0.25 million to apply. For painting the structural steelwork of a new power station, the cost was approximately £0.5 million about a year ago but the ratio of application to material cost was remarkably low—of the order of 2 to 1.

Mr R. L. J. Morris asked whether after selection of the most suitable proprietary paints, the Board informed the paint manufacturer of the criteria of acceptance so that the manufacturers were aware of the significance of changes in formulation.

Mr Bayliss replied that the policy was to ask paint manufacturers for their best product and not to specify a particular formulation, although the suppliers were kept informed of the tests carried out on their products and the results obtained.

The CEGB had reduced the number of paint products it used and it was, therefore, much easier to write a code of practice for the use of its engineers and to confine the recommendations to the situations that would arise within their industry. It was, however, very important to remember that intelligent and otherwise very highly qualified engineers were often ignorant of the simple facts of paint technology.

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Flocculation–its measurement and effect on opacity in systems containing titanium dioxide pigments*

By J. G. Balfour and M. J. Hird

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Summary

Some simple tests for the detection of flocculation of titanium dioxide pigments in alkyd gloss paints are discussed. A more sophisticated technique for the measurement of flocculation involving the scattering of infrared radiation is described, and a variety of paints are examined using this technique.

The opacity of flocculent paints is then related to the pigment particle distribution in the dried paint film. A model is proposed in which the paint film is considered to consist of regions of different pigment concentrations. This model is used to interpret opacity results for air-drying alkyd and stoved alkyd/melamine systems. Finally, the pigment distribution derived from these results is compared with that measured experimentally.

Keywords

Raw materials:

binders (resins, etc)

alkyd resin
melamine alkyd resin

prime pigments and dyes

titanium dioxide

Processes and methods primarily associated with:

manufacturing or synthesis

flocculation
pigment dispersion

storage, protection or preservation

sedimentation

Properties, characteristics and conditions primarily associated with:

materials in general

light scattering
opacity
particle size

bulk coatings and allied products

pigment volume concentration

La floculation—sa mesure et son influence sur l'opacité de systèmes contenant des pigments de dioxyde de titane

Résumé

On discute quelques essais faciles pour déceler la floculation en peintures alkydes brillantes aux dioxyde de titane. On décrit et une technique plus évoluée, entraînant la diffusion de radiation infra rouge, pour mesurer la floculation, et l'investigation au moyen de cette technique d'une gamme de peintures.

Alors on établi un rapport entre l'opacité des peintures floculantes et la granulomètrie des pigments en feuils de peinture sec. On propose un modèle où l'on considère que le feuil est constitué des zones ayant des concentrations pigmentaires différentes. On utilise ce modèle pour interpréter le niveau d'opacité des systèmes alkydes sèchant à l'air ou alkydes/mélamines sèchant au four. Enfin on compare la répartition pigmentaire dérivée de ces résultats avec celle déterminée à l'aide des expériences.

Ausflockung—Ihre Messung und Auswirkung auf die Opaztät in Titandioxidhaltigen Pigmentsystemen

Zusammenfassung

Einige einfache Prüfungen zur Entdeckung der Ausflockung von Titanpigmenten in Alkydglanzemaillelacken werden besprochen. Ebenso wird eine elegantere Technik zur Messung der Ausflockung unter Benutzung der Streuung von Infrarotstrahlung beschrieben. Vielerlei Anstrichfarben werden unter Benutzung dieser Technik geprüft.

Die Opazität geflockter Anstrichfarben wird alsdann mit der Verteilung der Pigmentpartikel im getrockneten Anstrichfilm in Beziehung gesetzt. In Vorschlag gebracht wird ein Modell, in welchem der Lackfilm als aus Regionen verschiedener Pigmentkonzentrationen bestehend angesehen wird. Dieses Modell dient zur Interpretierung von Opazitätsresultaten für lufttrocknende Alkyd- und ofengetrocknete Alkyd/Melamin-Systeme. Schliesslich wird die von diesen Ergebnissen abgeleitete Pigmentverteilung mit der experimentell gemessenen verglichen.

Introduction

A flocculent system is one in which suspended solid particles combine to produce loosely bound clusters or flocculates. In the particular case of a white gloss alkyd paint, the flocculates consist of titanium dioxide pigment particles, and the phenomenon can be clearly demonstrated by using transmission electron micrographs of thin dried films of such paints (Figs. 1-3).

It is well known that the presence of flocculation has a considerable effect on the physical properties of a paint. Optical properties are invariably adversely affected since both the gloss and particularly the opacity depend on the pigment distribution in the paint. It is important to be able to detect the presence of flocculation in a paint system and to understand its effect on these important properties.

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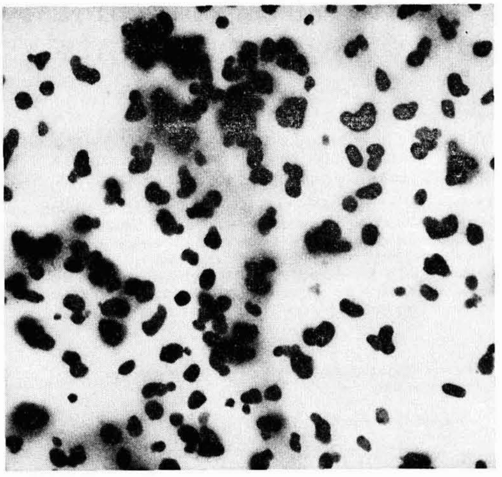

Fig. 1. Transmission electron micrograph of a thin film of an alkyd paint containing little flocculation

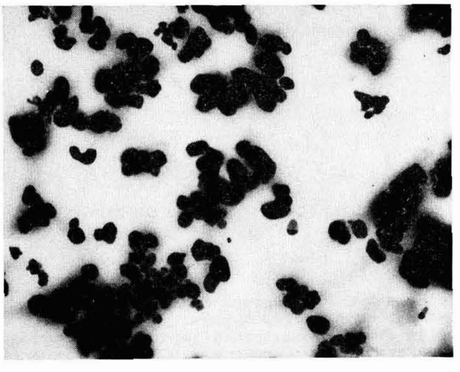

Fig. 2. Transmission electron micrograph of a thin film of an alkyd paint containing some flocculation

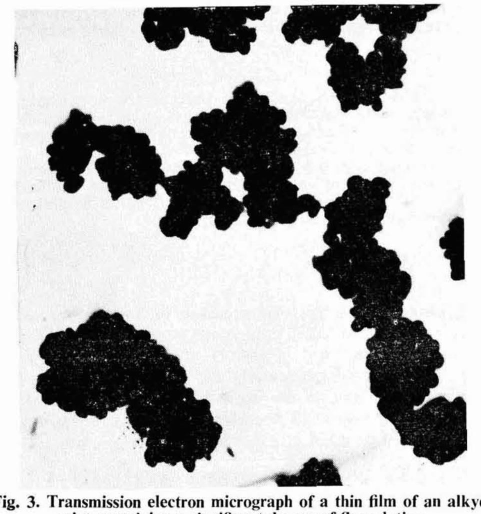

Fig. 3. Transmission electron micrograph of a thin film of an alkyd paint containing a significant degree of flocculation

Here, some simple ways of detecting flocculation in gloss alkyd paints, which do not require the use of expensive apparatus (e.g. electron microscope), are discussed briefly. However, they are insensitive, generally, to small variations in the degree of flocculation. For this reason a more sophisticated method based on infrared scattering has been developed and is discussed in detail.

Finally, the effect of flocculation on possibly the most important paint property, opacity, is examined in detail. A model is proposed which interprets the measured opacity of flocculent alkyd paints very well.

Detection of flocculation

Traditionally to detect flocculation, a paint is shaken in its container and the presence of a characteristic pattern on the walls of the container taken to indicate a flocculent paint. Conversely, the absence of a pattern indicates good dispersion. In reality, this test is very insensitive, a considerable degree of flocculation being required before any such pattern is formed.

Flocculation gives rise to a number of other physical phenomena and it is possible to utilise some of these to obtain more accurate information regarding the state of dispersion of a paint.

In order to examine several ways of detecting flocculation, six paints (designated *A* to *F*) were prepared, based on a long oil soya alkyd medium and pigmented with a general purpose rutile titanium dioxide pigment at a pigment volume concentration (PVC) of approximately 17.5 per cent. The millbase formulation is given in the Appendix. Flocculation was induced in the paints by including differing amounts of a particular additive in each paint. The degree of flocculation in these paints was known to depend on the amount of additive used. Each paint then differed only in the degree of flocculation, paint *A* being the best dispersed and paint *F* the most flocculent.

Sedimentation

Ref. 1

Generally, any large pigment flocculates present in a flocculent paint behave as single large particles and settle under gravity more quickly than the individual pigment particles in a well dispersed paint. The more flocculent the paint, the larger and more numerous are the pigment flocculates, and the greater is the rate of settling. In a typical gloss alkyd paint this is a slow process and, in order to obtain results reasonably quickly, it is necessary to dilute the paint with solvent to reduce the resistance to settling. In some instances the act of dilution may affect the state of dispersion. However, this is not common with alkyd gloss paints and in practice does not limit the usefulness of sedimentation techniques.

To illustrate briefly one particular sedimentation method which has been described in detail previously[1], samples of all six paints *A*-*F* were diluted with equal weights of white spirit and placed in cylindrical aluminium containers. The pigment concentration at various heights in the containers was measured by means of X-ray absorption, the greater the pigment concentration the greater being the absorption. Initially it was found that the absorption, and hence the pigment concentration, was constant with height. The paints were then allowed to stand for seven days and the measurements repeated. The results are shown graphically in Fig. 4.

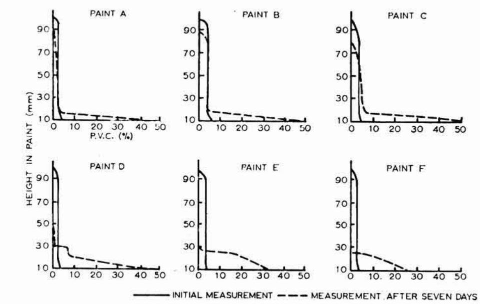

Fig. 4. Sedimentation

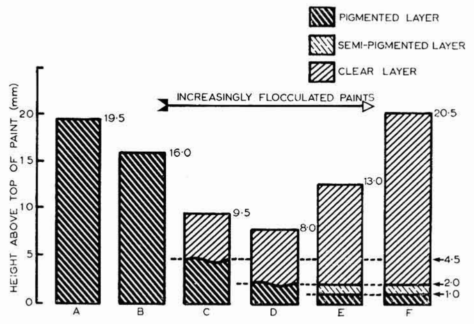

Fig. 5. Chromatography

The increase in pigment concentration at the bottom of the cylinders indicates the degree to which settlement has occurred, and the shape of the graph gives an indication of the nature of the settlement. The diagrams for paints *A*, *B* and *C* show a compact settlement, and indicate relatively good dispersions. Those for paints *D*, *E* and *F* show a more voluminous settlement, which is typical of more flocculent systems. Thus, the method can distinguish between dispersed and flocculated paints, but it appears to be relatively insensitive to minor changes except over a limited range, i.e. the changes which occur between paints *C* and *E*.

Chromatography

Refs. 2, 3

Differences in the degree of flocculation of paints of similar types can be assessed qualitatively by means of chromatography. The technique, described by Kresse[2], is based again on the fact that flocculates settle faster than well dispersed pigment particles and, consequently, there is less pigment at the surface of a flocculent paint after the paint has been allowed to stand for a time. If chromatography paper is then immersed in the paint, the nature of the migration of pigment and medium up the paper gives an indication of the pigment concentration at the surface and, hence of the state of dispersion.

In the method, strips of chromatography paper approximately 1cm by 20cm are cut and immersed in a (10 per cent by weight) slurry of silica gel in distilled water. The silica gel is incorporated to increase migration up the paper and prevent premature drying of the paint. The strips are dried in an oven at 100°C for ninety minutes and subsequently stored at 60°C in order to keep the silica gel activated. Samples of the diluted paints are then placed in small beakers in a desiccator and allowed to stand under vacuum. After thirty minutes the desiccator is opened and any bubbles on the surface removed by using a paper tissue. This prevents the formation of bubbles at the bottom of the strips which might otherwise affect migration of the paint. The strips of chromatography paper are then suspended vertically so that they are immersed about 5mm into the paint. The desiccator is again evacuated and, after sixteen hours, the strips removed and allowed to dry. The results for the paints *A-F* are shown diagramatically in Fig. 5 and they clearly demonstrate that the pigment migration decreases and the medium migration increases with increasing degrees of flocculation. The same paints were tested a number of times and, whilst the relative performances of the six paints were the same in every test, the heights of migration tended to vary from test to test.

The paints need not be diluted and this offers an advantage over the X-ray sedimentation technique. As Kresse indicates, other factors such as the presence of certain additives in the paints may also affect the results. However, the method has been found to be very useful for qualitative comparison.

The two ways of detecting flocculation in the wet paint discussed briefly above are by no means the only ones. There are a number of others most of which are based on sedimentation[3].

Lamp filament colour

Ref. 4

There are cases where the flocculation is associated with the paint film drying conditions. It is important in such cases to be able to assess the flocculation by examining the dried paint film. A simple means of doing this is by using the lamp filament colour technique[4].

The apparent colour of a tungsten lamp filament when viewed through a thin film of paint, gives an indication of the state of dispersion. The changes of colour due to changes in the ratios of scattered to transmitted wavebands are shown in Table 1. A red colour indicates good pigment dispersion; lilac, some flocculation; and blue or white, more flocculation.

Table 1

Appearance of filament colours

	Well dispersed ———→			Severely flocculated
Preferentially scattered light	Blue and green	Green, some blue, some red	Green and red	Infrared
Transmitted light	Red	Some blue, some red	Blue	White
Apparent colour of filament	Red	Lilac	Blue	White

In order to prepare sufficiently thin films, it is necessary to dilute the paints with equal weights of white spirit. A thin film of the paint is spun on to a glass panel and then dried at 60°C for twenty minutes. The colour of the filament of a tungsten lamp is then examined when viewed through the paint film.

The results for paints *A-F* are shown in Table 2.

Table 2
Filament colours for paints A-F

Paint	*A*	*B*	*C*	*D*	*E*	*F*
Filament colour	Red	Pale red	Red/lilac	Lilac	Blue	White

Again the test places the paints in the expected order, though the difference in colour between paints *A* and *B* is very slight, indicating some insensitivity at low levels of flocculation. In addition, paints as bad as, or worse than paint *F* would all show a white filament. However, the degree of flocculation in these cases would be so great as to be detected easily by visual examination.

Other factors which may affect the filament colour include film thickness, pigment concentration and the type of lamp used. Thus, when using this test it is important to keep these as constant as possible.

The filament test is a quick and a valuable means of examining flocculation in the dried paint film.

Measurement of flocculation

The methods described so far give an indication of the amount or degree of flocculation in a paint. They are quick qualitative tests for detecting the presence of flocculation and for comparing similar paints. It is, however, often necessary to be able to assess the degree of flocculation in paints more accurately, and a more sophisticated technique for doing this has been developed.

Infrared scattering technique

In common with the filament test, measurements are made on the dried paint film. The wavelength of the light preferentially scattered by a pigment particle depends upon, among other factors, the pigment particle size: generally, the larger the particle size the greater is the wavelength of the light that is preferentially scattered. To provide good opacity and whiteness, the particle size of titanium dioxide pigments is controlled to give maximum scattering of radiation in the centre of the visible region of the spectrum (i.e. green).

Here, as in the case of sedimentation, flocculates can be regarded as large particles in their own right and consequently will scatter long wavelength radiation (e.g. infrared radiation). The amount of scattered light is dependent on the size and number of flocculates; that is, on the degree of flocculation of the paint. This is the basis both of the filament test and of the infrared scattering technique that follows.

Simple illustration of the test

Paint films are applied to a substrate by means of shims and a doctor blade to give nominal wet film thicknesses of 75μm. After forty eight hours drying, the back scattering (relative to magnesium oxide) from the film is measured on a spectrophotometer (e.g. Beckman DK2A recording spectrophotometer) with a reflectance attachment.

Typical scans for films of paints *A-F* on glass panels over a range of wavelengths in the infrared region of the spectrum are shown in Fig. 6. At wavelengths above about 1 500nm the

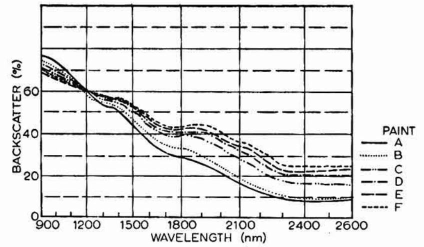

Fig. 6. Effect of flocculation on backscatter in the infrared

curves separate, those of the more flocculent paints showing more scattering. At approximately 2 300nm the curves tend to become almost horizontal and parallel to one another. In the test, the backscattering at 2 500nm can be used to compare the paints. The curves are well separated at this point and are nearly parallel. Moreover, at this wavelength, mono-disperse particles are unlikely to affect scattering to any great extent, the predominant effect being caused by the flocculates. At longer wavelengths, the detector on the spectrophotometer becomes insensitive.

The backscatter at 2 500nm for the six paints is given in Table 3.

Table 3
Backscatter for paints A-F at 2 500nm

Paint	Backscatter at 2 500nm (%)
A	7.4
B	8.8
C	16.3
D	20.4
E	22.5
F	24.6

In order to make measurements of this kind it is necessary to use a substrate which does not itself contribute to the measured value. It was for this reason that glass was chosen initially. However, as described below, to achieve more accurate results, it is necessary to measure dry film thicknesses and here polyester foil of film thickness 125μm has been found to be more useful.

There are a number of parameters (e.g. PVC, film thickness) on which the backscattering could be expected to depend and these are considered below.

Effect of film thickness on infrared scattering

A new series of paints (designated *1-6*) was prepared using the same formulation (17.5 per cent PVC) but with less additive. The most flocculent paint (paint *6*) was such that the pattern on the side of the can, as described above, was just detectable. Thus, the six paints were thought to cover the range of flocculation normally encountered in commercial alkyd gloss paints.

The paints were applied to the polyester foil using wire wound applicator bars to give nominal wet film thicknesses of 25, 36, 50, 60, 75, 100, 120, 175 and 200μm. The three thickest films were applied in two coats, the second coat superimposed a day after the first had been applied. The paints were allowed to dry and then a square was cut out of each of the drawdowns and the backscatter of radiation of wavelength 2 500nm measured on the spectrophotometer. The dry film thicknesses were found by stripping and weighing, and using a density calculated from the formulation.

The infrared scattering results are shown in Fig. 7 for a number of film thicknesses. Smooth curves have been drawn through the points for each paint and the absence of any scatter by the uncoated polyester sheeting justifies extrapolation of these through the origin. For film thicknesses less than 30μm there is a linear relationship between film thickness and amount of backscattered light. The greater the gradient, the more flocculated is the paint.

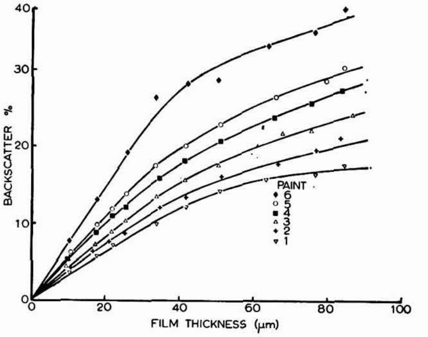

Fig. 7. Backscatter of incident light of wavelength 2 500nm

Effect of pigment volume concentration on the infrared scattering

A new series of paints was prepared at five different pigment volume concentrations in the range 10 to 20 per cent, and with five levels of flocculation at every PVC.

The paints were applied to polyester sheeting at nominal wet film thicknesses of 25, 36, 50 and 60μm using wire wound applicator bars. The backscatter at a wavelength of 2 500nm at each film thickness was measured as before.

The flocculation gradients are listed in Table 4 and are shown in Fig. 8.

Table 4

Gradients showing relationship between flocculation, infrared scattering and PVC

PVC	Gradients Increasing flocculation →				
10.0	0.33	0.36	0.42	0.49	0.55
12.5	0.34	0.39	0.44	0.55	0.66
15.0	0.32	0.37	0.44	0.58	0.72
17.5	0.36	0.40	0.49	0.63	0.81
20.0	0.34	0.40	0.49	0.68	0.87

The results show that the gradients obtained for well dispersed paints are unaffected by changes in PVC over the range 10 to 20 per cent. However, for flocculated paints, an increase in PVC results in an increase in the gradient; the more flocculent the paint, the greater the increase in the gradient.

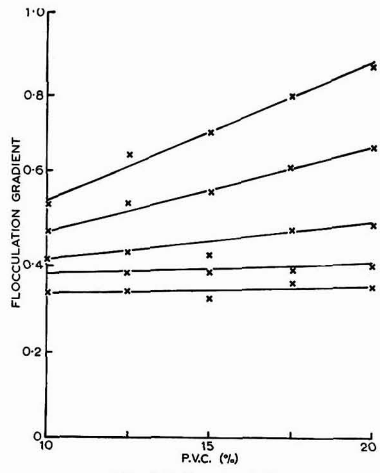

Fig. 8. Infrared technique

The absence of any pronounced effect for the well dispersed paints is at first sight surprising, since it might be expected that there would be an increase in scattering because of the presence of more pigment. However, the contribution to long wavelength scattering by well dispersed particles is small, and most scattering is as a result of a relatively small number of larger particles, aggregates and flocculates. The well dispersed particles and medium, thus become nearly "transparent" to radiation of this wavelength. Upon increasing the pigment concentration, the number of large particles present becomes greater, and the amount of scattering is increased. Conversely, an increase in the number of small, well dispersed particles increases the refractive index of the "transparent" surroundings and tends to reduce the scattering power of the aggregates. It appears that these two effects cancel out each other, and when the PVC of a flocculent paint is increased there is little corresponding increase in the refractive index of the "transparent" surroundings, because of the small number of well dispersed pigment particles. There follows then an increase in scattering with increased PVC.

The influence of aggregates on infrared scattering

Obviously, the presence of unmilled aggregates of pigment in the paint film will have some effect on the scattering of infrared radiation, and in order to assess their influence, five paints (17.5 per cent PVC) based on the same rutile pigment and long oil soya alkyd resin were prepared. These had identical formulations, but were ballmilled for different periods of time: 1, 2, 3, 5 and 7 hours.

Each paint was examined on a fineness of grind gauge. The paints were also applied to polyester foil, the backscatter at 2 500nm and film thicknesses measured and the gradients calculated as before.

The results are shown in Table 5, the first gauge reading is the main reading, whilst the second represents the size above which there are no "stragglers".

A paint with a main reading in excess of 12μm would normally be regarded in the paint industry as unacceptable. Thus, it can be seen that the presence of aggregates up to and above an acceptable level in paints has little corresponding effect on scattering.

Table 5

Fineness of grind gauge readings and flocculation gradients

Gauge reading (μm)	Gradient	Milling time (hours)
20–40	0.41	1
18–28	0.38	2
12–22	0.34	3
8–17	0.34	5
7–16	0.36	7

Effect on opacity

Refs. 5-9

The single most important consequence of flocculation is that it lowers the opacity of the paint. In order to illustrate the magnitude of the effect for the amount of flocculation discussed above, the opacities of paints *A-F* were measured.

Samples of the paints were applied to black and white opacity charts at three wet film thicknesses, nominally 50, 75 and 100μm, by means of wire wound applicator bars. After drying for forty-eight hours, the reflectances of the paint films for green light were measured using a Model V Colormaster.

Opacity may be expressed in a number of ways and one which is particularly suitable here is called "the efficiency of pigment utilisation". This is defined as the area which a given weight of pigment would cover in order to achieve a given contrast ratio. From chart weight measurements, the spreading rate was calculated for every film and using the measured values of contrast ratio, the spreading rate to give a contrast ratio of 90 per cent was found by interpolation. The efficiency of pigment utilisation was then calculated from that spreading rate. The results are shown in Table 6.

Table 6

Efficiencies of pigment utilisation

Paint	Utilisation efficiency ($m^2\ kg^{-1}$)
A	101.6
B	94.3
C	88.0
D	86.7
E	78.8
F	78.6

Clearly, the flocculation discussed above has a considerable effect on the opacity of paints *A-F*.

The flocculation in the paints was induced by an additive, which is used to modify the rheological characteristics of paints. This modification is achieved simply by flocculating the pigment, an effect which is not uncommon with a variety of other such additives widely used in the paint industry[5]. However, the state of dispersion and opacity of paints containing different commercial titanium dioxide pigments even without additives can also vary.

To illustrate this point a further series of 10 paints, all containing a different grade of titanium dioxide pigment, was prepared at a PVC of 17.5 per cent. The paints were examined by the infrared technique and their flocculation gradients calculated. In addition, the efficiency of pigment utilisation for each paint was measured, with corrections made to allow for the different concentrations of titanium dioxide in the different pigment grades (the result of different coating levels). The flocculation gradients and utilisation efficiencies are shown in Fig. 9.

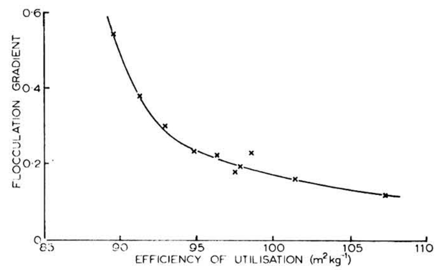

Fig. 9. Effect of flocculation on opacity

Despite the differences in the types of pigment used, there was a pronounced relationship between opacity, expressed as efficiency of utilisation, and the degree of flocculation as measured by the infrared technique. Whilst opacity differences may arise from other factors, such as crystal size and particle size distribution, the predominant factor is the extent to which the pigment is flocculated.

To examine in more detail the effect of flocculation on opacity, it is necessary to relate opacity to the individual scattering properties of the pigment particles. The value of the pigment utilisation discussed above is related directly to the scattering power of the pigment.

Scattering power of the pigment

In all the paints considered here, the scattering of visible radiation (opacity) is provided by the titanium dioxide pigment only. The scattering power of the pigment can be expressed as S/f (where the backscattering per unit volume of paint film is described here by the Kubelka-Munk backscattering coefficient S, and the pigment volume fraction f = PVC/100).

It is well known that the opacity per unit of pigment concentration decreases[6] as the PVC is increased. This is because the scattering power of the pigment decreases. The scattering efficiency E_f of the pigment in a paint film of pigment volume fraction f is defined as

$$E_f = (S/f)/S_0 \quad \text{.....(1)}$$

where

$$S_0 = (S/f)_{f\to 0} \quad \text{.....(2)}$$

The quantity S_0 is determined principally by the particle characteristics of the pigment and not by its state of dispersion in the paint film. However, the scattering efficiency E_f is dependent on the state of flocculation of the paint: the more flocculent the paint, the lower its opacity and the lower the scattering efficiency of the pigment.

The magnitude of the loss in scattering efficiency is related to the pigment particle distribution in the dried paint film.

Well dispersed paints

The form of the scattering efficiency E_f at different PVCs has been discussed fully for well dispersed systems[7]. To a good approximation the titanium dioxide pigment distribution in dried films of such systems can be characterised solely by the mean surface-to-surface distance between the pigment particles. The successful analysis of earlier results demonstrates this. It was found that the scattering efficiency at all but very small PVCs (<2 per cent) was dependent only on the ratio of the surface-to-surface distance c and the wavelength of incident light λ. The higher the PVC the smaller is the ratio c/λ and the greater is the loss in scattering by the pigment. The surface-to-surface distance c is related[7] to the PVC and the mean pigment particle size d by:

$$c = d\left[\sqrt[3]{\frac{0.49}{f}} - 1\right] \quad (3)$$

where 49 per cent is the experimentally determined critical PVC. The equation for the scattering efficiency is:

$$E_f = 1 - (1/f)\exp(-13.15\,c/\lambda - 1) \quad (4)$$

Equation 4 was derived using sound physical principles and with Equation 3 gave excellent agreement with experiment. Thus, both the well known loss in opacity per unit volume of pigment as the PVC is increased and also the relative advantage in opacity of large particle size pigments at high PVCs are very well described by Equations 3 and 4.

Flocculent paints

In films of paints which are flocculent, it is no longer valid to describe the titanium dioxide pigment distribution by a single mean surface-to-surface distance; there is, in fact, a wide distribution of surface-to-surface distances. The paint film of such a system can be conveniently described here as consisting of a distribution of PVCs throughout the film. The local surface-to-surface distance is related to the local PVC by Equation 3. The magnitude and frequency of occurrence of the higher PVC regions and of the lower PVC regions must be such that the mean PVC is equal to the nominal PVC. The low scattering efficiency of pigment particles in the former case is not fully compensated by the high scattering efficiency of the latter and the net effect is a loss in scattering and, therefore, in opacity. This effect can be described on a quantitative basis by using Equation 3 and an equation to describe the distribution of PVC regions.

Let the probability be $\varphi(f_i)$ that a local region of pigment volume fraction f_i will occur in a paint film of nominal pigment volume fraction f. Then from the definition of probability:

$$\sum_i \varphi(f_i) = 1 \quad (5)$$

and from the condition that the higher and lower PVC regions should be such that the mean PVC is equal to the nominal PVC, then:

$$\sum_i \varphi(f_i) f_i = f \quad (6)$$

If S_i is the backscattering coefficient for a region of pigment volume fraction f_i, then the overall backscattering coefficient of the paint film is given by:

$$S = \sum_i S_i\,\varphi(f_i) \quad (7)$$

Re-arranging

$$S = \Sigma\,\varphi(f_i)(S_i/f_i) f_i$$

or

$$S/f = S_0/f\,\Sigma\,\varphi(f_i) E_i f_i \quad (8)$$

Substituting Equation 8 in Equation 1 gives:

$$E_f = 1 - \frac{1}{f}\sum_i \varphi(f_i)\exp\left(-13.15\frac{c_i}{\lambda} - 1\right)$$

where c_i is the mean surface-to-surface distance in region of pigment volume fraction f_i. In the limit:

$$E_f = 1 - \frac{1}{f}\int \varphi(f')\exp\left(-13.15\frac{c(f')}{\lambda} - 1\right)df' \quad (9)$$

Equation 9 relates the scattering or opacity of a flocculent paint to the pigment particle distribution in the paint film. For the interpretation of the opacity of flocculent systems, the flocculates have been considered as high PVC regions. This is in contrast to the methods given above where the flocculates have been considered as behaving as large particles. The reason why the different interpretations can be used in the two cases is related to the wavelength of the incident light. Infrared light, because of its longer wavelength, is unable to resolve the detailed make up of the flocculate and consequently treats it as a homogenous particle. However, green light is of much smaller wavelength and can distinguish between the individual pigment particles in the flocculate.

There are two ways of examining experimentally the relation described by Equation 9.

1. The pigment distribution in a typical dried film of a paint can be measured and the calculated scattering efficiency compared with that measured experimentally for the paint.
2. The scattering efficiency can be measured and the derived pigment particle distribution compared with that measured experimentally.

However, pigment particle distributions are difficult to measure accurately and consequently method (2) is simpler for this study.

One of the problems in examining flocculent systems is that, because they are unstable systems, it is difficult to reproduce accurately a given degree of flocculation. The two systems considered here were chosen to minimise this problem, and to relate as far as possible to practical systems.

Experimental

The first system is an air-drying gloss paint based on the long oil soya alkyd used before. The degree of flocculation of a particular pigment X (a general purpose rutile grade with a coating consisting principally of silica and alumina), depends in this system on water content of the pigment. For water contents less than approximately 0.6 per cent of the weight of the pigment, the smaller the water content the more flocculent the paint (Fig. 10). Thus, by varying the water content, the degree of flocculation can be varied simply. In practice, this was achieved by drying the pigment at 110°C overnight and including the appropriate amount of water in the millbase during paint preparation to give moisture contents of zero, 0.1, 0.2 and 0.6 per cent by weight of pigment.

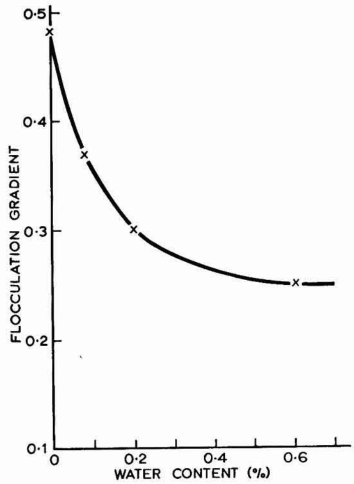

Fig. 10. Pigment *X* in the alkyd

The second paint considered is a stoved alkyd/melamine industrial finish. Here the degree of flocculation for pigment *X* and for a pigment *Y* depends on the alkyd to melamine ratio in the dried film. The measured flocculation gradients are shown in Fig. 11. Pigment *Y* is a rutile titanium pigment with a predominantly alumina coating. Varying the alkyd/melamine ratios, therefore, offers another simple means of varying the degree of flocculation; the alkyd to melamine ratios considered were 2 to 1, 3 to 1, and 6 to 1.

The paints were made up to the formulations given in the Appendix. The PVCs were restricted to the range 0 to

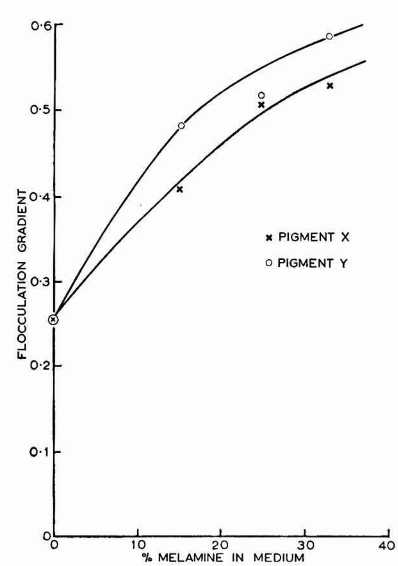

Fig. 11. Pigments *X* and *Y* in the alkyd/melamines

30 per cent. A number of films of each were prepared by spinning on to 10 × 10cm (4 × 4in) glass panels in the case of the air-drying alkyds, and by drawdowns with wire wound applicators on tinplate in the case of the stoved systems. After a drying period of two days under controlled temperature and humidity for the air-drying alkyds and of 30 minutes at 150°C for the stoved systems, the paint film thicknesses were measured by an X-ray fluorescence technique described elsewhere[8]. Reflectances were measured on the Model V Colormaster with both the green and blue filters. To minimise surface reflectances, the air-dried films were measured over a black background, glycerol being used to obtain a good optical contact between the glass panel and a black tile.

The scattering per unit volume of the paints was derived using a modified Kubelka-Munk method. The success of this

Table 7

Scattering efficiencies for blue and green incident light; pigment X in the simple alkyd paints

f	Water content							
	0.0%		0.1%		0.2%		0.6%	
	Green	Blue	Green	Blue	Green	Blue	Green	Blue
0.025	0.841	0.894	0.855	0.890	0.877	0.880	0.973	0.982
0.050	0.800	0.829	0.841	0.857	0.866 0.909	0.863	0.936	0.935
0.075	0.766	0.780	0.807	0.824	0.848	0.843	0.927	0.955
0.10	0.718	—	0.780	0.788	0.832	0.827	0.898	0.922
0.15	0.643 0.705	0.720	0.727	0.765	0.716 0.766	0.816	0.836	0.898 0.871
0.20	—	0.690 0.676	—	0.718	0.739	0.745	0.777	0.876
0.25	0.539	0.614	0.591	0.641	0.632	0.706	0.689	0.788
0.30	0.498	0.565	0.520	0.590	0.534	0.625	0.582	0.696

approach has been demonstrated previously[7, 9].

The weight-mean particle diameters of the pigments were measured after equivalent milling in a well dispersing alkyd medium by a novel centrifuge technique (patents pending). The method will be the subject of a future publication.

Results

The scattering powers of the pigments in the paints for PVCs in the range 0 to 30 per cent were determined. Values of the scattering power at infinite dilution S_0 were found initially by extrapolating the results to zero PVC. Slight modifications to some of the values were made after a crude form of the ultimate scattering efficiency equation had been fitted. However, none of these modifications was outside the limits of experimental error of the scattering power determination. This procedure was necessary, since insufficient values of the scattering power were obtained at very low PVCs to allow accurate extrapolation.

The scattering efficiencies are listed in Tables 7, 8 and 9 and the results of the particle size determinations are shown in Table 10.

Table 8

Scattering efficiencies for blue and green incident light; pigment X in alkyd/melamine systems

f	Alkyd/melamine ratio					
	2/1		3/1		6/1	
	Green	Blue	Green	Blue	Green	Blue
0.05	0.866	0.898	0.905	0.941	0.955	0.980
0.075	0.827	0.902	0.923	0.961	0.952	0.933
0.10	0.814	0.833	0.864	0.871	0.909	0.914
0.15	0.686	0.722	0.823	0.849	0.895	0.922
0.20	0.616	0.710	0.723	0.800	0.798	0.884
0.275	0.484	0.594	0.555	0.680	0.614	0.716
0.30	0.455	0.518	0.518	0.643	0.550	0.692

Table 9

Scattering efficiencies for blue and green incident light; pigment Y in alkyd/melamine systems

f	Alkyd/melamine ratio					
	2/1		3/1		6/1	
	Green	Blue	Green	Blue	Green	Blue
0.025	0.974	1.000	1.037	1.050	1.004	1.007
0.05	0.913	0.939	0.948	0.982	1.000	1.048
0.10	0.807	0.834	0.837	0.850	0.857	0.891
0.15	0.625	0.711	0.676	0.705	0.778	0.830
0.222	0.507	0.543	0.552	0.634	0.633	0.750
0.275	0.437	0.471	0.496	0.527	0.522	0.563
0.300	0.415	0.448	0.441	0.539	0.448	0.555

Table 10

Pigment particle diameters

Pigment	Diameter (μm)
X	0.287
Y	0.275

Analysis of results

Refs. 10, 7

The pigment distribution in the film cannot be derived directly from the scattering efficiency results. A form for the distribution function φ must first be assumed and inserted in Equation 9. The scattering efficiency is then calculated and compared with experiment. If a realistic function is chosen, good agreement should result.

A point to consider when choosing a form for the distribution function concerns the limits of integration. Here, PVCs are physically restricted to within the range 0 to 49 per cent.

The distribution function. By analogy with a number of physical phenomena (e.g. titanium pigment crystal size[10]), a log normal function is considered as being potentially suitable to describe the distribution of PVCs in the film. In addition, the restricted range of PVCs can be included in the function, if the variable is $f(0.49 - f)$ and not simply f. In fact, it is shown below that such a function fits the experimental results very well and gives a realistic description of the pigment size distribution in the film.

Let the normalised pigment volume fraction

$$p' = f'/0.49 \quad \ldots\ldots(10)$$

$$\text{Then } \varphi(p') = \frac{1}{p'(1-p')} \frac{1}{B\sqrt{\pi}} \exp\left[\frac{-(u-a)^2}{2B^2}\right] \ldots(11)$$

$$\text{where} \quad u = -\ln(1/p' - 1) \quad \ldots\ldots(12)$$

$$\text{and} \quad a = -\ln(1/P_2 - 1) \quad \ldots\ldots(13)$$

P_2 is the normalised mean function pigment volume fraction and B is the distribution width parameter. The quantity B is the logarithm of the geometrical standard deviation of the normalised PVC distribution. Simply, it defines the extent of the PVC variation in the film. In addition, $\varphi(p') \rightarrow 0$ as $f \rightarrow 0$ irrespective of the value of B.

Equation 11 must and does satisfy the conditions of Equations 5 and 6 above.

Values for the width parameter. For every experimentally determined scattering efficiency given in Tables 7-9, the value of width B is found such that the calculated scattering efficiency from Equations 9 and 11 is in exact agreement. The values of B found in this way are shown in Figs. 12-14 for the systems studied here. The values of wavelength used were the mean values *in vacuo* for the blue and green filters of the Colormaster (i.e. 0.55μm for the green, and for blue 0.45μm). Although these are not the wavelengths in the alkyd medium, the ratio of the former to the latter is the refractive index of the medium and, as previously explained[7], is in the factor 13.15 in Equation 4.

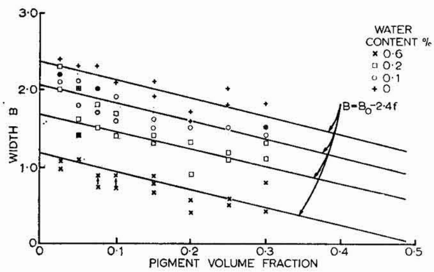

Fig. 12. Values of the width parameter; pigment X in the alkyd

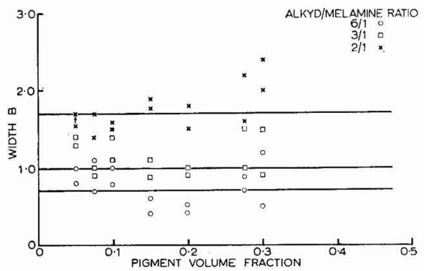

Fig. 13. Values of the width parameter; pigment X in the alkyd/melamines

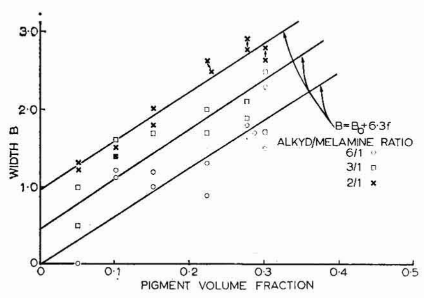

Fig. 14. Values of the width parameter; pigment Y in the alkyd/melamines

To a good approximation the same values of B are found for blue and green incident light for a particular paint at a given PVC. This must be so if Equation 11 is to be a good description of the pigment distribution. In all cases B is approximately linear with PVC. Again this simple relationship is taken as justification for Equation 11.

For pigment X in the air-drying alkyd, a good fit to the results is given by:

$$B = B_0 - 2.4f \quad \text{.....................(14)}$$

where B_0 is defined as the flocculation constant.

Values for B_0 are shown in Table 11 and the values of B for a 17 per cent PVC paint in Fig. 15.

For pigment X in the stoved alkyds there is no PVC dependence for B and

$$B = B_0 \quad \text{.............................(15)}$$

For pigment Y in the stoved alkyds

$$B = B_0 + 6.3f \quad \text{.....................(16)}$$

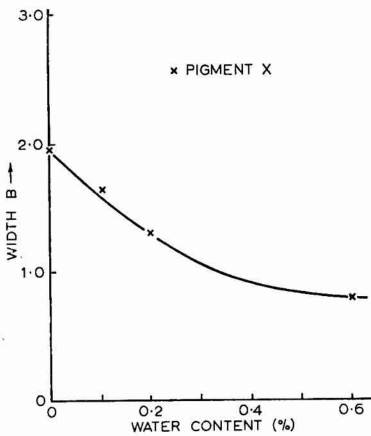

Fig. 15. Values of the width parameter for a 17 per cent PVC alkyd paint

Values of B_0 are shown in Table 12 and values of B for a 17 per cent PVC paint are shown in Fig. 16.

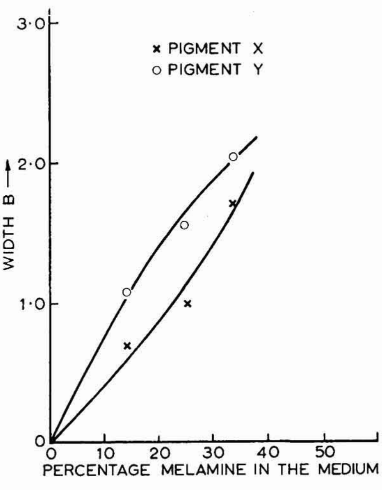

Fig. 16. Values of the width parameter for a 17 per cent PVC alkyd/melamine paint

Table 11

Values of the flocculation constant for the simple alkyd paints

Water content (%)	B_0
0.6	1.2
0.2	1.6
0.1	2.1
0.0	2.4

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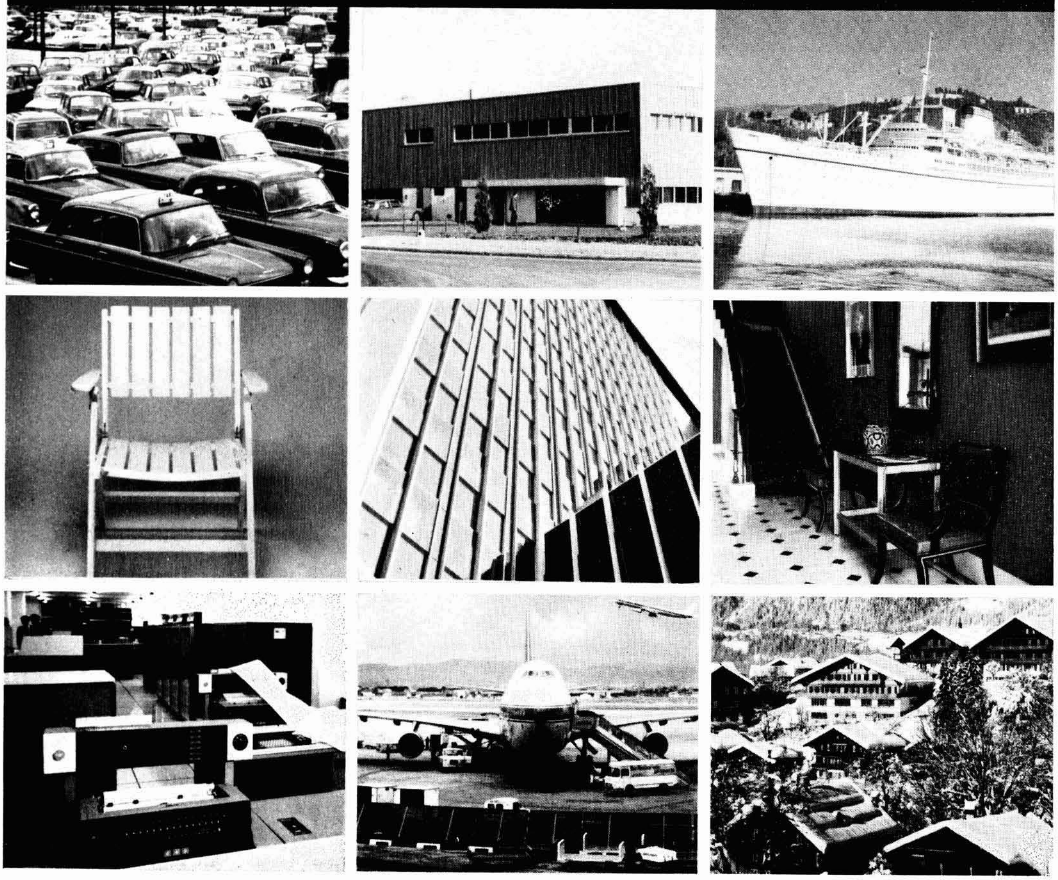

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Table 12

Values of the flocculation constant for the stoved alkyd paints

Alkyd/melamine	Pigment X B_0	Pigment Y B_0
2/1	1.7	1.0
3/1	1.0	0.5
6/1	0.7	0.0

Comparison with experiment

Scattering efficiencies. The values of B_0 given above and the Equations 9, 11, and 14-16 have been used to fit the experimental results (Figs. 17-22). The agreement between theory and experiment is good, considering the errors involved in determining the scattering efficiencies of unstable systems. In addition, scattering efficiencies for the two extremes of flocculation are shown in the PVC range considered.

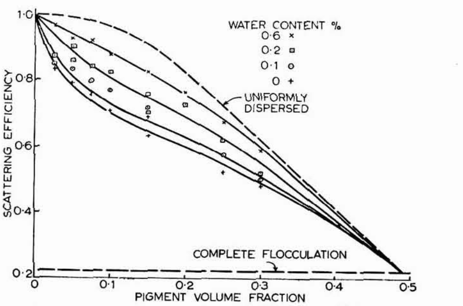


Fig. 17. Scattering efficiencies for green incident light; pigment X in the alkyd

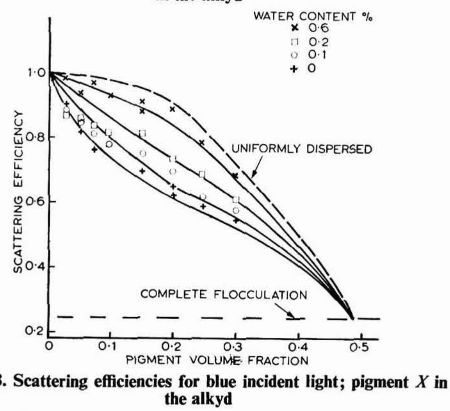


Fig. 18. Scattering efficiencies for blue incident light; pigment X in the alkyd

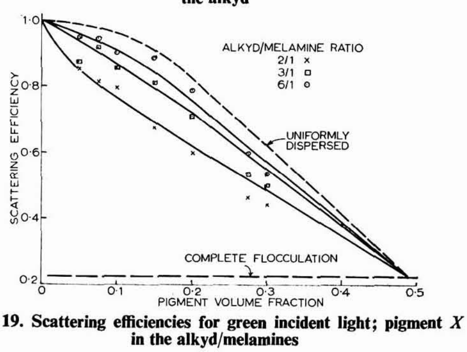


Fig. 19. Scattering efficiencies for green incident light; pigment X in the alkyd/melamines

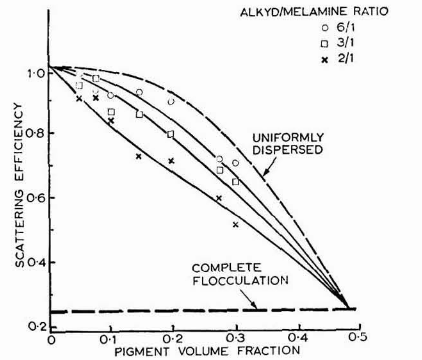


Fig. 20. Scattering efficiencies for blue incident light; pigment X in the alkyd/melamines

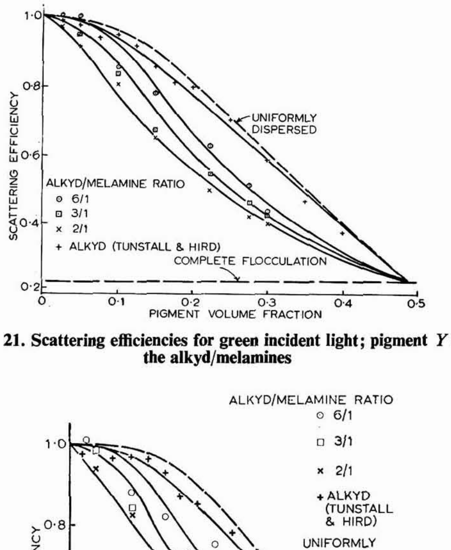


Fig. 21. Scattering efficiencies for green incident light; pigment Y in the alkyd/melamines

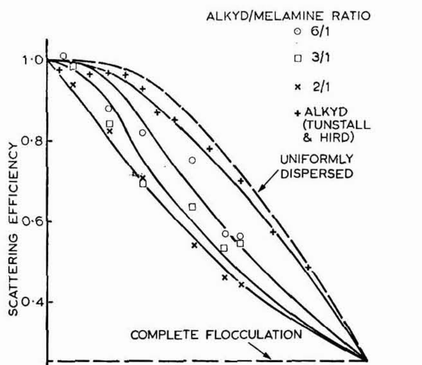


Fig. 22. Scattering efficiencies for blue incident light; pigment Y in the alkyd/melamines

In the case of complete flocculation, all the pigment at every nominal PVC is found within regions at the critical level of PVC and the scattering efficiency of the pigment is equal to that value for a film at the critical PVC. The maximum scattering efficiency possible at any PVC occurs for a film in which the pigment is uniformly dispersed. The pigment particles can be considered as being sited on a hexagonal close packed lattice. This corresponds very approximately to the cases considered previously[7] of well dispersed alkyds. The earlier results were analysed by assuming $B = 0$. In Figs. 21 and 22 for these, it has been assumed that $B = 0.5$, independent of PVC. There is little difference between the two cases.

Flocculation gradient. The width B and the flocculation gradient are both measures of the degree of flocculation. The relation between them at 17 per cent PVC for the systems considered above is shown in Fig. 23. To a good approximation, the alkyd/melamine results fall on the same curve for pigment X and pigment Y. A different relation is evident for the simple alkyd systems and possibly can be attributed to a different type of flocculation.

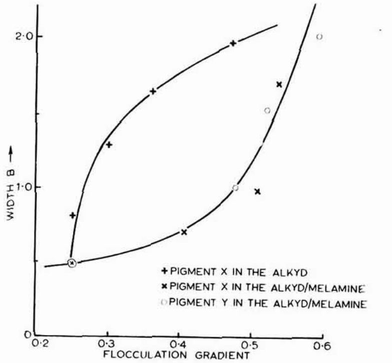


Fig. 23. Comparison of the alkyd and alkyd/melamine paints

Pigment distributions. As stated previously it is extremely difficult to measure pigment particle distributions in paint films. This has been attempted using a transmission electron micrograph of a thin film. Only the first near neighbour distance of each pigment particle was measured. The paints considered were at 14 per cent PVC and consisted of pigment X in the soya alkyd and a pigment similar to Y, but with a larger particle size, in the same alkyd. The results are shown in Fig. 24 and the most probable surface-to-surface distances for the two pigments are given in Table 13. They are displaced as predicted. The quantities measured are, in fact, projected distances from a two dimensional print of a three dimensional film. A relation between real distance b and projected distance b' is given by[11]:

$$b = (4/\pi)\, b' \qquad \ldots\ldots\ldots\ldots\ldots\ldots (17)$$

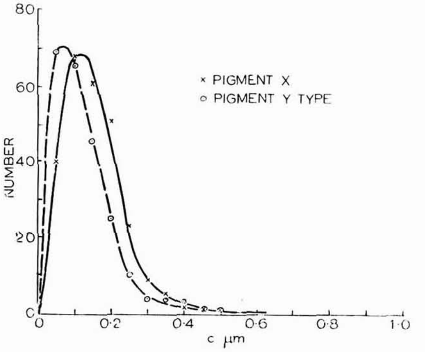


Fig. 24. Distribution of surface-to-surface distances

This assumes that the length b is randomly orientated. Although in this case there is a distribution of distances and not a single distance (which is required for Equation 17 to be strictly valid), to a good approximation this equation can be used to correct the most probable surface-to-surface distance.

The most probable surface-to-surface distances derived from the scattering results are in excellent agreement with those found by making the correction.

Table 13
Comparison of surface-to-surface distances

Method of measurement	Surface-to-surface distance (μm) Pigment X	Pigment Y
From opacity measurements	0.120	0.155
Projected values determined by counting	0.096	0.125
Calculated using Equation 17	0.120	0.160

Simple interpretation

The distribution function φ (p) can be transformed into a function depending on the near neighbour surface-to-surface distance between particles by using Equation 3. The near neighbour surface-to-surface distributions are shown in Fig. 25 for pigment Y in the stoved alkyds at

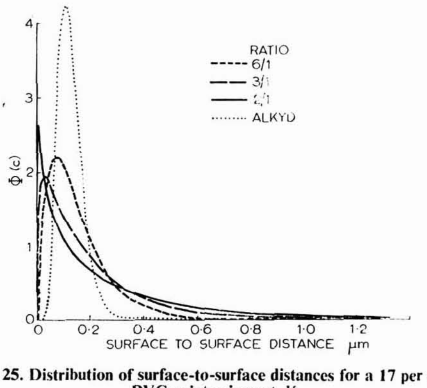
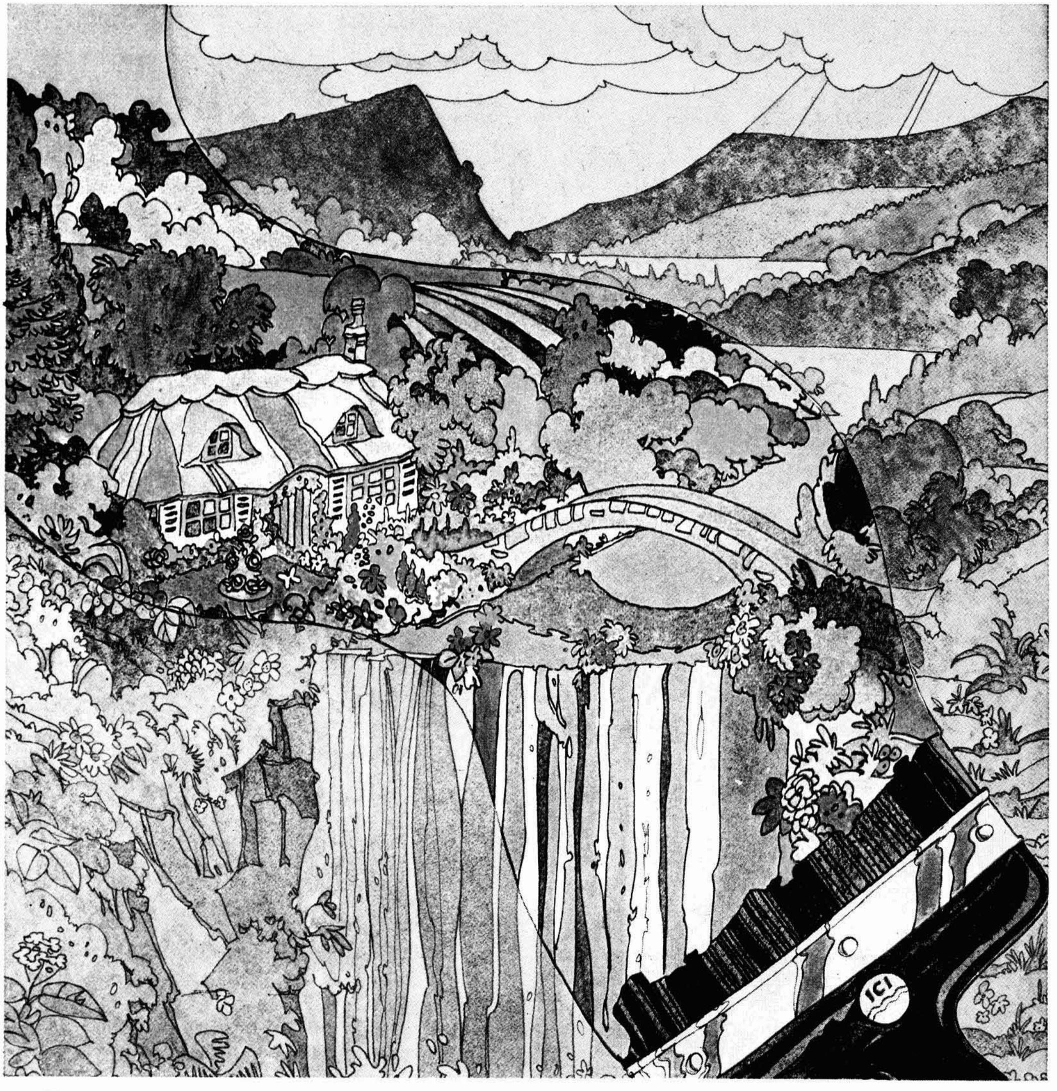


Fig. 25. Distribution of surface-to-surface distances for a 17 per cent PVC paint; pigment Y

17 per cent PVC. It can be seen that the most probable surface-to-surface distance, and also the mean surface-to-surface distance, decrease with increasing degree of flocculation. This demonstrates the increased interference due to particle crowding in flocculent paints and leads to the simple interpretation of such paints as being at an effectively higher PVC than the nominal PVC[12]. However, such an interpretation is over-simplified and is of little use when considering the optical properties of more complex systems, for example, of glossy emulsion paints.

Conclusions

The three methods, sedimentation, chromatography and lamp filament colour, are simple ways of detecting the presence of flocculation in gloss alkyd paints. A more accurate com-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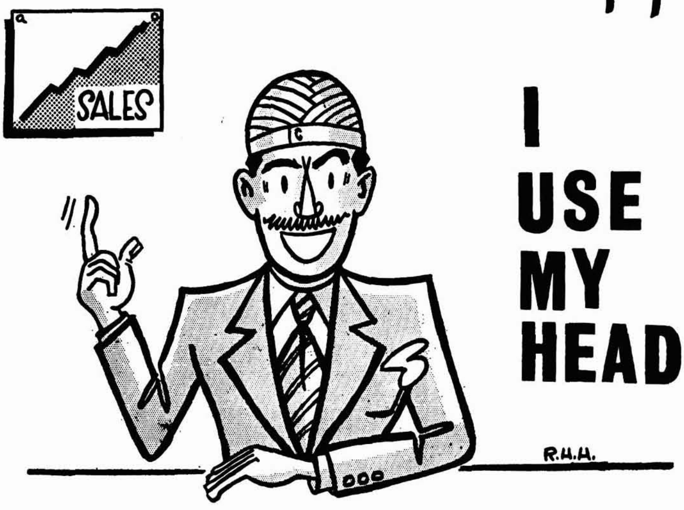

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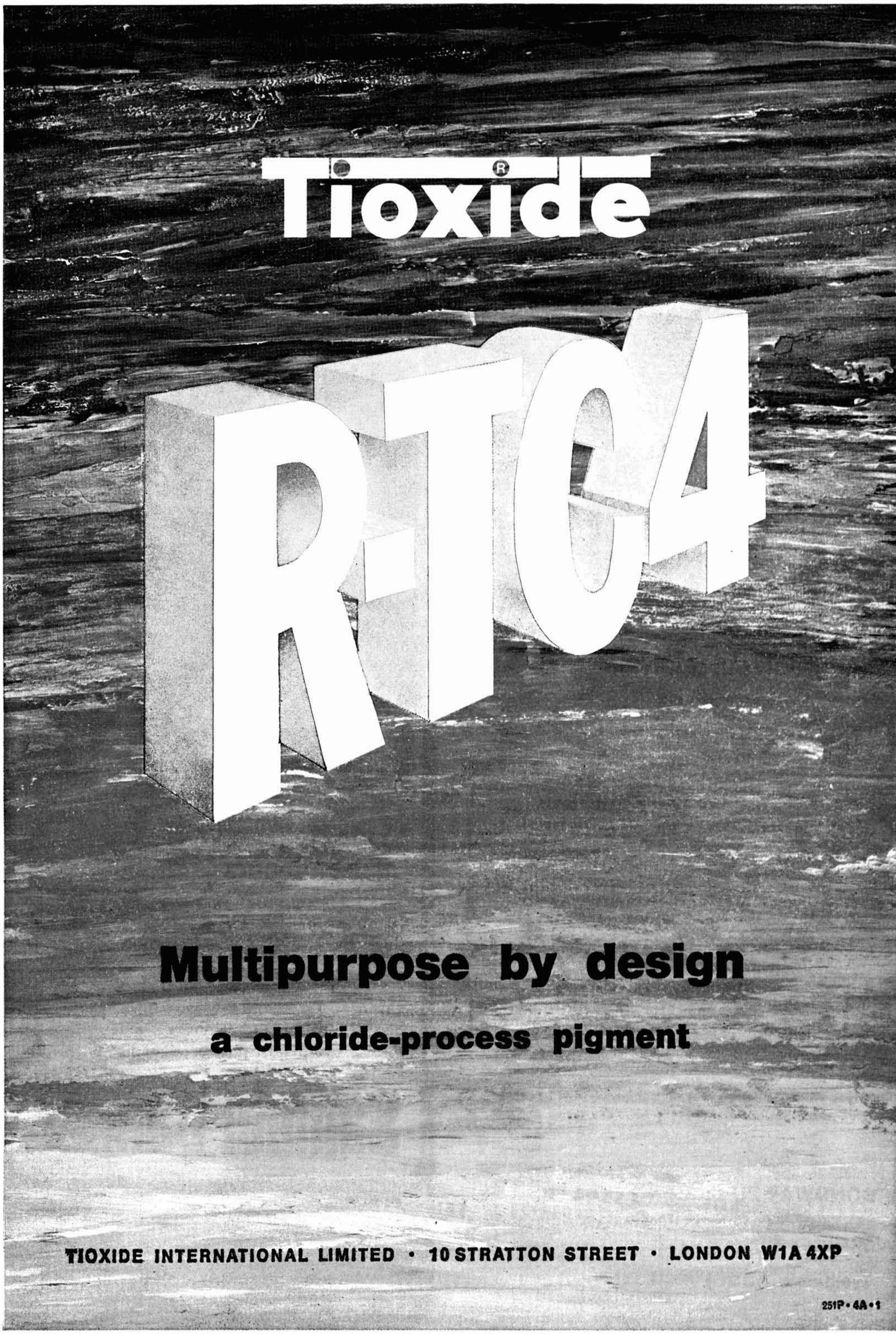
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parison of the degree of flocculation in gloss alkyd paints can be made using the infrared scattering technique discussed in detail above.

The detrimental effect of flocculation on the opacity of these paints can be very well explained by using a model in which the dried film of a flocculent paint is assumed to consist of regions of higher and lower PVCs than the nominal PVC. The loss in scattering by titanium dioxide pigment particles, due to the proximity of the neighbouring particles in the higher PVC regions, is greater than the gain in scattering in the lower PVC regions, and the overall effect is a reduction in the opacity.

Acknowledgments

The authors are grateful to the Directors of Tioxide International Limited for permission to publish this paper and to their colleagues in Central Laboratories for helpful discussions.

[*Received 17 January 1975*

Appendix

Millbase formulation

Air-drying alkyd paints

Pigment 45g

Seventy per cent alkyd resin solution 13g

High flash white spirit 20g

Eight mm ballotini 130g

Milled for 16 hours in a 0.213 litre (3/8 Imperial pint) jar on typical laboratory rollers.

After milling, the millbases were let down to a known PVC with 70 per cent resin solution.

In the paints which were deliberately flocculated, the additive was included in the millbase.

Stoved alkyd/melamine paints

Pigment 369g

Fifteen per cent alkyd in xylene butanol 122g

Eight mm ballotini 750g

Milled for 16 hours in a 1.18 litre jar on typical laboratory rollers.

A further 92g of 60 per cent alkyd solution added to stabilise the millbase. The stabilised millbase was milled for another hour. The millbases were then let down to a known PVC and alkyd to melamine ratio.

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Discussion at Scarborough Conference

Mr L. J. Williamson referred to the relationship between gloss of a film and degree of flocculation. Data given by Mr Balfour during the lecture indicated a maximum value for gloss when a small degree of flocculation existed in the paint. Work being carried out by the speaker with more viscous systems had given similar results. A plot of shear rate versus shear stress suggested that the phenomenon might be related to the rheological properties of the system. Mr Williamson asked whether the author had examined the effect of degree of flocculation on the rheological properties of his paints.

Mr Balfour said that they had made some preliminary investigations in an attempt to relate rheological behaviour with the degree of flocculation, but had met with little success. The paints used were all typical air-drying gloss paints at a viscosity of about 5 poise and small degrees of flocculation did not have a marked effect on the rheological properties of the paints.

Dr K. M. Oesterle pointed out that all the calculations in the paper were based on pigment volume concentration, and he asked if it would not be better to transform these to give figures on the basis of some value representing the active surface area of the pigment. This subject had been raised at the 1974 FATIPEC Congress in Garmisch Partenkirchen and it was the speaker's opinion that all the reactions of pigments in paints, including wetting and the degree of flocculation, depended on the surface area of the pigment rather than its volume.

Mr Balfour thought that he was adequately describing what happened in a flocculant system by using a model based on pigment volume concentration. The authors were not attempting to explain the causes or likely causes of flocculation; if this were the case, then he agreed that Dr Oesterle's approach would be more satisfactory. The model used in the paper, however, was merely used to show what happened in a physical sense.

Mr A. N. McKelvie said that if the highly flocculant systems did provide a random distribution of differing PVCs throughout the dry film, this might provide yet another clue why the "same paint" often performed differently under differing practical conditions. The degree of flocculation, for example, might depend on the method of thinning. It would be interesting to compare the durability characteristics of the same paint flocculated to differing degrees.

Mr Balfour replied that out of interest they had made a brief assessment of the effect of flocculation on the durability performance of alkyd gloss paints in terms of weight loss and loss of gloss. There were indications that as the flocculation increased so did the weight loss and rate of loss of gloss, but only up to a point—say, during the first 200 hours in a Marr weatherometer—but beyond this time the flocculation had no effect on either the weight loss or the rate of loss of gloss. Again this would suggest that there was a greater "clear layer" in a flocculant system.

Mr Williamson said that he thought the lecturers were to be complimented on the range of tests they had employed to detect flocculation. Mr Williamson considered that it might not be too difficult to find a set of conditions which would allow flocculation to be rapidly determined by the Joyce Loebl disc centrifuge. By means of the photo-sedimentation attachment, a pen trace could be obtained which might be useful as a "finger print" technique for detecting small changes. He wondered whether the lecturers had found such a set of conditions.

Mr Balfour said they had not.

J. Oil Col. Chem. Assoc. 1975, 58, 345-353

Why did it fail?*

By A. N. McKelvie and A. F. Sherwood

Paint Research Association, Teddington, Middlesex TW11 8LD

Summary

Modern paints can be formulated for high durability, low permeability to water and resistance to destructive agents but in practice too often fail to achieve their full potential of long term film integrity or protection of the substrate. The reasons for failure are analysed with attention to specific cases which have arisen in building, heavy construction and marine application.

Recommendations are made for the avoidance of premature failure by improvements in design, formulation for higher application tolerance, programming of construction and protection and better control of application.

Keywords

Types and classes of structures or surfaces to be coated

wood
masonry
steel

Processes and methods primarily associated with analysis, measurement or testing

inspection
testing

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

exterior durability

Specifications, standards and regulations

specification

Pourquoi s'altère-t-elle?

Résumé

On peut formuler les peintures modernes qui possèdent une durabilité élevée, une faible perméabilité à l'eau, et une bonne résistance aux agents nuisibles, mais très souvent dans la pratique elles ne mettent pas en évidence leurs possibilités maximales à l'égard de la solidité à long terme de feuil ou de la protection accordée au support. On analyse les raisons pour ces défaillances en faisant appel aux exemples spécifiques qui se sont passés aux industries de bâtiment, de génie civile et de construction navale.

On propose des recommandations pour éviter les altérations prématurées par l'amélioration de la conception, par l'emploi des formules donnant une tolérance plus large à l'égard des caractéristiques d'application et de protection, et par le contrôle plus efficace des procédés d'application.

Warum Mangelhaft?

Zusammenfassung

Moderne Lacke können für Dauerhaftigkeit, geringe Wasserdurchlässigkeit und Widerstandsfähigkeit gegen zerstörende Agenzien entwickelt werden aber weisen nur zu oft nicht genügend die zu erwartende, langanhaltende Lebensdauer als Film auf oder gewähren nicht genügend Schutz des Substrates. Die Gründe für Schäden werden unter Beachtung spezieller im Baugewerbe, bei Massenkonstruktionen und im Schiffbau vorgekommener Falle analysiert.

Vorschläge zur Vermeidung vorzeitiger Zerstärung durch verbesserten Entwurf, durch Vorschriften, welche beim Auftragen weiteren Spielraum geben, durch Planung von Konstruktion und durch besseren Schutz und schärfere Kontrolle während der Anwendung, werden gemacht.

Introduction

The following considerations are based largely on the experience of one of the authors (A. N. McKelvie) in detailed observations of preparation and painting practices in a major shipyard, and of the other (A. F. Sherwood) in site observation of joinery protection problems. The authors have also drawn liberally on the records of many consultancies and the results of "trouble shooting" enquiries handled by the Paint Research Association (PRA) in recent years.

The performance potential of paint has improved remarkably in the post-war era but, unhappily, there is little sign of reduction in the incidence of severely premature failure. Paint scores many successes, but the occasional failures continue and yearly become more expensive.

When discussing this subject, it must be appreciated that a very one-sided account of the performance of paint is presented—only the casualties are presented, whereas for every casualty which occurs in practice, very many satisfactory performances are achieved. It is by a study of these casualties, however, that weak points in the painting process can be identified and steps taken to eliminate them.

At first sight it might be considered that conditions encountered in the steel construction and building industries were too disparate for the performance of their respective paint systems to be considered in a single paper. On consideration, however, it will be appreciated that many common factors exist.

In both industries, a high proportion of the paint systems are applied under site conditions and hence are subject to the hazards of the weather and site conditions. For both, painting is a labour intensive operation and, apart from being costly, is subject to the quality of the labour. In both again, the painters are frequently expected to operate whilst other and often dirty operations are being carried out. It is not surprising that, for both industries, there is a history of a

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significant proportion of the first-finish systems failing to achieve their potential lives.

The purpose of this paper is not to lay down basic principles involved—many of these are contained in British Standard Codes of Practice CP231 and CP2008 (under revision)—but rather to highlight a few of the initial causes of the premature failure of protective coating systems.

The steel construction industry

Refs. 1, 2

Investigation of the failures of protective coatings used in the steel construction industry and in the marine section, in particular, reveals a serious lack of appreciation of the basic principles involved in protection. On the side of the contractor, this manifests itself as an unwillingness to ensure that the stages involved in the efficient application of a protective system are carried out properly and also in a failure to provide proper facilities for the process. With the design engineer, the fault is so often due to corrosion hazards built in during the design stage. There is no doubt that many corrosion problems could have been solved more readily on the drawing board than by use of the paint pot.

Previously reported work[1, 2] by one of the authors highlighted the importance not only of blast cleaning steel surfaces prior to application of the protective system, but also of avoiding serious rusting of the steel prior to cleaning. This is because rust-producing contaminants are more difficult to remove completely than mill scale and the presence of residual traces of these contaminants is not readily seen.

The fresh metal surface exposed by the blast cleaning process must be seen to remain clean before being protected by a suitable primer.

Problems arising from the use of blast primers

Because of welding requirements, the accepted procedure is to protect blast cleaned steel with a so-called "blast primer" during the fabrication stage. Unfortunately, what is too often forgotten is the limited life that can be expected from a protective film only 15-25 micrometres thick and the necessity to repair damage caused during the course of fabrication. Lack of attention to these points will inevitably induce early failure of the complete protective system applied directly to a degraded blast primer coating.

Local heating of steel during fabrication can completely destroy the primer vehicle and fuse the remains to the steel surface. It is not sufficient just to wire brush the damaged areas and recoat with blast primer, as rust break-through will soon occur if this is done. The damaged surfaces must be blast cleaned back to white metal before re-priming if early failure is to be avoided.

More serious forms of damage occur when welding or heat forming steel, as mill scale (bloom) is then re-formed; unless this mill scale is removed by blast cleaning back to white metal, premature failure of any further protective system can be expected. It is not uncommon for steel, during construction, to be protected only with blast primer and to collect water in cavities or interior spaces and remain "ponded" for several weeks. Such submerged areas are almost certain to exhibit early breakdown of the complete finishing system if they are not cleaned back to white metal and re-primed. A design for adequate drainage in the structure (and sometimes temporary drainage) goes a long way to solving this problem.

Blast primers are normally formulated to dry very quickly in order to meet the handling problems of automatic blast cleaning plants. Occasions do arise, however, when it is necessary to blast clean after fabrication in the open and to apply a holding coat of the blast-primer type. It is not unknown for normal quick drying formulations, used in such circumstances, to give a dry powdery surface which, if not detected (and this can easily happen when spraying the flank of a box girder or side of a ship), will cause premature failure of the subsequent protective system because of poor adhesion.

There is no doubt that in the protection of steel, the blast primer is often the weakest link in the protective system. More attention should be given to improving application properties and, particularly, the flow properties at the high spots of the blast profile. If it is necessary to limit the dry film thickness to 15-25 micrometres (average 20μm) then a minimum of 15μm should be obligatory. Three factors are very important:

1. Ensure a small blast profile—this means using fine grades of grit for blast cleaning.
2. Build into the formulation controlled flow to give an even film thickness over an irregular surface.
3. Apply by skilled operators or use foolproof automatic application equipment.

As a longer term objective, however, the development of blast primers which would not interfere with welding requirements at film thicknesses of 35-50μm is a worthwhile target.

Protective systems for steel

Because of the particular problems associated with blast primers they have been discussed separately although when used they are obviously a component part of the protective system and must be compatible with it. Organic protective systems normally consisting of inhibitive primer, undercoat and finish are simply classified as:

1. Conventional types, based on oleoresinous, alkyd, epoxy ester, urethane oil or similar as the binder or resinous component of the paints.
2. Chemical resistant types broadly classed as:
   (a) One-pack system—mainly plasticised chlorinated rubbers and vinyl resins.
   (b) Two-pack systems—mainly two-pack epoxy and polyurethane resins.

Problems with conventional systems

These are considered much easier to handle in practice and, therefore, should not give rise to many problems, nevertheless they do sometimes fail prematurely, especially if the severity of the environment has been under-estimated. The degree of tolerance they have over other systems becomes a handicap if used as a pretext for lower standards of surface preparation and application together with inadequate film thickness; it is mainly to these causes that premature failure can be attributed.

In these systems the inhibitive primer is of great importance and it must give complete coverage to be effective. All too often, sharp edges are left when cutting and shaping steel and priming paints will recede from these leaving thin films of little protective value. Even when properly radiused (2-3mm radius), all edges should be strip coated with primer in addition to the overall coating, so that adequate and even additional thicknesses are ensured at these weak points. Because of the high shearing action of brush bristles, brush application of primers is the best means of ensuring intimate contact and wetting of the surface, but this method is so labour intensive as to be considered uneconomical for treating large surface areas. The best alternative is undoubtedly airless spray application provided highly trained operators are available. In the hands of the unskilled, this method leads to many defects common to spraying and, in addition, wide variations in film thickness. It is a serious mistake to roller coat primer on to steel, and especially fabricated steel, as the roller tends to give an uneven coating and never successfully covers irregularities on the surface. The "holidays" will inevitably promote early breakdown of the system.

Recommended protective systems for specific environments will behave satisfactorily only when applied in the specified time sequence for the complete system. Early breakdown can often be attributed to poor protection for too long a period during the construction stage and then completing the system over an inhibitive primer which has already broken down.

Problems with chemical-resistant systems

One-pack

One-pack, chemical resistant systems for steel protection have a great advantage in their ability to be readily overcoated at all time intervals to give good intercoat bonding because of solvent softening. They are prone to solvent retention, however, especially in thick films, and this is accentuated in cold weather. This can present problems when stacking prefabricated parts during the early life of the coating. When high build formulations are used in cold weather, skilled application is necessary to prevent serious sagging problems. Whilst the chlorinated rubber types have very low water permeability values and, therefore, perform well in moist conditions, they are lacking in good resistance to ultraviolet radiation. The vinyl types are much better for ultraviolet resistance but are extremely critical with respect to surface preparation requirements and often become detached in sheets from poorly prepared substrates or show poor intercoat adhesion due to dirt retention between intermediate coatings.

Two-pack

Two-pack chemical resistant systems, in theory, will provide extremely resistant protective systems for steel if mixed in the correct proportions and applied under optimum conditions, and certainly under laboratory conditions, excellent performance results can be obtained. Formulators have exercised skill in developing variants exhibiting differences in rates of cure and solventless types to be applied for "instant" cure using two-component spray guns. Unfortunately, practice does not match up to theory and until it does this type of protective finishing will be fraught with the possibility of serious failures. The problems are made worse by the fact that because of high chemical resistance these paints are often used in confined spaces such as the inside of sewage outflow pipes, tunnel linings, oil fuel and chemical storage tanks etc.

The only way to guard against failure is to have available throughout the entire processing, skilled supervisors familiar with the problems involved, very well trained applicators who really know how to do the job, and above all the best tools for the job.

The basic requirements are:

(i) To mix in the correct proportions and to mix thoroughly.

(ii) To ensure that the temperature of the mixture is within the recommended limits.

(iii) To ensure that the ambient and substrate temperatures are within the recommended limits.

(iv) To provide the correct ventilation requirements when working in confined spaces.

It is not sufficiently realised that the chemical reaction that takes place is time and temperature dependent and when heat is evolved (exothermic) also dependent on the amount of material mixed. The pot life may become dangerously short for large volume mixes.

Some of the failures in practice experienced by one of the authors are outlined below.

Failures due to bad mixing

Materials are usually supplied in two containers with facilities to add the smaller portion to the larger container when mixed. If the operator is not aware of the absolute necessity to get complete homogeneity he is likely to:

(i) Leave a fair portion in the smaller container because it may be rather too viscous to pour out completely, and if it contains sediment to leave most of this in the small container.

(ii) Omit to homogenise completely the contents of the larger container before mixing and leave considerable sediment (sometimes hard sediment) at the bottom.

The resulting mix is either deficient in or has excess of one component and although when applied it may appear satisfactory it is not likely to stand up to the end use requirement (resistance to specific chemicals or solvents).

Cases are known in multicoat systems where:

(i) Intermediate coats are insufficiently reacted and cause lifting and cracking of perfectly satisfactory top coats.

(ii) Top coatings are insufficiently reacted and in use lift away from perfectly satisfactory intermediate coatings.

Failures due to unsatisfactory solvent balance

Materials which have been satisfactorily mixed can also fail due to faulty formulation. This usually takes the form of an early surface reaction and skin formation in the applied coating before all the solvent has been released, followed by bubble formation and/or cissing. The difficulty is in providing a satisfactory solvent release balance for a variety of temperature and air movement conditions without embarking on tailor-made formulations for each set of conditions. A good supervisor can usually adjust the solvent balance with appropriate thinners if he has the authority to do so, but solvent adjustment by the supervisor is not the correcting procedure if the cause is large volume mixing, encouraging an exothermic reaction to go too quickly. A peculiar cause of bubbling was encountered due to the formation of a relatively stable froth on the surface of the mix. On airless spraying this appeared as stable bubbles on the cured surface coated with paint from about the last tenth of the container.

Failure due to poor ventilation in confined spaces

When applying two-pack materials in storage tanks, inside pipes etc, it is essential to provide changes of air to remove solvent and to ensure that no "dead spaces" remain. One of the authors has experienced a case where the solvent remaining in the tank condensed on the curing surface and as it streamed down it leached out unreacted components which then concentrated as a yellow liquid at the bottom of the tank.

Failures due to poor application

The most common failure in this category is caused by uneven film thicknesses which on prolonged ageing may lead to cracking. In mechanically strong films, considerable stresses arise during curing and the adhesion forces have to be large to prevent detachment; it is not, however, sufficiently well recognised that uneven film thickness can cause differential stresses ultimately leading to cracking. These faults usually appear on bottom ledges and floors where excess material has flowed down from vertical surfaces and collected along weld runs and the like; cracking usually appears after several months of ageing and can be promoted by thermal cycling of the steel substrate.

The building industry

As the building industry uses mainly what could be classed as "conventional paints", it might be expected that relatively few problems would occur. A good quality alkyd paint system can be regarded as having a potential life in excess of five years. This claim of life expectancy is well supported by the many housing authorities who work to a five-year maintenance period, since maintenance ideally should be carried out before the existing system has failed. In practice, however, many instances occur where these conventional paints achieve only a fraction of their potential life. This is particularly so on new properties where repainting is often necessary within two years. All too often, this premature failure is accepted complacently—the owner having been "persuaded" that this is normal with modern paints. Apart from the bad publicity received by the paint industry, these premature failures, and subsequent high maintenance costs, represent a large economic loss.

It is convenient to classify and consider failures of paints for building under three headings, each covering a particular area of prime responsibility. These are:

1. Failures arising from defective design or specification.
2. The consequences of poor building practice.
3. Failures due to defective paint.

In practice, responsibility may spread across more than one of these headings.

Paint failure by design or specification

Refs. 3, 4

In many instances poor paint performance can be directly attributed to defects in the original building design or specification of materials. A common factor is the failure to appreciate, in the building design stage, the immense capability for damage possessed by water, in particular the water produced within a building during its normal use, that manifests itself as condensation. The aim in good design should be:

(a) to attempt to minimise condensation by good, but not heat-wasting, ventilation;

(b) to minimise cold surfaces on which condensation can occur; and

(c) to encourage any condensation which forms to flow away from situations where damage may occur.

However, in many buildings visual impact, rather than low maintenance costs, appear to be the major design consideration. Architecture has been passing through a period where extensive areas of glazing have been incorporated, often with the space between window and floor closed with a decorative infill panel of coloured or textured glass. The combination of the window and infill panels provides a large area of cold surface on which heavy condensation can form, run down and settle on the glazing and transom bars, which generally are made of softwood and seldom shaped to deal with condensation. If allowed to remain on the frame members, this water eventually enters the timbers, through such weak points as poorly fitting joints and defective back putty, to the detriment of both the timber and the paint system. Instances have occurred where the maintenance costs of these window/infill panel combinations has been so excessive that it became economic to replace the infill with a section of brickwork.

Even on relatively small windows certain situations exist where condensation can be severe. When one block of flats was viewed from the rear, it could be seen that the paint had broken down severely and was flaking from every third window in each horizontal row—these were all kitchen windows. On another development site, both bathroom and kitchen windows could be similarly identified from the severity of breakdown of the external paint system. In yet another block of flats where poor paint performance on wooden window frames was alleged, it was found that a considerable number of the frames and window boards were rotting, a defect which, judging from their position, could only be the result of excessive condensation.

In all the above examples no provision had been made in the joinery design to safeguard against condensation damage and in all cases the lower frame members and window boards were not shaped or channelled to lead the collecting water away from sensitive areas.

A further consequence of the high levels of in-house humidity which are so frequently encountered could be the many instances which are now reported of fungal disfigurement of decorations. On the other hand, with the prevailing use of white and pastel shades any disfigurement is more apparent than it would be on the darker colours previously in fashion.

External architectural features designed to achieve a visual impact can have consequences differing from those envisaged by the designer. A good example was provided by a varnish failure on the wooden facia affixed to the lower storey of a moderately high building. On this facia, the varnish was severely broken down and peeling in vertical strips some 4m apart. Above the ground floor, the windows were fixed in housings which projected substantially from the surface of the building and, being aligned in vertical rows, channelled the rain run off down on to the wooden facia in lines, again some 4m apart.

On one building, brightly coloured decorative panels were fixed to the outer surface of brick infills—the panels consisting of painted board protected by clear sheet glass. Rapid degradation of the paint occurred on those panels facing into the sun due to excessive temperature rise through a "greenhouse" effect beneath the glass.

Many large developments and new town complexes are being built on sites which can pose particular environmental difficulties—for example, the bleak situation of Cumbernauld and the low lying marshy area of Thamesmead. In selecting protective and decorative systems for use in these areas, particular attention should be paid not only to the gross environmental features but also to the very local environment of a particular building. The presence of close neighbours can produce a local exposure pattern—in some cases providing shelter, whilst in others increasing severity of the purely local conditions. For high-rise buildings, the conditions prevailing on the higher stories can differ greatly from those at ground level. Lacquered aluminium windows in the upper stories of a high-rise building near the coast, rapidly showed abrasion damage due to windborne particles, whereas the windows of the more sheltered lower floors remained in good condition.

In exposed coastal and estuarine situations, wind-carried salt spray can cause damage not only to the exterior but also within a building. A recently investigated example of a paint failure on light gauge metal fittings within a building, revealed severe corrosion on surfaces facing opening windows which in turn faced on to the coast. The protective system on these fittings consisted of a thin coat of a stoving finish applied over a lightly pretreated surface and whilst it might have been adequate under normal commercial conditions proved inadequate when exposed to that quantity of sea spray carried through the open windows by mild breezes.

Miscalculations concerning water have also caused difficulties in the renovation of older properties—particularly where high-build masonry paints have been used. In older properties it would be reasonable to suspect that at least minor defects existed in the damp-proof course, but in many instances the quantity of rising damp has been such that ready escape of the water occurred by evaporation whilst the walls were unpainted. Once escape was impeded by the masonry paint system, however, damp patches and stained decorations developed on interior walls. For the majority of enquiries on this subject which have been received by the PRA, it has been found that the person specifying the particular paint system had been misled by the term "breathing paint" as often used in the description of the materials and failed to appreciate that an unpainted wall will "breathe" far more readily than one which has been painted.

Paint performance on windows is probably the region where the greatest dissatisfaction occurs. Frequently, it has not been appreciated that for the large opening lights used in many of today's structures, timber of adequate cross section must be employed and that it is advisable to hang the windows at balance points to minimise strain. Poor paint performance on the windows on one housing estate was to a large extent the result of failure to appreciate these factors. The large windows concerned were not only constructed from timber of small cross section (and were, therefore, whippy), but were also of a vertically pivotted type with the pivots affixed considerably off balance along the horizontal members. The large number of open joints through which water had entered and disrupted the paint system could be attributed to a combination of the strains produced in the frames through whip and the off-balance suspension.

Many building designers do not appear to appreciate that a large proportion of paint failures in joinery are caused by inadequate wood primers. Many of the industrial wood primers are formulated primarily to meet the requirements of the mass production methods employed by the joinery manufacturers. Work carried out at the PRA[3] and BRE[4] demonstrated that the majority of these primers did not produce films capable of accommodating the dimensional changes which can occur in timber due to changes in water content. The usual combination of a short oil resin and high pigmentation level in these primers frequently results in poor durability and hence degradation of the primer film can occur during the poor conditions of storage so often found on a building site.

Normally joinery is delivered to the site with the horns left in position, to be cut back or removed when the joinery is installed in the building. All too often, unless the designer has specified that the cut ends are to be primed before installation, they will be left as unprotected end grain through which water can readily enter.

Where factory primed joinery is employed the usual specification for site finishing is "apply undercoat and gloss finishing system". It has been noted, however, that even this specification can cause difficulties if the architect has not appreciated any unusual features in the particular joinery units which he has selected. In this particular example, a softwood window unit was fitted with a galvanised steel vent light and delivered to the site with the timber primed but the vent light as bare metal. As the painting specification only called for undercoat and finish, this was all that was applied, even to the metal work. After a relatively short exposure, the paint system embrittled and broke down severely over the galvanising.

Paint failures due to poor building practice

With the conditions prevailing on the average building site and, in particular, under which the painting is carried out, it might be thought surprising that the rate of premature failure of first paint systems is not higher than actually encountered. The painters generally are the last workers on the site and hence are rushed if the contract is running late. Often other trades (even "wet" trades) who are behind schedule, are still in possession whilst the painting is being carried out.

A growing usage has also been observed of a two-coat paint system (that is, a single coat of site applied finish over the factory primer), no doubt to cut time and hence capital costs. It must be assumed, if the clerk of the works is performing his proper function, that this retrograde practice is within the specification. This will no doubt give rise to yet more premature failures.

To date, however, the major building practice which has been found responsible for premature paint failure has been the lack of care for components and joinery, in particular, during site storage. All too often, when investigating failures it has been found that the undercoat/finish has parted from the primer with clear evidence of a degraded, dirty layer on the surface of the primer which is often infected with fungal growth.

In a similar incident, joinery treated with preservative had been delivered, by specification, to the site without primer, so that the complete system could be site applied. After some 18 months, severe breakdown was occurring, with the paint stripping from the wood surface—a situation for which the paint maker was blaming the preservative manufacturer and vice versa. The detached paint flakes, however, carried on their underside a considerable quantity of degraded wood fibres, dirt and nodular fungal organisms, indicating that the wood surface had been severely degraded through prolonged exposure to the weather before the paint system had been applied, and hence the builder was responsible for the failure of the paint system.

Light gauge steelwork often suffers poor on-site storage conditions to the detriment of the service life of the protective system. Paint defects developed rapidly in one new market complex where light gauge steel components were blast cleaned and factory primed before delivery to the site, with the finishing system applied some time after erection. One of these failures occurred on steel staircases, delivered as pre-fabricated units, and consisted of severe breakdown of the primer with considerable rust breakthrough on the treads and risers. Similar units could be seen on site, which were stored horizontally, in the open, and holding 5 to 10cm of rainwater in the angle between each tread and riser. Another defect which was occurring in completed market halls consisted of a loss of adhesion of the finishing system with the backs of the paint flakes contaminated with a light coloured dust which was partially water soluble and contained a high proportion of calcium and thus probably cement dust. Judging from the site conditions, a considerable amount of sand and cement dust was being carried in the breeze on to the unprotected surfaces of the steelwork.

A paint failure which occurred at another market complex underlined the need for careful supervision when builders were faced with handling what, to them, were unusual materials, particularly if the careful mixing of components was required, such as with two-pack paint systems. In this particular case, there was complete and utter disregard for the paint manufacturer's instructions on the mixing of a two-pack etch primer contributing to the rapid appearance of paint defects.

Paint failure on buildings can often be avoided quite simply, but the strict demarcation between trades prevents this. An extraordinary number of paint failures occurs on painted wooden cladding sections on houses. A main cause—and one to be deprecated—is the false economy of using relatively short boards resulting in an excessive number of butt joints. (On the 1.3m high stretch of cladding across the front of one semi-detached pair, no less than 15 were counted.) If the exposed end grain in these butt joints were sealed with paint before erection, much difficulty could be avoided. As only a carpenter is involved in fixing the cladding, however, no paint is applied to the end grain and hence water readily enters, diffuses along the boards and degrades the paint system.

Whilst this is not the place to discuss the activities of building operatives who have apparently never heard of a spirit level or plumb line, it is necessary to mention that houses have been seen on local authority sites where windows were inserted so far from plumb that the sill directed rain-water back on to the sill beam rather than away from the main structure. In all cases, the paint system failed rapidly.

An example of the results of using poor quality labour for painting arose from a situation where the use of specified primer and high-build finish in a position of difficult access resulted in complaints of severe rivelling. Tests failed to reproduce this defect until—almost by accident—a grossly over-thick film of primer was laid down. When the finish was applied over this, severe rivelling occurred. Samples finally taken from the building confirmed that in the rivelled areas the primer film was grossly over-thick.

Joinery surfaces in contact with masonry seldom have any further protection applied other than the shop primer. Unless gaps between the joinery unit and the masonry are efficiently sealed, rain-water may penetrate and result in paint failure on an exterior surface. One of the authors experienced a paint failure of this kind on the lower section of the wooden surround to a steel window frame. Here water was entering timber which appeared to be efficiently sealed against both rain and condensation. It was finally discovered that the majority of the fixing screws which should have held the steel frame into the surround had not been fitted. Water was entering behind the glazing due to defective back putty running through the open screw holes in the steel frame and on to the hidden wood surface which appeared to have received very little if any priming.

It is well known that weather conditions at the time of painting can influence the performance of the paint system; in a particular incident, though the weather conditions might be suspect, it is often difficult to determine the actual conditions on the day when the paint was applied; however, in two incidents no doubts existed. In the first, which occurred some years ago, a definite pattern of ice crystals could be seen on the back of paint flakes which became detached from an exterior surface a short time after redecoration, and hence showed that the paint had been applied under conditions of frost.

In the second incident, the failure occurred so quickly that there was no doubt as to the cause. A stair well, sheltered from the weather but open to the atmosphere, was painted with an emulsion paint during a prolonged period of cold but not frosty weather. It was found one morning that a considerable amount of the previous day's work had "run off the walls" during the night, when much warmer weather and higher humidity had come in, resulting in a very heavy deposition of condensation on the well chilled walls in the stair well. As the surfaces were cold when the emulsion paint was applied, drying had been slow, and the film remained susceptible to damage by the condensation.

Paint defects

Incidents in which defective paint was involved have been far less frequent than those previously discussed. Under this heading, however, must be included those cases where instructions were not perfectly clear, descriptive terms not rigidly defined or packing not the most appropriate for the product.

One striking example of an unsuitable paint formulation was provided by a bronze lacquer employed as a decorative finish on aluminium windows. After only a short service period a complaint was received that corrosion was causing extensive disfigurement and indeed the samples submitted presented a very dismal appearance with considerable areas of corrosion products. On examination, however, it was found that the underlying metal was in good condition and that the corrosion was essentially confined to the paint layer and, in fact, resulted from the corrosion of the aluminium bronze pigment used in the lacquer.

Another example of an unsuitable material involved the use of a saponifiable medium in a sealer employed to hold back stains arising from the use of contaminated sand in an underlying mortar screed.

Under this main heading must also be included the twilight zone where a paint may be formulated to meet an immediate requirement but may be unsatisfactory in a later occurring context. Many of the rapid drying, solvent thinned joinery primers (previously described) fall into this category in that they readily meet the requirements of the joinery manufacturers' mass production methods, but can be unsatisfactory as the basis of a durable protective system.

Terms descriptive of special features of a paint can cause difficulty if not fully defined in context. One such example previously mentioned is "breathing paint". There is clear evidence that this has been interpreted by some architects as meaning that the escape of water vapour is essentially unimpeded by the paint coating when, in fact, all that can be claimed is that the water vapour permeability of the film is relatively high.

Another term which has been misinterpreted is "self-cleaning" as applied to paints formulated to undergo a degree of chalking to remove the soiled surface layers. It has been found that many architects do not appreciate the chalking action and hence difficulties have arisen when, for example, a "self-cleaning" paint has been employed on the upper storey of a house, and the lower face, consisting of deep red facing brick, has become disfigured by rain-carried chalk streaks. In the formulation of these paints, great care must be taken to ensure that the degree of chalking which will occur is the minimum required for the self-cleansing action. It is felt that an example of "failure" at a hospital, where the rain run-off from the painted upper section had turned the lower floor facing bricks from deep red to a patchy pink, was a result of unsuitable formulation.

Difficulties have arisen when building labour has had to use unfamiliar materials, particularly those which have involved the careful mixing, in defined proportions, of two-pack materials. Often the difficulty is increased by the product having a definite pot life after mixing and further exacerbated by the product still appearing usable after the expiry of this period. A good example is the two-pack etch primer mentioned previously. Many of these difficulties could be avoided by the use of special packs, for example, two-part packs containing the components in the right proportions for use, and clear statements of special conditions, such as pot life, printed on the pack.

Conclusions

Ref. 5

From the case histories mentioned, there emerges a definite pattern, with most paint failures arising from the consequences of poor site conditions or inadequate design and/or specification. Frequently, it appears that the underlying principles involved in obtaining the maximum service life from a paint system have either not been appreciated or have been ignored.

If the paint system is to achieve its potential protective and/or decorative life, a series of positive actions must be taken:

(a) Good site conditions for surface preparation and application of the paint must be provided. These must include adequate protection from both the weather and the prevailing site dirt. Every effort should be made to allow the painters both sufficient time for the operations and freedom from interference from other trades who are behind schedule. Adequate site supervision is also necessary, particularly if the painters are paid on bonus terms, or various "short-cut" practices can arise.

(b) Adequate site storage facilities must be provided for components awaiting installation in the structure, otherwise appreciable deterioration or soiling will occur before the paint system is applied. Whilst it has not been possible to obtain data on the proportion of, say, joinery which has been installed in a building in a substandard condition through poor storage, the comments and photographs in a recent report on wastage of building materials[5] are indicative of what might be expected. In this report, it is claimed that the quantity of bricks wasted through poor storage, could be used to build 15 000 houses a year. A photograph shows wooden roof trusses on site: if the joinery were similarly stored on this site, only a poor level of performance could be attained by a subsequent first finishing system.

(c) Careful forward planning and programming for the delivery of components to the site must be undertaken by both the designer and the contractor in order to prevent excessive periods of site storage. Such a situation as was recently observed on a building site where the joinery was delivered and left unprotected, even before the footings were dug, is absurd.

(d) Where a long delay is unavoidable between inserting a component into an exposed position in a structure and finishing the paint system, a holding coat of a paint more durable than the primer should be applied.

(e) The aim of the designer must be to avoid features which aggravate protection problems, such as water traps, water run-off on to sensitive areas, blind positions and positions of difficult access.

It is appreciated that economic factors can add to the designer's problems, such as the designer being forced to simplify features or use lower grade components because of capital cost restrictions. It must be stressed, however, that these restraints frequently result in excessive maintenance costs.

With the complexities of modern construction methods and materials, it is essential that the design team should include or have available the services of a protection engineer or senior maintenance engineer, who would be involved from the initiation of the project.

(f) Specifications as to materials, degree of surface preparation and conditions of application must be both reasonable, so that no undue difficulties arise in complying with them, and explicit.

Having produced a specification for the protective system it is essential that the designer should require an adequate level of site supervision to ensure that the often expensive, protective system is not imperilled by poor workmanship or malpractice. Conditions of site storage of components should also fall within the sphere of the site inspector.

It is appreciated that the provision of a suitably trained inspector can be expensive, but a large scale paint failure could be even more expensive to make good, in terms of loss both of the time during which the building is out of service for repairing, and of reputation of all parties concerned.

With vagaries of weather at the site, and also of labour and conditions under which the surface preparation and painting will be undertaken, the design engineer or architect should give serious thought to the advantages of factory finished components. Under factory conditions, it is possible to maintain high standards of surface preparation and paint application without any of the hazards of exterior operations. It is appreciated that opposition to new construction methods may be experienced, but the advantages in terms of better performance should outweigh these. The improved performance likely to be attained will not only be the result of better preparation and application, but also of adequate coverage on surfaces which become hidden by the building operations, and of a better standard of handling on site. Once properly instructed, site labour is likely to treat, for example, a fully finished and glazed window unit far more carefully than normal joinery, and the present practice of using the joinery unit as framework to support the surrounding brickwork during construction would be abolished.

(g) The paint manufacturer must ensure both that the formulation can give the required service life and that application tolerances are not such as to make practical application unrealistic. This could involve a careful appraisal of any accelerated or artificial test methods employed in the evaluation of the system, in order to determine whether the results were realistic in the light of the proposed use for the material.

(h) Great care must be taken in the packaging of two-pack materials to ensure that they are adequately mixed in the correct proportions and to prevent the use of the product beyond the stated pot life. Whilst initially more expensive, long term economies could be made by supplying these in the correct proportions in reasonably small packs consisting of a double container, from which the least viscous material was run into the more viscous. A small pack of, say, 5 litres capacity, is one in which adequate mixing is more likely to be obtained.

(i) Responsibility for control of the finishing operations and for variation from the original specification must be clearly defined, with minimum opportunity for "buck passing". Clearly, there can be considerable advantage in the paint manufacturer undertaking to supply not only the paint, but also a complete consultancy, inspection and site control package.

Acknowledgments

The authors are grateful to the Director and Council of the Paint Research Association for permission to publish this paper, and to their colleagues, who brought relevant examples of failure to their attention.

[Received 20 March 1975

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4. Whiteley, P., and Rothwell, G. W., *JOCCA*, 1975, **58**, 90.
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Discussion at Scarborough Conference

MR F. G. DUNKLEY asked Mr McKelvie how he would establish that the minimum of 15 microns of paint had been applied and how he would satisfy himself that harmful ferrous sulfate contamination had been removed, at least to the point where any residues were not likely to accelerate corrosion after painting.

MR MCKELVIE said that the problem of ensuring the minimum of 15 microns thickness of blast primer was a difficult one. He thought that it would be easier if a finer grit were used in the blasting operation to achieve a more uniform surface profile; this would also speed up the blasting operation. In addition, it was important to ensure that the paint manufacturer gave sufficient body to his product to prevent flow-out away from the peaks. It was the author's experience that with attention to the above two factors and using an automatic spray plant suitably adjusted, it was quite feasible to expect a working range of 20 $\pm$ 5 microns.

On the question of contamination, Mr McKelvie thought that the four-hour rule could be rather misleading. He had done work which had shown that providing there were no soluble salts remaining on its surface after blast cleaning, the steel could be left before priming for a considerably longer period than the four hours recommended in the relevant British Standard and there was still no significant rusting back. He was not concerned here with flash rusting or re-rusting of the surface, but rather with the re-rusting caused by soluble salts coming out of the pits. With regard to testing for the presence of any soluble salts left in the pits on the surface, he was one of a number of people who had looked at the potassium ferrocyanide test and this seemed a very promising method. As far as removing the contamination was concerned, spraying with a high pressure water jet would probably be ineffective in most cases. It was usually better to run water over the surface. In fact, it had been shown that continuous rain for a period of, say, two or three days on exterior rusted steelwork would remove almost all the soluble salts present on the surface. When the rain stopped, however, these salts would soon build up to their former concentration.

MR DUNKLEY replied that for a surface which showed serious rusting and a high concentration of soluble contaminants it was his experience that satisfactory cleaning could best be achieved by high pressure water blasting jets either at a pressure of about 100MPa (15 000psi) or at a lower pressure—say, 30 to 55MPa—incorporating some fine silica sand. He was sure that Mr McKelvie would know the work which CIRIA had done on this subject, which had shown that the method was effective for removing not only ferrous sulfates but also chloride ions.

MR MCKELVIE confirmed that he was aware of this work and he did consider high pressure water blasting to be a good method, but it could not completely clean the very deep pits on the surface and if these pits were left uncleaned then re-rusting could be seen around their edges after a period of only half an hour or so.

MR FRENCH said that he was interested in one of the slides which the authors had shown of failure over a weld, since this seemed to indicate that failure was due to the flux which had been used in the welding operation.

His question concerned blast primers; there seemed to be an increasing tendency to use ordinary shop primers or "travel coats" (coats which had a design life of about six months and which were intended to protect structural steelwork on site during the erection period). The finishing coats were then applied on site, but there was still the problem of what to do with the fraying surfaces where, for example, the steel was bolted together.

He also wondered whether the authors had any comments to make on zinc silicate primers since they had made no mention of these in the paper. There seemed to be a revival in the use of this type of coating in the UK at the present time.

Mr McKelvie answered that on the slide which he had shown the weld had, in fact, been made on the other side from the coated surface. The slide had been intended to show an example of the deleterious effect of unremoved burn primer.

It was perhaps an omission in the paper not to mention the disadvantages of using zinc silicate primers. Certainly there were a number of problems with these primers, and he would recommend people to be very careful in their application.

On the question of travel coats, Mr McKelvie said that users should be clear to differentiate between these and blast primers. Blast primers should be applied as thin coats—certainly not more than 30 microns in thickness—so that it was possible to weld over them. Travel coats needed to be much thicker to do their job effectively and it was, therefore, not possible to weld over them.

Mr C. E. Hoey said that during his presentation Mr Sherwood had mentioned a number of defects in design of buildings and made a plea for paint manufacturers to try to educate architects. He entirely agreed that this was desirable, and felt a number of companies was already prepared to do this—if asked. Both architects and engineers (in other contexts) would benefit from such advice, but were rarely interested enough to seek it. Paint to them was a minor concern, although its failure was the first thing which met the eye. He did not know how it was possible to get the message across. What it seemed was required was something like a table giving fairly simplified answers, and perhaps "codes of practice" were the answer.

Mr Sherwood agreed that this was a difficult problem. Firstly, it was necessary to overcome the artistic temperament of the architect and make him interested in the technological aspects of his design, and secondly there was the problem that once the building had been commissioned the architect was no longer interested. On this latter point, however, there was increasing pressure these days on the architect from maintenance engineers, and particularly local authorities, and this could only be beneficial.

Mr French commented that the British Standard codes of practice for painting buildings were quite impractical at the present time because the weather conditions in this country made it impossible to adhere to the codes and at the same time keep to within that part of the erection schedule given over to painting.

Next month's issue

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

Prediction of the corrosion protective properties of paint films by permeability data *by H. Haagen and W. Funke*

Problems encountered in testing paint films *by M. B. Kilcullen*

Implications of the paint film contraction theory for comparisons of accelerated and natural weathering results *by J. Colling and T. W. Wilkinson*

Erratum An error has been overlooked in the paper by J. Bijleveld and H. Krak, "Some aspects of spray applied water-borne paint binders", published last month. The units of viscosity given in Table 3 should *not* read "N s m^2) but rather "N s m^{-2}". We regret any inconvenience caused.

Newcastle

Ultraviolet curing

On 10 April 1975, over 200 delegates from 11 countries assembled for the first major symposium on ultraviolet curing held in Europe. Over 120 companies were represented from Belgium, Denmark, France, West Germany, Italy, Norway, Sweden, Switzerland, U.S.A., and the U.K.

The format of the symposium was to a certain extent experimental, in that the proportion of speakers from the academic world was unusually high. There is no doubt that the inclusion of such people was a substantial contribution to the success of the symposium. Their contribution of the basic concepts and developments in the photochemistry should prove to be of considerable help to UV development work as a whole. The rest of the speakers were drawn from a broad spectrum of the coatings industry.

Dr R. Cundall's (Nottingham University) paper presented the basic concepts of photochemistry. Dr A. Ledwith (Liverpool University) and Dr D. Phillips (Southampton University) developed these concepts with respect to aromatic carbonyl photo-initiators, exciplexes, photo-oxidation and ionic and free-radical polymerisation. Dr I. McNeill presented a paper on photodegradation of polymers and the academic representation was highlighted by a fascinating discourse on photo-polymerisation by Prof. F. de Schryver.

The "consumer" was represented by the Metal Box Company in the person of Mr A. Lott, who discussed the advantages, difficulties and potential of UV curing in packaging. Dr A. Gamble represented the printing ink industry and gave an interesting paper discussing types of systems and photo-initiators being used in printing inks for UV curing.

The interest shown by resin manufacturers in UV curing was reflected in two papers from Ancomer Ltd and Resinous Chemicals Division. Mr J. Younger (Ancomer Ltd) discussed both the formulation of UV systems with respect to the effect of acrylic monomer content on curing speed, and flexibility. He also referred to the problems of volatility and toxicity of various monomers. Mr A. Laws (Resinous Chemicals) spoke on the formulation of UV-curable polyester systems. In the photo-initiator field, Dr A. Price (A.B.M. Chemicals) gave a paper reviewing the literature of photo-initiators; a major feature of this paper was the number of invaluable references contained in it. Dr B. E. Hulme (Tioxide International) presented absorption and transmission data for titanium dioxide grades, and demonstrated how formulation techniques could alleviate the problem of rivelling. Union Carbide presented two papers. One was concerned with the advantages of curing under a nitrogen blanket and the other, given by Mr J. Weigel, gave a broad review of all aspects of photo-curable formulations. Finally, Mr R. Knight made an important contribution from the "lamp engineering" side, when he spoke on the design, maintenance and manufacture of UV curing systems.

Between the two working sessions, a symposium dinner was held on the Thursday evening in St. Mary's College, where many of the topics of the day were taken up and discussed at great length over good food, good wine and amongst good company.

B.E.H.

It is intended that most of the papers presented at this Symposium will be published in the *Journal* during 1976.

South African

Natal Branch

Industrial painting

A lecture entitled "Out with the old, in with the new" was given to the Branch by Mr B. Newby-Fraser, managing director of Reef Industrial Painters.

He pointed out that the African worker now needed extensive training for the satisfactory application of sophisticated coatings with airless spray equipment. It was suggested that suppliers of two-pack products use a symbol system to differentiate the two materials, as it was thought that this would be easier for the semi-skilled labourer to understand.

Six years ago the cost of industrial painting was approximately 3 per cent of the project, and the paint specification, more often than not, was unsophisticated. Today, painting specifications called for a high degree of surface preparation, high performance primers and high build coatings. This has increased the painting costs to about 15 per cent of the project cost but these increases were compensated for by the reduced maintenance costs. Retention money and performance guarantees tied up large amounts of an industrial painting contractor's capital.

Because of the number of large projects at present being undertaken and those in the pipe line, there appeared to be no signs of recessional tendencies in this sector of the local industry.

The talk was followed by a question time and finally a vote of thanks was proposed by Mr L. F. Saunders.

L.F.S./P.A.J.G.

Transvaal Branch

Reminiscences and crystal-ball gazing

Dr A. M. Milner, formerly Senior Research Officer at the South African Paint Research Institute, gave a most lucid and interesting lecture to the Branch on the occasion of her retirement. The lecture was entitled "Reminiscences and crystal-ball gazing", and was given on 22 January 1975 at the Sunnyside Park Hotel, Johannesburg.

Dr Milner gave a brief account of the history of the South African Paint Research Institute, together with an outline of some of the major changes which had taken place in the coatings field during the past 25 years.

The Institute had opened in 1949 and was closed, for financial reasons, at the end of 1974. It was the smallest of five such institutes each of which derived part of its income from annual subscriptions from industry, had close ties with a University and was sponsored by the CSIR, who gave a grant equal to the industrial subscriptions, besides assisting with advice and in the initial equipping of laboratories. The other institutes represented the sugar milling, wool textiles, leather, and fish industries, all four of which were closely connected with one of South Africa's primary industries. Paint manufacture was, however, a purely secondary industry in South Africa and the speaker considered that this was at least partly responsible for the fact that the Paint Research Institute always remained the smallest and least wealthy of the five.

Dr Milner joined the Institute in 1952, when paints were still mainly based on natural vegetable oils, gums and resins.

She became responsible for editing and indexing a quarterly Digest in which articles from the technical journals were abstracted. She also initiated a service for members both for routine tests and for investigations and long-term assessments.

As criteria of changes in the coatings field, Dr Milner used both the increase or decrease through the years in the number of published articles on any subject and also the changes in the type of problem encountered over the years. She considered that the major single change was the swing from natural binders to synthetic film-forming polymers. This transition had already started by 1950, when almost all the polymers now in common use were at least mentioned in the literature.

Several examples were given of problems encountered by the Institute, and it was shown how useful instrumentation had been in their solution. In particular, the Institute's former Director had designed a number of gas/liquid chromatographs of increasing efficiency and suited to the Institute's particular needs. These had been built in the Institute's workshop and together with commercial infrared and ultraviolet spectrophotometers provided the basis for a useful analytical service.

Dr Milner concluded by expressing her sorrow at the closing of the Institute, and by giving some very brief predictions of future coating trends. She foresaw an increase in specialised, factory applied coatings and the probable impact in South Africa of anti-pollution legislation, particularly in the solvents field. This was expected to increase the use of water-based and solvent-free coatings.

P A.J G.

Information Received

Joint company for powder coating manufacture

Agreement in principle has been reached between Donald Macpherson Group Ltd and BICC Ltd to form a company as a joint venture to manufacture powder coatings in the UK for the home market and for export.

The new company, to be called Macpherson Powders Ltd, will be owned 75 per cent by Donald Macpherson and 25 per cent by BICC, and will have an initial capital of £300 000. The company will operate from Donald Macpherson's existing site at Barking in Essex.

The new company is acquiring the existing business in polythene, epoxy and nylon coatings of Telcon Powders, a unit of BICC's wholly owned subsidiary Telcon Plastics Ltd, for a consideration of approximately £250 000 payable in cash, and representing the present plant and stock of Telcon Powders.

Literature

Chemical industry statistics

The Chemical Industries Association has recently published "UK Chemical Industry Statistics Handbook 1975" and copies are available (full price £10 per copy including postage to UK addresses) from the Chemical Industries Association Ltd, Alembic House, 93 Albert Embankment, London SE1 7TU.

Investment forecasts

The tenth report on investment forecasts for the process industries has been published recently by the National Economic Development Office's Process Plant Working Party to describe in broad terms the economic trends and development programme of the process industries.

The high level of expenditure forecast last year and up to the end of 1976 has been substantially maintained. Of the total capital expenditure of £8 640 million forecast up to the end of 1977, 40 per cent is accounted for by expenditure on North Sea oil production development.

Copies of the report are available, price £1.00 each, from Neddy Books, National Economic Development Office, Millbank Tower, Millbank, London SW1P 4QX.

Non-Newtonian flow

A working party of the Science Research Council has issued a report on non-Newtonian flow and would welcome any comments or criticisms on the contents of the report. Copies may be obtained from the Science Research Council, State House, High Holborn, London WC1R 4TA (Telephone: 01-242 1262, Ext 211).

New products

Polymist B-6 and B-12

N.V. Allied Chemical International S.A. has announced the addition of two new grades to its "Polymist" range of micronised polyethylene used for anti-mar, anti-scuff agents in printing inks.

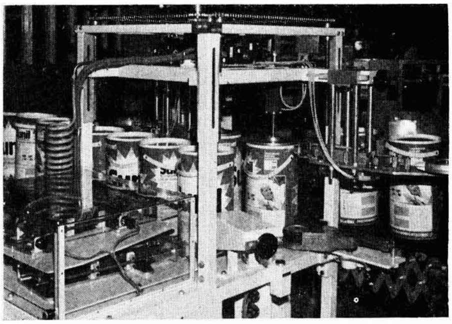
Polymist A-12 has been available for many years and is well established in this area.

The two new products are designated B-12 and B-6 and are available in fine dry powder form of average particle size 12 microns.

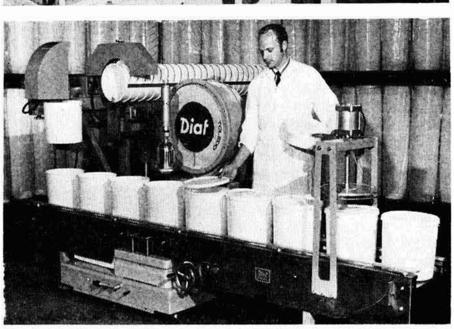
Seelfos E

Jenolite Division of Duckhams Oils has announced the availability of "Seelfos E", which has been specially designed for the treatment of aluminium and steel prior to epoxy powder coating.

Seelfos E is applied to the metal after degreasing and allowed to dry for approximately five minutes, after which time the metal is ready to receive the epoxy resin. This treatment produces in the cold a condition equivalent to that which would normally result from light-weight and zinc phosphate coatings.



A new automatic drum sealer, capable of operating at a sustained speed of 45 drums per minute, recently introduced by Precision Engineering Products Ltd, Bury St. Edmunds, Suffolk



A Diaf filling line for plastic bucket packs, available from Superfos Packaging (UK) Ltd, Rutland

OCCA-28 Exhibition

Alexandra Palace, London. 23-26 March 1976

The target for 1976!

The international forum for technical display and discussion in the surface coating industries

New arrangements for OCCA-28

The Exhibition Committee has decided that the Twenty-eighth Annual Exhibition of raw materials, plant and equipment for the paint, printing ink, colour and allied industries organised by the Association will take place at Alexandra Palace, London N22 from 23 to 26 March 1976.

Alexandra Palace was the venue for the Exhibitions held by the Association from 1965 to 1969 and has many attractive features as the venue for this unique Exhibition. Alexandra Palace occupies a commanding position high on the North London hills and is less than two miles from the North Circular Road. Since the Association's last Exhibition at Alexandra Palace, travel arrangements have been improved by the addition of the Victoria Line to the Underground system, which now links Victoria Station to the Piccadilly Line at Finsbury Park. The building of the extension of the Piccadilly Line from Hounslow to the Airport terminal at Heathrow is now well advanced and when this is completed in due course it will give a direct link with Turnpike Lane Station on the Piccadilly Line. In the meantime, a bus service operates from Heathrow Airport to Hounslow West Station. Those travelling by the Piccadilly Line should alight at Turnpike Lane Station and the Association will be running a bus shuttle service from this station to and from Alexandra Palace. The journey from central London to Turnpike Lane takes approximately 18 minutes.

Visitors who prefer to trave from Heathrow to the West London Air Terminal in order to leave their luggage at Hotels before travelling to Alexandra Palace can board Piccadilly Line trains at Gloucester Road Station. A map will be included in the *Official Guide* showing the connections between the main line stations and the Piccadilly Line and also showing the link with the North Circular Road.

For those travelling by car from the Midlands or the North, the motorway system now links with the North Circular Road, from which Alexandra Palace is easily accessible; there will be ample free car parking space available at Alexandra Palace. The Exhibition will be open on four days commencing on the Tuesday morning at 09.30 a.m. and closing on the Friday at 16.00. There are two restaurants with full dining facilities together with a cafeteria and several bars.

Motif of the Exhibition

The motif for 1976, designed by Robert Hamblin, continues the theme of the last two Exhibitions—in which attention was drawn to the heavy participation by exhibitors and visitors from overseas—by showing the target for 1976 as London, where all the previous Association annual Exhibitions have been held. The colours of the motif this year are those associated with an archery target and these colours will be carried throughout the publicity leading to the Exhibition. Two of them will be incorporated on the facias of the stands—the blue colour from North to South and the yellow colour from East to West. As in previous years, this will give the Exhibition both an entity in design and will afford pleasing differences in colour as visitors move from corridor to corridor.

Invitation to Exhibit

Copies of the Invitation to Exhibit have been despatched to companies and organisations in the United Kingdom and overseas which have shown at previous OCCA Exhibitions or have requested information for the first time for the 1976 Exhibition. Completed application forms for stand space must be returned to the Director & Secretary of the Association not later than **Wednesday 1 October 1975.**

Since it was the overwhelming decision of the British people (in a Referendum held in June 1975) that the UK should remain a member of the European Economic Community, it is expected that even more European based firms will participate in this Exhibition, but any organisation in any part of the world wishing to exhibit should write immediately for details to the Director & Secretary of the Association since exhibitors and visitors alike are welcomed from all countries.

Any organisation which has not previously exhibited and wishes to obtain an Invitation to Exhibit should contact the Association's offices immediately.

International forum

At OCCA–XXVII in April 1975 there were direct exhibits from 15 countries. Listed in the *Official Guide* were over 150 companies, many of whom were overseas companies showing through British associates. The full review of this important Exhibition appeared in the June issue of this *Journal* and the Committee emphasises that the Exhibition affords a splendid opportunity annually for the technical display of information and a unique forum for informal discussion between suppliers and manufacturers.

Technical education stand

In continuance of its interest in the educational field, the Association will once more provide a stand devoted to technical education, at which details of courses at technical colleges will be available as well as information on the optional Professional Grade for Ordinary Members, introduced in September 1971, which has attracted widespread interest and support.

Information in foreign languages

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

"Official Guide"

This unique publication will contain descriptions of all exhibits and advertising space is available both to exhibitors and those organisations not able to show at the 1976 Exhibition. As in previous years, the *Official Guide* will be published several weeks in advance of the Exhibition so that intending visitors can obtain copies and plan their itineraries.

For the 1975 Exhibition, it was decided that a small charge should be made both for the *Official Guide* and for season admission tickets to the Exhibition. This policy undoubtedly prevented casual visitors who might otherwise be attracted to exhibitions for which no admission charge was made and who gathered quantities of technical literature from the stands. The innovation was welcomed by many exhibitors and in no way acted as a deterrent to visitors to this Exhibition. It is envisaged that a similar charge will be made for the *Official Guide* to OCCA–28.

Each Member of the Association, at home and abroad, will be sent a copy of the "Official Guide" and free season admission ticket.

As for the 1976 Exhibition, copies of the *Official Guide* and season admission tickets will be available several weeks in advance of the Exhibition (*pre-payment only*) from the Association's office and they will also be available for purchase at the entrance to the Exhibition Hall.

Full details of advertising in this publication, the basic rates for which are the same as for the *Journal*, can be obtained from the Association's offices.

Irish Section

Golf outing

The annual golf outing of the Section was held on Friday 6 June at the Deer Park Hotel & Golf Course, Howth, Dublin, in beautiful weather.

It was gratifying to find that the number of entries constituted a record, namely 35 members and friends, and it was even more pleasing to note that in this International Women's Year there were two lady visitors who also competed.

No doubt next year the Section will encourage more ladies to take part and will probably provide a special prize for them.

The Kershaw Memorial Trophy for members was won by Mr Michael Purcell, with 29 points Stableford, with Mr John Chambers also scoring 29, but Mr Purcell having the better score on the second nine.

Supper was provided by the Hotel in the evening, and a number of non-playing members and several wives also attended. This made a most enjoyable finish to a very successful event and full appreciation should go to the new Social Secretary, Mr Kevin Callaghan assisted by Programme Secretary Mr Robbie Rea. Together they put a tremendous amount of hard work and enthusiasm into the event.

Newcastle Section

British Titan Cup

The fourteenth annual tournament for the British Titan Cup was played for on Saturday 31 May 1975 at Whitby Golf Club.

The "Bogey" competition was won jointly by Messrs C. H. Morris of Berger Chemicals and J. G. Goodrum of Camrex Ltd. This is the first occasion that the competition has been held in Yorkshire and all contestants very much enjoyed playing this picturesque and interesting course.

Mr C. H. Morris (left) and Mr J. G. Goodrum, joint winners of the British Titan Cup

Reunion Dinner for past and present members of Council

Following the successful innovation in 1973 of a Reunion Dinner for those members who have served on Council at any time, Council has decided to hold a similar event this year. The Dinner will take place on Wednesday 15 October 1975 at the Rugby Club, 49 Hallam Street, Portland Place, London W1N 5LJ, at 6.30 for 7.00 p.m., and informal dress will be worn.

The price of the ticket, for the dinner and wine. will be £7.00 (inclusive of VAT), and a cash bar will be provided at the reception and after the dinner. Past Presidents, Past Honorary Officers, Honorary Members and Founder Member have been invited as guests of the Association. All other past and present Members of Council must send the necessary remittance with their completed application form. Any member with service on Council who has not received an application form and wishes to do so should write to the Director & Secretary at the Association's offices.

Notice of meetings

FSCT Convention

Mr J. H. Sinclair (Anchor Chemical Co Ltd), an Ordinary Member attached to the Manchester Section, will present a paper on behalf of the Association at the 53rd Convention of the Federation of Societies for Coatings Technology, to be held in Los Angeles from 29 to 31 October 1975. The paper is entitled "Recent developments in epoxy resin-based coatings" and a short summary is given below.

Summary

The various types of curable epoxy coatings are discussed. Developments have centred round solvent-free coatings, powder coatings and water-dispersible coatings, with solvent-based coatings being largely ignored, although they are still of major importance.

The effect on film properties and overall performance of the newer curing agents and diluents and the improvements which can be expected from new resins currently under development, and from resin blends, in solvent-free systems, are considered.

Of particular significance to the future use of powder coatings is the work which is being carried out on the application of thin films and on improved methods of particle classification. Both these topics are discussed and mention is also made of the improvements which result from the use of recently developed resins and diluents.

Water-dispersible epoxy coatings still fall short of conventional epoxies in a number of respects, and further development work is required in order to produce a more widely acceptable product. Suggestions are made on how this is likely to be accomplished.

Midlands Section

The Section wishes to draw special attention to its meeting at 6.30 p.m. on Friday 17 October 1975, when a lecture entitled "The coatings industry in a changing world" will be given by Dr H. A. Wittcoff, General Mills Chemicals Incorporated, Minneapolis.

Summary

All enterprises must adjust to the environment in which they operate, and the coatings industry is no exception. Thus, the coatings industry finds itself operating in an environment characterised by pollution, actual and potential raw material shortages, automation, rising labour costs and exponential consumption. These realities contribute to far-reaching consequences. These consequences, as they relate to the coatings industry, will be discussed with emphasis on the adaptive posture assumed both in the United States and England. Emphasis will be placed on the effect of these factors on creativity, technology and economics within the industry. The inter-relationship of technical achievement and viability of the industry will be stressed.

The speaker

Harold Wittcoff, in his role as Special Adviser to the President, General Mills Chemicals Inc., is engaged largely in long range planning. He is, in addition, an adjunct professor of chemistry at the University of Minnesota, where he has developed one of the first and one of the most intensive courses in industrial chemistry in the United States.

Dr Wittcoff joined General Mills in 1943 and successively occupied the positions of research chemist, project leader, director of the chemical research activity, director of corporate research, vice-president of chemical research, and vice-president of corporate research. He assumed his present position in February 1973. Dr Wittcoff has over 140 issued patents and has written more than 30 technical papers as well as a book entitled "The Phosphatides".

Presentation in London

The speaker will also present his lecture to the London Section on Thursday 16 October 1975 at an afternoon meeting commencing at 2.30 p.m.

Forthcoming Events

Details are given of meetings in the United Kingdom up to the end of the month following publication.

September

Thursday 4 September

West Riding Section: The OCCA Golf Tournament at the Pannal Golf Course, Harrogate.

Tuesday 9 September

West Riding Section: "Aspects of titanium dioxide durability and accelerated weathering techniques" by a speaker from Laporte Ltd, to be held at The Griffin Hotel, Boar Lane, Leeds at 7.30 pm.

Friday 19 September

Midlands Section: Ladies' Night to be held at Botanical Gardens, Edgbaston, B15 at 7.00 pm for 7.30 pm.

Irish Section: "Management" by Mr P. Rock, Irish Management Institute, to be held at the Clarence Hotel, Dublin at 8.00 pm.

Thursday 25 September

London Section: "North sea oil and gas—its effect on industry". Chairman's Evening to be held at the Imperial College of Science & Technology, Prince Consort Road, Kensington SW7 at 7.00 pm.

Friday 26 September

Midlands Section: "The elements of product coating" by Mr. B. Mickie of Carrs Paints, to be held at the Apollo Motel, Hagley Road, Edgbaston, B15 at 6.30 pm.

Bristol Section: "English Silver" by Miss E. C. Witt of Bristol City Museum and Art Gallery. Ladies' Evening to be held at the Royal Hotel, Bristol at 7.15 pm.

October

Thursday 2 October

Thames Valley Section: "Safety: recent acts" by Mr R. E. L. Everett, Safety Officer, ICI Paints, to be held at the Beaconsfield Crest Motel (White Hart), Aylesbury End, Beaconsfield, Bucks at 6.30 pm for 7.00 pm.

Newcastle Section: "Recent developments in organic pigments" by Dr E. R. Inman, Ciba-Geigy (UK) Ltd, to be held at the Royal Turks Head Hotel, Newcastle upon Tyne at 6.30 pm.

Friday 3 October

Hull Section: Annual Dinner/Dance to be held at the Willerby Manor Hotel, Willerby, Hull.

Saturday 4 October

Scottish Section—Eastern Branch and Student Group: Subject to be announced. The meeting will start at 10.30 am in the Lady Nairn Hotel, Willowbrae Road, Edinburgh, followed by lunch and the annual skittles match.

Monday 6 October

Hull Section: "Polyesters for boat building, tank storage and chemical engineering" by a speaker from Scott Bader Ltd. Joint meeting with the Institution of Chemical Engineers at the Haven Inn, Harrow Haven, Lincs.

Thursday 9 October

Midlands Section—Trent Valley Branch: "Lead chromes: their present uses and future trends, with particular emphasis on recent regulations" by Mr R. M. W. W. Wilson of SCC Colours, London, to be held at the Crest Hotel, Pastures Hill, Littleover, Derby at 7.00 pm.

Friday 10 October

Manchester Section: "Handling of powders and pigments in bulk" by Dr N. Harnby, School of Chemical Engineering, University of Bradford, to be held at Manchester Literary and Philosophical Society, George Street, Manchester at 6.30 pm.

Thursday 14 October

West Riding Section: "Gloss emulsion paints" by Dr Faulkner of Rohm & Haas (UK) Ltd, to be held at The Griffin Hotel, Boar Lane, Leeds at 7.30 pm.

Wednesday 15 October

Reunion Dinner for past and present members of Council to be held at the Rugby Club, 49 Hallam Street, Portland Place, London W1N 5LJ at 6.30 for 7.00 pm. Informal dress.

Thursday 16 October

London Section: "The coatings industry in a changing world" by Dr H. Wittcoff, Prof. of Chemistry, University of Minnesota and Special Adviser to General Mills Chemical Inc. *Afternoon meeting:* lecture commencing at 2.30 pm at the Imperial College of Science & Technology, Prince Consort Road, Kensington, SW7.

Scottish Section: "The health and safety at work act" by Mr F. Hyland, HM Factory Inspectorate, to be held at the Beacons Hotel, 7 Park Terrace, Glasgow at 6.00 pm.

Friday 17 October

Irish Section: "Fuel economy" by Mr S. W. Carroll, Institute for Industrial Research & Standards, to be held at the Clarence Hotel, Dublin at 8.00 pm.

Midlands Section: "The coatings industry in a changing world" by Dr H. Wittcoff, of General Mills, to be held at the Apollo Motel, Hagley Road, Edgbaston, B15 at 6.30 pm.

Friday 24 October

Manchester Section: 50th Anniversary Dinner/Dance, Piccadilly Hotel, Manchester.

Friday 30 October

Midlands Section—Trent Valley Branch: Halloween Dance at Cross Keys Inn, Turnditch, at 7.30 pm.

Friday 31 October

Bristol Section: "Gloss paints: water thinned or solvent thinned?" by Mr D. G. Dowling of Berger Paints, to be held at the Royal Hotel, Bristol at 7.15 pm.

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

CARR-BROWN, ALAN, BSc, 36 Sunset Drive, Bayshore, Trinidad, West Indies *(General Overseas)*

LINCOLN, BARRY NEVILLE, 35 Riversmeet, Hertford, Herts. SG14 1LF. *(London)*

NAUGHTON, ANTHONY, 89 Stoney Lane, Bloxwich, Nr. Walsall, West Midlands WS3 3RE. *(Midlands)*

NICHOLLS, MURRAY JOHN, BSc, PhD, Helena Rubenstein NZ Ltd, PO Box 13-094, Onehunga, Auckland. *(Auckland)*

ROBBINS, JOSEPH SHELBY, Desert Sunshine Exposure Tests Inc., Box 185, Black Canyon Stage, Phoenix, Airzona 85020 *(General Overseas)*

ROBERT, CLAUDE, UNIFAP, 126 Rue Marius Aufan 92300, Levallois-Perret, France. *(General Overseas)*

SCHLUSSAS, UDO KLAUS, 34 5th Avenue, Malvern, Natal. *(South African)*

SMITH, WILLIAM THOMAS, 32 Moorfield, Edgworth, Turton, Bolton, Lancs. *(Manchester)*

WADDELL, COLIN WALTER, BF Goodrich Chemical NZ Ltd., PO Box 12-171, Penrose, Auckland. *(Auckland)*

WAN, ERIC CHAN KIN, 9 Dragon Road 3/F, Causeway Bay, Hong Kong. *(General Overseas)*

WEBB, JOHN PETER, Oakmead, Rushton Avenue, South Godstone, Surrey. *(London)*

ZERLAUT, GENE A., BSc, Desert Sunshine Exposure Tests Inc., Box 185, Black Canyon Stage, Phoenix, Arizona 85020 *(General Overseas)*

Associate Members

HENNING, TIMOTHY JOHN, 11 Pinsent Road, Morningside, Durban. *(South African)*

HOPPER, LESLIE GEORGE, 18 East Gardens, Woking, Surrey GU22 8DP. *(Thames Valley)*

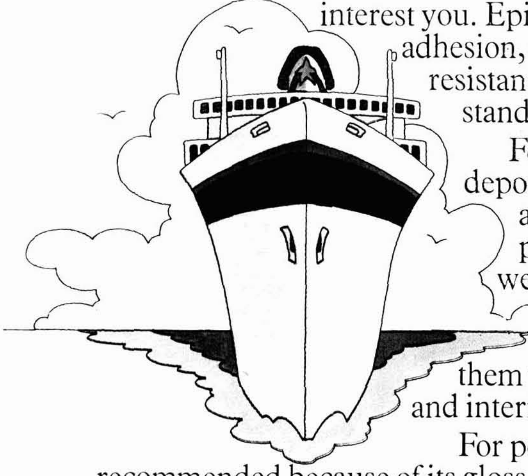
NEWELL, ANTHONY, 4 Wainterburn Avenue, Chorlton-cum-Hardy, Manchester 21, Lancs. *(Midlands)*

PETERS, DENNIS MARTIN, PO Box 92, Isando. *(South African)*

WALKER, GARRY, 3 Kedleston, 87 Botanic Gardens, Durban. *(South African)*

WYNN, LESLIE WALTER, 31 Norton View, Halton, Runcorn, Cheshire. *(Manchester)*

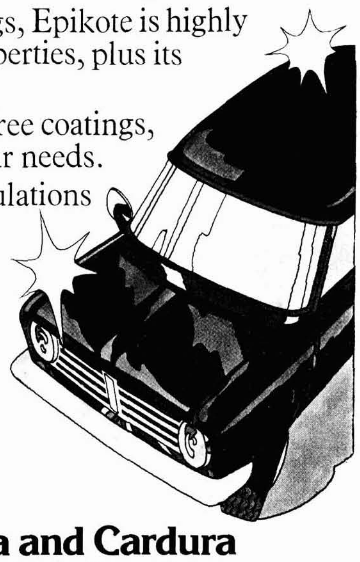
If you can't benefit from one of these resins, you aren't in the paint business.



If you make solvent-borne paints, two of our resins should interest you. Epikote, which offers excellent adhesion, toughness, flexibility and chemical resistance. And Cardura, which offers outstanding gloss and outdoor durability.

For water-based primers for electrodeposition Epikote is ideal for its adhesion and anti-corrosive properties. For emulsion paints, we make VeoVa. VeoVa paints have good outdoor durability and colour stability, which makes them particularly suitable for external and internal decoration of buildings.

For powder coatings, Epikote is highly recommended because of its gloss and flow properties, plus its durability.



And if you make high solids or solvent free coatings, we have an Epikote grade which is right for your needs.

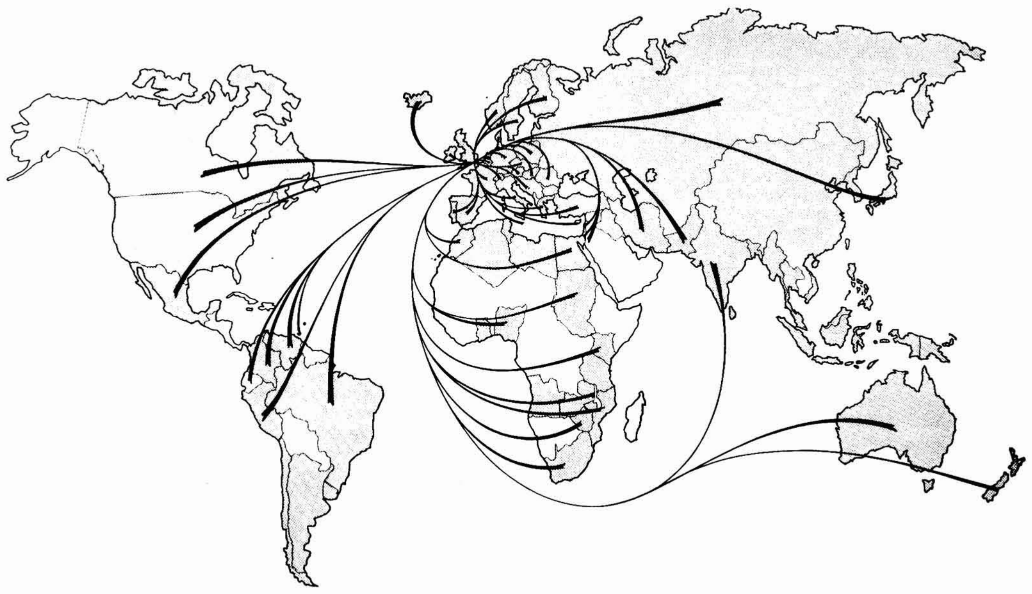
We are now developing new resin formulations for spray-applied, water-based paints. We are developing Cardura high solids coatings with good outdoor durability and gloss. And we are developing Epikote powders for automotive primers, drum linings, can coatings and pipe coatings. For more information, please contact your Shell company.*

Epikote VeoVa and Cardura
Better resins make better paint.

Shell Chemicals

In the U.K. this is Shell Chemicals UK Ltd., Villiers House, 41-47 Strand, London WC2N 5LA. Tel: 01-839 9070

Just look at JOCCA's cover!



We don't just mean the cover of this *Journal* (but lots of people do, of course, since our ABC circulation is larger than that of any other UK publication covering the surface coatings industries—see graph on page xxi). Consider what advertisers get by taking space in OCCA publications:

Firstly the *Journal*, with its unrivalled circulation, is sent each month to readers in over 70 countries shaded on the map. Can you as advertisers afford not to take advantage of this coverage?

Secondly, there is the "Official Guide" to the annual technical Exhibition at Olympia, London. The arrows show the 50 countries from which visitors travelled to OCCA-25 in May 1973. The basic rates for advertisements in this publication are the same as for the *Journal*. Why not take advantage of the reduced six or twelve insertion rates and advertise in both the Official Guide and the *Journal*?

For further information concerning advertisements in these or other OCCA publications, contact C. A. Tayler, JOCCA Journal of the Oil and Colour Chemists' Association, Priory House, 967 Harrow Road, Wembley, Middlesex, England HA0 2SF. Tel: 01-908 1086. Telex 922670 (OCCA Wembley).

CLASSIFIED ADVERTISEMENTS

Classified Advertisements are charged at the rate of £2.50 per cm. Advertisements for Situations Wanted are charged at 60p per line. A box number is charged at 50p. They should be sent to the Director & Secretary, Oil & Colour Chemists' Association, Priory House, 967 Harrow Road, Wembley, Middlesex HA0 2SF

SITUATIONS VACANT

Organic Chemists (Development)

W. A. Mitchell & Smith are seeking qualified chemists to staff the Company's new laboratories scheduled to open in September.

The type of work will centre around synthetic resin development based on polymer reactions such as esterification, phenol formaldehyde condensation, vinyl polymerisation, urethane formation etc.

Applicants should be aged about 30, possess a University degree or membership of the Institute of Chemistry and have some experience in the above fields of organic chemistry preferably related to the paint and ink industries. Write to:

**Technical Director,
W. A. Mitchell & Smith Ltd.,
54, Willow Lane,
Mitcham,
Surrey, CR4 4NA.**

giving details of qualifications, academic career and industrial experience.

SIGMA COATINGS

CHIEF CHEMIST
(DIRECTOR DESIGNATE)

Sigma Coatings Ltd., one of the most rapidly expanding paint companies in Britain, is seeking a qualified chemist, extensively experienced in surface coating technology, to take charge of all its technical functions in the United Kingdom, including those of its subsidiary company, E. & F. Richardson Ltd.

The successful candidate is likely to be in the 35-45 age group, will certainly have wide practical knowledge of all types of coatings from the aspects of formulation, development, manufacture and testing, and must be capable of sound administrative control of a complex technical organisation; experience of field service and inspection management, involving high performance coatings on steel, would also be relevant.

He will be directly responsible to the Managing Director and must be of sufficient calibre for eventual promotion to the Board. It is unlikely that any applicant currently earning less than £5,000 per annum would be suitable for this senior appointment.

The Chief Chemist will be located in modern laboratories in Buckingham, but will spend considerable periods on the Continent, in liaison with Sigma central research units in Holland and Belgium.

The salary will be attractive to the successful applicant. A company car will be provided, and the usual fringe benefits will apply. A Pension Scheme with excellent benefits is in operation.

Please apply in confidence, giving brief details of qualifications and career, to

**The Managing Director,
Sigma Coatings Ltd.,
Castle Mills,
Buckingham, MK18 1ED.**

PROJECT MANAGER

required for international company to develop the technical possibilities (patented) of new chemicals and to be responsible for commercial exploitation. The candidate should be 35-45 years of age with a sound chemical education, a good organiser, and experience of negotiations at international level. It is possible that for an energetic, goal-orientated creative person, that this position could lead to general management.

Curriculum vitae to Box No. 413.

SITUATIONS WANTED

Indian, 33 years, working in USA. Broad experience in paint, printing ink formulation. Knowledge of G.C. and I.R. Also, emulsion and acrylic solution polymer experience. Looking for an opening in India or other parts of Asia. Box No. 410.

Paint technologist HNC, FTC, group leader (additive development), seeks responsible post in England or Wales. Technical sales and/or laboratory work acceptable. Fluent German (sales experience in W. Germany) plus paint formulation and corrosion prevention knowledge. Box No. 412.

MISCELLANEOUS

PAINTMAKERS' ASSOCIATION SYMPOSIUM

The Paintmakers' Association has announced the holding of a Symposium *"Powder for Profit"* which will take place from Tuesday 28 to Thursday 30 October 1975 at Penns Hall Hotel, Sutton Coldfield, near Birmingham. The Symposium is being organised for the Powder Coatings Group of the Paintmakers' Association of Great Britain Limited by the Conference Division of Wheatland Journals Limited, 157 Hagden Lane, Watford WD1 8LW. The registration fee for three days will be £50.00 plus VAT, and for two days £35.00 plus VAT.

You can send a telex for an advertisement in JOCCA (or in reply to one), at any time of day or night, by dialling:

922670 (OCCA WEMBLEY)

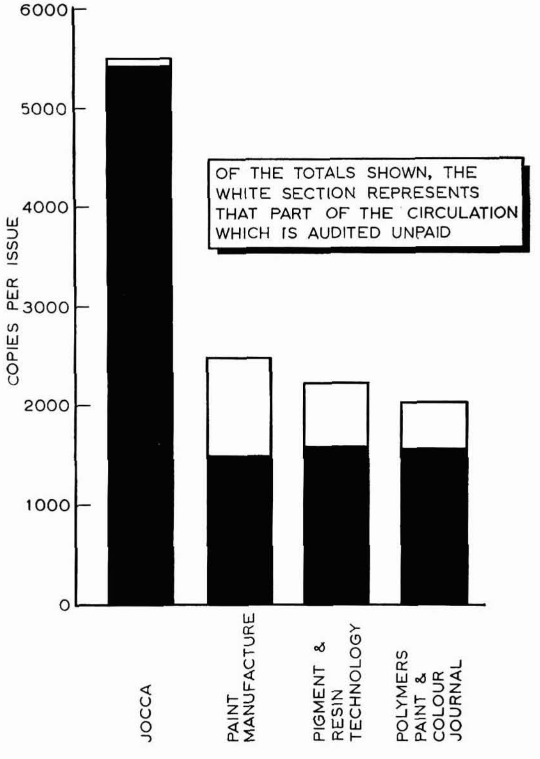
OCCA-28—The continuous dialogue between suppliers and manufacturers

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

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

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

For full details, see page 356.



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