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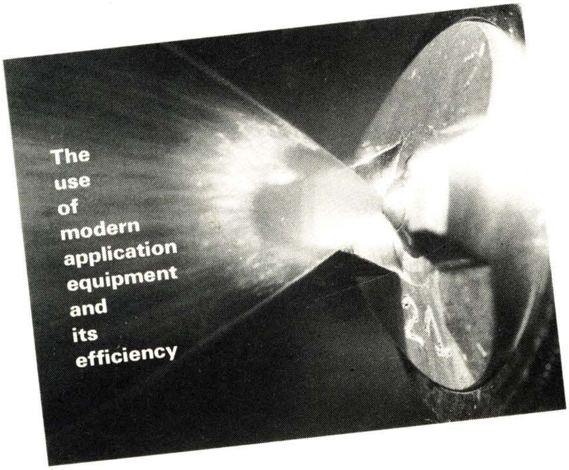
# JOCCA

Automobile body finishes – where from, where to?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1984
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*Reader Enquiry Service No. 280*

# Automobile body finishes – where from, where to?*

**H. L. Quick**

Talbot Motor Company Limited, Engineering Services, Administrative Offices, Abbey Road, Whitley, Coventry CV3 4GB, United Kingdom

## Introduction

The motor car possibly constitutes one of the most challenging objects that has ever had to be protected and decorated. The objective, from the beginning, has been to erect, as far as possible, an inert barrier between the reactive metal surface of the body and the environment in which the vehicle operates. It is true to say that a great deal of effort has gone into improving both the methods and materials of motor vehicle painting over the years, particularly in the last 20. While no one will pretend that the ultimate has yet been reached in terms of vehicle body life, there can equally be no doubt that significant advances have been made in resisting the effects of a more aggressive environment while meeting the demands of an increasingly critical consumer.

The painting processes and materials applied to practically all automobile bodies in this and other countries are similar and can be considered under three main headings:

1. Pretreatment and priming
2. Surface preparation
3. Colour finishing

## 1. Pretreatment and priming

Contrary to popular belief, the methods of metal pretreatment and paint systems employed pre-War were less effective than those subsequently developed, and very poor indeed compared with those currently being employed. Again contrary to popular belief, the motor industry was, and is, very conscious of the need to improve the situation and in conjunction with paint and pretreatment industries has engaged in continuing development programmes to this end.

The technical people charged with effecting improvements were well aware that one of the biggest shortcomings in the processes being conducted in the post-War boom days of the industry was the inability to achieve a satisfactory metal surface condition prior to painting. The early fifties, therefore, saw the introduction of phosphating processes as a means of metal treatment, the use of which resulted in cleaner surfaces with increased mechanical keying offered to the subsequently applied paint films.

Large spray plants were devised for the treatment of bodies, but these were not without disadvantages. For instance, many areas such as door shuts were shielded from sprays, and box sections were not treated at all. Developments gave rise to alternative methods resulting first in the roto-dip method and then in a combined dip/spray method. The latter was practised first by Talbot and its predecessors in the UK as long ago as 1969, only recently being introduced by other UK companies.

Having phosphated the body, it was still in need of protection and decoration.

Most of the damaging corrosion was in the lower parts of the body and largely occurred from inside surface out, so attention was concentrated on protecting the inside surfaces of box members and other essentially closed sections. Various methods of prime painting were devised and it seemed that underbody dipping, or slipper dipping as it was originally called, could be the most practical. By this process the body, after degreasing and phosphating, was passed through a tank containing a priming paint to a depth of about three feet. Thus all the underbody of the car and the whole structure up to a point well above the bottom of the doors was immersed in paint.

At about the same time the roto-dipping method of phosphating was extended by adding a priming stage. By this method the whole of the body received a coat of primer. Whereas, however, the underbody dip plants were mechanically simple, the roto-dip plants were massive and complex in operation; paint formulation and control was extremely critical in plants of both types, but particularly in roto-dipping, if runs, sags and other defects were to be minimised on production lines dealing with up to 40 bodies per hour.

Having invested in these facilities, it is true to say that the motor industry as a whole was perturbed to find that the protection was not all that their earlier tests had indicated. Investigations showed this to be largely due to solvent washing. This is a phenomenon whereby the vapour from the evaporating solvents condenses on areas of still wet paint and washes it away, or much of it, leaving at best only a thin film. This occurred most in enclosed areas such as box sections, bottoms of doors etc., where, due to lack of air circulation, heavy concentrations of solvent vapour were present. Thus the phenomenon conspired to deprive of protection those areas most in need of it, indeed those areas which the processes were specifically designed to coat and protect.

Development work was conducted on both the resins and the solvents to a point where the primers became more resistant to solvent washing, although this was never completely eliminated.

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*Paper presented at the Association's York Conference, 15-18 June 1983, session IV. Following presentation of the four papers of this session, general discussion took place which was not recorded.

Since the late sixties the shortcomings of the earlier priming systems have been tackled by applying the paint film by electrodeposition and this process is now operated by all the major manufacturers in the world.

The process as originally developed used the car body, after phosphating, as the anode in the system and substantially overcame the major problems arising from normal dipping operations involving solvent-based paints. Solvent washing was eliminated because the electrodeposited film contained only a very small amount of volatile solvents. An even film was deposited instead of one varying in thickness from the top to the bottom of panels as exhibited by conventional dipping, and finally, but not least important, the electrodeposited film was more effective in covering sheared edges which, due to surface tension, a solvent-based paint will not do.

Having said this, it must be admitted that once again the process and materials as originally developed were both a benefit and a disappointment to the motor industry. They were a benefit in that areas of motor bodies hitherto difficult to coat could be painted and given reasonable protection. A small amount of properly formulated paint can confer a lot of protection under specific environmental conditions – the difficulty hitherto was in applying that small amount of paint in a continuous film.

The disappointment arose from the comparatively poor performance of the deposited films as part of the whole system of body finishing. Chip resistance left much to be desired and there were instances of a rapid spread of corrosion from small areas of damage on the exterior surface of vehicle bodies. The importance of the phosphate film in relation to paint film properties had not been adequately appreciated prior to the introduction of this method of priming, and painful and expensive lessons were learned by vehicle manufacturers as a result.

More recent developments, largely of American origin, have resulted in the introduction of cathodic electrophoretic primers. This change of polarity was accompanied by extravagant claims for its superiority over the earlier anodic process in terms of corrosion protection, throwing power, lay down etc. While the original claims have to some extent been modified, there are advantages to be gained from the process and there is no doubt that if one is contemplating a change of process or plant replacement then the cathodic method must be the way to go. In this connection it is worth noting that the first automobile body plant in Europe to employ the cathodic process was in Talbot (then Chrysler) France and the first automotive body plant employing the process in the UK was the Talbot (then Chrysler) Dodge truck plant at Dunstable. It was at this latter plant that one of the advantages of the cathodic system, better lay down of the film, enabled the intermediate coats to be dispensed with, so that the process of van body painting consisted of primer and colour coats only. This good lay down of the primer gave a gloss to the finish which is considered to be perfectly acceptable for a commercial vehicle.

## 2. Surface preparation

The processes used in building a motor car body involve a considerable amount of work on the panels which make up that body, in addition, that is, to the normal pressing operations. Thus small dents or dings are hammered out, while joints in panels may be filled with solder and subsequently filed or ground to give a smooth surface of the correct profile.

Paints used in the second stage of body processing have had as their main properties the ability to fill minor imperfections in the metal surface, and to be further processed so as to present the body in a suitable condition to receive its final colour coats.

The development of such materials has been influenced by the improving standards of pressings over the years since the introduction of all steel bodies. Thus the early materials, known as fillers for obvious reasons, were formulated to give extremely high build. Due to their open nature a further coat, a sealer coat, was applied prior to the application of the colour coats.

As the early fifties saw the installation of the first mechanical phosphating and priming plants, so that period also gave birth to the basic technology of materials for surface preparation. Alkyd materials were followed firstly by epoxys and then by polyesters with all sorts of mixtures in between. Anticorrosive properties were incorporated and the range of formulations developed were variously referred to as surfacers, primer-surfacers or even primer-sealers. As the motor industry became increasingly aware of the cost of applying such materials only to rub most of them off again, developments occurred in the direction of non-sanding surfacers.

However, near-perfect metal conditions and freedom from dirt inclusions are necessary to achieve reasonable visual quality standards in the fully finished vehicle, and these have stretched the capability of volume car producers on a day-in day-out basis in the absence of a sanding operation. Certainly, at present, the visual difference between a non-sanded body and one which has had a reasonable wet sand is readily appreciated by most observers and is worth money in the showroom.

## 3. Colour finishing

As with other aspects of body finishing, the top or colour coats have also developed over the years from the universally used cellulose of the pre- and immediate post-War years through the alkyds to the acrylic enamels of today.

There have been times in this development when the changing patterns of requirements in motor industry markets caught up with and overtook the technology of paint manufacture. This situation arose from the increasing influence of the stylists in post-War years. These people, encouraged by strong transatlantic influences, selected colours and effects which were beyond the capability of the local paint industry to manufacture successfully, bearing in mind the climatic conditions existing in the markets in which cars were being sold, for this was in the heyday of the export of built up vehicles from the UK. Thus the early attempts at metallic finishes, for instance, put back their adoption by many years.

In fairness, paint manufacturers have, over recent years, greatly improved their products by technological investments on a large scale and today the motor industry is finishing cars with high quality, high durability alkyd and acrylic materials, the latter as both solutions and dispersions.

The improvements which have occurred in both resin and pigment technologies have resulted in the availability of a range of extremely bright colours which have significant advantages to both manufacturers and the buying public. From the manufacturers viewpoint it has to be admitted that lighter colours are easier to handle than darker colours and result in fewer rejects first time round. From the public viewpoint, as well as being aesthetically attractive they have a safety aspect in that they are more easily seen in conditions of poor visibility. The problems of poor durability of metallic finishes have been overcome by the advent of base plus clear systems, utilising either polyester or acrylic base coats, and covering the vulnerable metallic pigment with a thick coat of clear varnish usually based upon acrylic resins. Such systems are now in worldwide use and have resulted in a very high level of showroom appeal and service durability.

At this Conference* we are concerned with the efficient use of surface coatings. In the future, as in the past, the objective of surface coatings in the motor industry will continue to be to protect and decorate the product and to achieve the maximum in both at the minimum cost. With this in mind perhaps some discourse on the UK vehicle market is not entirely out of place at this point.

The UK market is peculiar in that around 70 per cent of all new vehicles are bought by businesses. They are therefore part of the equipment of a company and their costs and maintenance must be covered in the business accounts of that company. With the private buyer, a vehicle is bought out of savings which are, in effect, the profits an individual makes by efficiently managing the business of living on a salary. The significant differences in the attitudes and requirements of these two types of buyer present the vehicle manufacturer with difficult decisions in respect of producing a vehicle which is neither over priced nor under specified. The driving force behind any product decision in the motor industry is essentially the competitive nature of the business; the knowledge that if a competitor can offer customers something more attractive either in price or feature, then we risk losing business to that competitor. So the customer becomes that driving force and the need to satisfy him is paramount. But what does the customer want?

The majority of commercial or business buyers are short term owners interested in a car which will exhibit the maximum in performance, in all meanings of the word, with the minimum in maintenance costs and the maximum trade-in value. He may keep the car for a maximum period or to a maximum mileage, which may amount to the same thing, for two years or 60,000 miles are not untypical requirements. For such an owner, body decoration and protection is not a significant problem.

The private buyer, on the other hand, may be looking for longevity – although only a proportion of such buyers are what may be termed "whole life" buyers. Again the bulk of cars which are bought from new by private buyers are turned over, on average, after three years and these owners again look for high performance, low maintenance costs and high trade-in value. So here we have a situation where a significantly large percentage of vehicles are only retained by their first purchaser for, say, three years. By today's standards, not even the most ill-specified vehicle, from a protection standpoint, should exhibit any marked deterioration of the finish or suffer corrosion of the structure in that period of time. However, the termination of the first period of ownership is merely the start of the second, third and, in all probability, fourth periods.

Do we in the automobile industry give these later owners a fair crack of the whip or are we, as some allege, not interested after the first two or three years?

It has to be said emphatically that no manufacturer intentionally designs a car to corrode away or fall apart.

There is a constant battle to improve quality and lengthen the life of the product within price levels which enough potential customers – first purchasers that is – are prepared to pay. It is significant that manufacturers throughout the world implement the same principles of design and construction whether the cars are made in Russia, Japan, Europe or America. Conceivably, in capitalist Western society shorter life products may be expected, but in fact, Western products are generally much better designed and protected than those built in countries where the profit motive is not, allegedly, held in high regard.

The battle for increased durability has culminated in comprehensive anticorrosion guarantees being given by many of the major car manufacturers. Typical of such guarantees is that which covers all Talbot/Peugeot products. A six year warranty is given against perforation of the bodywork by corrosion provided certain conditions of re-inspection are complied with. The benefit of this warranty is available to the first and all subsequent owners of the vehicle up to this period of six years.

The means by which corrosion is retarded may include some or all of the following:

- The use of precoated steel in vulnerable areas (galvanised, electro-zinc or Zincrometal for example).
- The use of weldable primers on all welded flanges.
- The design of the body to permit adequate and effective draining.
- Pretreatment of the body by full or partial immersion in phosphating solutions.
- The application of an initial (prime) coat by total immersion of the body shell in an electrophoretic bath.
- The application of thermosetting anti-gravel compounds to the wheelarches, underfloor area and sills.
- The injection of wax compounds into the hollow box sections of the body shell.

Thus are employed a comprehensive range of surface coatings and surface coating operations, designed to meet the objective of providing a barrier between the reactive metal surface of the body and the environment in which the vehicle operates.

This, then, is where we are today. Where do we go from here?

In the future as in the past, the objective in the motor industry will be, as stated above, to decorate and protect the product and to achieve the maximum in both decoration and protection at the minimum cost.

In considering future developments in surface coating

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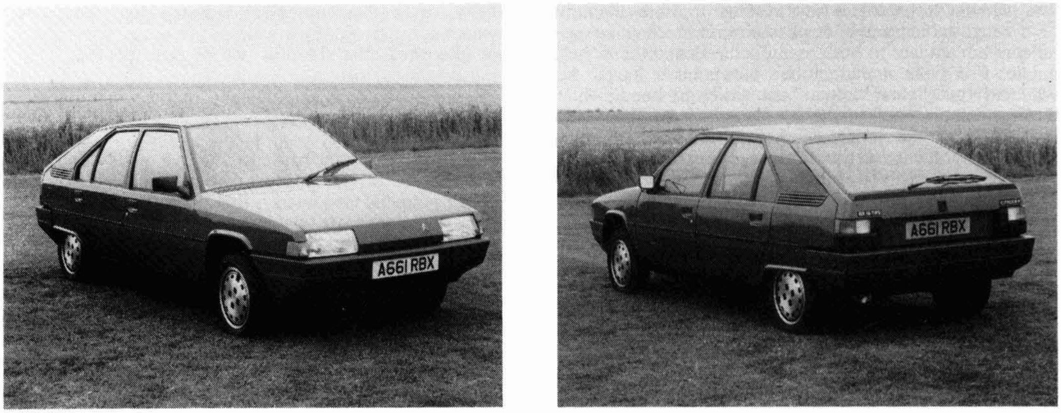
*See footnote on page 361.



Figures 1. (Left) and 2. (Right) The Citroen BX embodies bonnet, tailgate and other panels in reinforced plastics materials

materials and processes, it is necessary to look first at factors which may bring about the need for change.

Firstly there is the economic factor, that is the need to remain competitive according to all meanings of the word. Secondly there is the design factor, arising from the need to improve performance, appearance and durability. Thirdly there are the requirements of the law – the legislation factor – as they affect the design and performance of the vehicle, the methods used to protect and decorate that vehicle, and local environmental effects arising during vehicle manufacture and use.

These factors are obviously totally interdependent and none of them can be considered very far in isolation. Economic pressures are always with us and are not always under the direct control of the vehicle manufacturer. In terms of surface coatings, there are only limited means of effecting economic improvements given that the materials themselves are relatively cheap. True, materials utilisation is open to improvement and the present trends towards sophisticated automatic (robotic) equipment, frequently employing electrostatics, will probably exhaust that aspect. However, the expense of such equipment can never be justified on the basis of materials savings alone. It has to be coupled with savings in manpower and significantly improved "buy-off" rates. In the late seventies the average buy-off rate for most body paint shops did not usually exceed about 65 per cent on a day-in day-out basis. Today this figure on average is 80 per cent, although some claims are made for 95 per cent first time OKs. This high figure depends on how one defines "first time OK", however.

Taking, say, a 20 per cent loss rate, an analysis of the reasons for rejection shows a remarkable degree of similarity from company to company: 60 per cent plus of all rejects are due to dirt. The remainder are fairly evenly divided between application problems (runs, sags, lack of cover etc.) and physical damage. There is thus a great incentive to "win" that 20 per cent. This can happen by strict attention to detail but will come mainly from facility changes to booths and ovens, where air movement and vibrational problems have to be reduced and closely controlled, and by the extension of effective automatic methods of paint application.

Perhaps the possibilities for future development of surface coating materials should be discussed under the same three headings as used earlier viz. 1. Pretreatment and priming, 2. Surface preparation, and 3. Colour finishing, since it seems likely that such a processing breakdown will continue to be relevant for the foreseeable future.

Before entering upon any speculation under such headings, however, we should consider the material to be protected. Will the body remain essentially made of steel? Will it be injection moulded, blow moulded or vacuum formed in plastics materials? Will aluminium enter the picture?

Every vehicle manufacturer in the world is actively pursuing the design and development of vehicles with the objective of improving performance and reducing fuel consumption, and all manner of alternative body concepts in terms of design and materials are being evaluated. From time to time enthusiastic PR men show these models to the press and immediately give the reader or viewer the impression that "this is it". The copy makes better reading when the body is substantially made of plastics materials, giving full rein to the undoubted enthusiasm of plastics marketing people in conveying the belief that because progress has not been faster then we – in the automotive industry – are a lot of unimaginative stick-in-the-muds.

In truth it has to be realised that the motor industry has a huge financial investment in equipment, the bulk of which is of a "single purpose" nature, as presumably would be any which replaced it. And this consideration must be paramount in considering changes in the materials and processes of motor vehicle construction. However, all aspects of change are under evaluation and the most cost effective ideas will progressively find their way to the production line.

There is no doubt in the writer's mind that so far as passenger car bodies go, they will, for the foreseeable future, remain substantially of metal and that metal will be steel. There will be the progressive introduction of hang-on plastics parts (the Citroen BX is an example) but the essential structural performance of the car will be based upon the strength and energy absorption (plastic deformation) characteristics of steel.

## 1. Pretreatment and priming

If we are still making car bodies of steel, what are the likely developments in the years ahead?

**Figure 3. The newly introduced Peugeot 205 has a comprehensive anticorrosion specification based upon the use of zinc precoated steels, which account for over 40 per cent of the body weight**

The use of pre-coated steel will continue to increase – in the interests of protecting the less accessible parts of the vehicle body – even beyond the current level of about 40 per cent of the body weight employed on the Peugeot 205, a new car not yet on sale in the UK*. This increasing use of mixed metals in the body construction will continue to demand that phosphate pretreatments are utilised and further developed. The remaining spray phosphate plants will be replaced by more sophisticated ones employing dipping modes and there may well be a more widespread move towards electrolytic cleaning of the body as a first stage.

Priming will continue to be by electrophoretic cathodic means but there will be developments which will further improve the properties of the applied film. Thicker films may be applied in many cases, giving rise to the possibility of a deletion of the surfacer coats. However, there would have to be considerable further development in a number of directions before such a revised process would be capable of reproducing today's high standard of visual finish on passenger cars.

## 2. Surface preparation

The use of intermediate or sandwich coats between the primer and the colour has been necessary in order to fill minor imperfections in the body panel surface.

It seems unlikely that the quality of steel sheet or press tools will increase much beyond their present levels and the demand will still exist, therefore, for an intermediate coating to assist in achieving the final visual appearance and performance of the paint system applied to the vehicle.

The developments currently going on in non-sanding materials will continue, for sanding or flatting operations are expensive and are an obvious target for cost conscious management. Developments in the formulation of surfacers will be influenced by any changes to the primer and subsequent colour coats and will therefore be evolutionary in nature. There will still be activity in the region of water-borne surfacers and, possibly, powder coatings. The former is currently well-developed but still with significant drawbacks, while powder coatings are not, it is felt, really serious contenders as intermediate or other coatings on significant exterior surfaces of automobile bodies.

## 3. Colour finishing

The short term future for colour coats seems to lie in an extension of the present types of materials probably towards higher solids versions. In parallel will be the continued development of materials which will stick to such plastics panels as may be utilised and which will exhibit the necessary flexibility to go with some of the "soft-feel" effects which will probably be on the increase. The problems which may be most difficult to overcome are achieving adequate adhesion at low stoving temperatures, for most plastics are not capable of withstanding current production temperatures, and at the same time producing an acceptable appearance in terms of gloss, texture and colour-match.

It is hard to see that economic and design factors will be other than satisfied by evolutionary developments of current materials and processes over the next five to ten years. Legislation must therefore be considered a major factor to influence changes. Such legislation could affect vehicle design, if for example soft front ends were to become mandatory, but more likely the effective legislation in terms of surface coatings will be aimed at improving both the working and general environment.

The worst aspect of the working environment in the context of car body painting is the spray booth, where the investment in automatic painting equipment already referred to has improved both environment and paint utilisation. The car body, however, is such a complex shape that significant hand spraying may still be necessary with even the most sophisticated spray machinery. Proposed legislation, requiring all paint sprayers to wear a face mask employing a positive pressure of air, could open the door wider to materials which are currently held to constitute a health hazard.

Improvements in the general environment will result from pollution control measures aimed at booth and oven extract stacks. Legislation yet to come in this country may prohibit, or significantly reduce, the discharge of hydrocarbon solvents into the atmosphere. It is this possibility which strengthens arguments in favour of water-thinnable materials, powder coatings and high solids materials.

Powder coatings have been tried and discarded in many plants and must no longer be considered contenders in the auto-body finishing field. Water-borne finishes still have some support despite the drawbacks of such finishes: the expensive plant modifications and high energy costs involved. But they still may make an appearance in strength.

High solids materials for colour finishing, as well as intermediate coats, seem destined to be the first and major step in the direction of both efficiency of application and reduced pollution, although really high solids materials will call for modifications to application equipment and methods in order to realise their full potential.

High solids, two-component enamels, isocyanate cured, have been available for some time on the refinish market, but little has yet been done with them in volume production. Such materials have attractive advantages to set against their obvious major drawback. They give high build and can be cured at lower temperatures than conventional enamels. They will air dry and are therefore used for accident repairs, ensuring that such repairs – for the first time since the advent of stoving finishes – can be conducted with materials identical to those used by the vehicle manufacturer. This is an important advantage since the developments in factory applied enamels to date have caused a widening "durability gap" between the original finish and the garage repair job.

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*Put on sale in the UK in October 1983.

In preparing this paper, the writer was conscious of the fact that the end result could be no other than to forecast only evolutionary changes over the next ten years and perhaps relatively minor ones at that.

The motor industry has been producing cars in volume for over 60 years and the basic technology of the product has changed little in that period. The aim throughout has been continuously to improve that product, and the vehicle produced today is superior in performance, in durability and in relative price to anything which has gone before. These aims must, and will be, maintained for the future.

**Acknowledgement**

The author wishes to thank Talbot Motor Co. Ltd for permission to present this paper. The opinions expressed herein are his own and do not necessarily reflect the views of the company.

*[Received 17 June 1983*

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# The use of modern application equipment and its efficiency*

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## 1. Introduction

Before discussing the efficiency of different atomising applications, it is necessary to mention the general parameters in atomising the paint and how the atomised particles of paint are transferred to the article being painted. In the painting processes to be discussed, the paint is atomised by the following methods:

1. Conventional air spray
2. High pressure (airless)
3. High pressure and air (airmix)
4. High speed rotary atomisers (discs and bells)
5. Electrostatic blade coater

## 2. Paint atomisation

The ability of a paint to atomise is largely dependent on its viscosity and surface tension. The size of the paint droplet will vary with the method of application. The different stages of high pressure atomisation of the paint into droplets can be seen in Figure 1. First a sheet of paint is formed, this then breaks up into strands and finally into droplets which are transported to the article being painted by the initial velocity of the paint leaving the nozzle.

The sequence of atomising paint with high speed discs and bells is very similar but, in addition, the electrostatic charging of the paint droplets attracts them to the workpiece.

Atomisation with the conventional air spray gun takes place by the action of the air tearing the stream of paint into droplets as it leaves the nozzle.

The fineness of the atomisation governs the quality of the finish. With a paint that will not atomise easily, a thicker wet film has to be applied to achieve the flow and coverage required. If the particle is too small its momentum as it travels towards the object will be slowed down so rapidly by the atmosphere that it will never reach the workpiece. This is particularly noticeable with a conventional spray gun, where the compressed air rebounding from the workpiece produces more of a barrier for the atomised paint particles to penetrate. The smaller paint particles will also be pushed sideways as the compressed air leaving the spray gun expands outwards.

## 3. Application efficiency

The application efficiency of a piece of spray equipment is usually regarded as the amount of paint which is transferred from the paint container to the workpiece. It does not take into account the evenness/distribution of the coating over the surface of painted component.

### 3.1 Transfer efficiency

As already mentioned, this is the amount of paint transferred to the article being painted and is expressed as a percentage. The high speed rotary discs and bells are achieving transfer efficiencies of over 90 per cent, whereas with conventional air spray the transfer efficiency can be 50 per cent or lower. The higher the transfer efficiency, the less problems there will be with spray booth extraction and the treatment of the paint overspray.

### 3.2 Distribution efficiency

This is a measurement of the evenness/distribution of the coating over the painted article. Figure 2 shows the film thickness distribution of a dipped coating, to illustrate the unevenness of the paint.

When it is necessary to achieve a minimum dry film thickness of 12 microns, there could be 30 microns at the bottom of the panel. Although the transfer efficiency of the electrostatic discs and bells is very high, if the right jigging and settings are not used the distribution efficiency will not be very good, as the paint will build up on the edges.

Figure 3 shows the layout of panels passing in front of reciprocating air electrostatic guns or electrostatic bells. With the spacing between B and C being much greater

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*Paper presented at the Association's York Conference, 15-18 June 1983, session IV. Following presentation of the four papers of this session, general discussion took place which was not recorded.

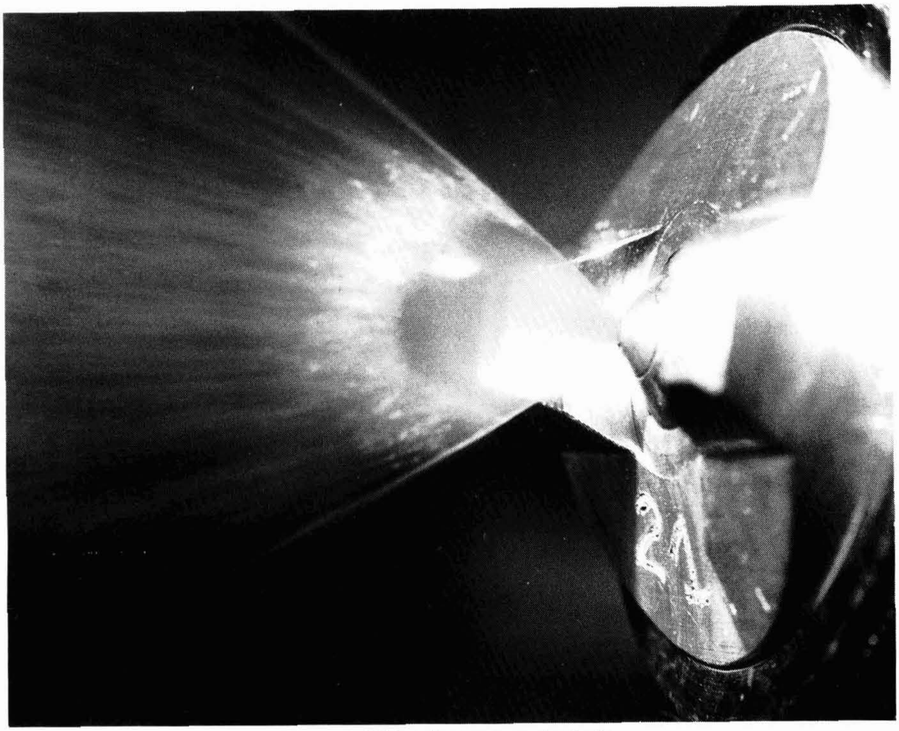


Figure 1. High paint-pressure atomisation

than that between A and B, there will be a paint build-up on the trailing edge of C and on the leading edge of B, unless there is a sensing device which will cut off or reduce the paint delivery.

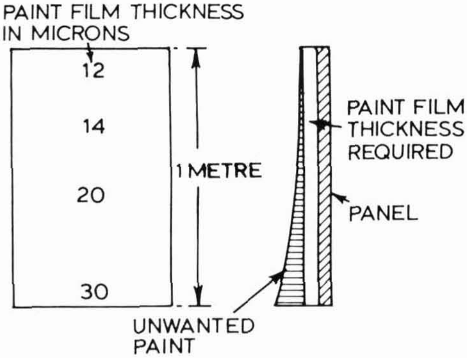

PAINT FILM THICKNESS IN MICRONS
12
14
20
30
1 METRE
PAINT FILM THICKNESS REQUIRED
PANEL
UNWANTED PAINT

Figure 2. The dry film thickness distribution of a dipped coating (in microns)

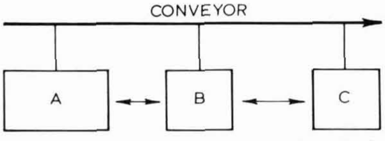


Figure 3. Panels on a conveyor line with a layout of differing spacings

It can therefore be seen that in selecting the application equipment to be used, the distribution as well as the transfer efficiency should be considered.

## 4. The more efficient spray application equipment

When considering a more efficient application method the first thought is towards some form of electrostatic spraying. Table 1 gives an indication of the transfer efficiency which can be achieved by different electrostatic application methods, and the effect that the electrostatic forces have on the degree of atomisation and transfer efficiency.

Electrostatic systems cannot always be used. They need to have a conductive substrate and it is difficult to get paint into recessed areas due to the Faraday cage effect.

Over the last few years we have seen the emergence of a very interesting new application system called airmix. This is a low pressure airless system with the addition of a small quantity of air to perfect the spray fan.

## 5. Electrostatic hand spray systems

The systems which will be discussed are conventional air spray, airless, and airmix with the addition of electrostatic charging. Figure 4 shows a typical air electrostatic hand spray gun.

The main difference from the same type of non-electrostatic spray gun is that the barrel and air cap are made of a plastic material, so that a spark cannot be produced which could ignite the paint.

*Table 1*

| Electrostatic equipment | Transfer efficiency (%) | Effect of electrostatic forces on degree of atomisation | Effect of electrostatic charging of paint on transfer efficiency |
|---|---|---|---|
| Pure electrostatic (blade coater) | 99 | very important | very high |
| Spinning discs or bells, low and high speed | 85–95 | low speed – important<br>high speed – not so important | high |
| Air spray electrostatic | 50–65 | not important | not so important |
| Airless electrostatic | 60–70 | not important | not so important |
| Airmix electrostatic | 70–85 | not important | high |

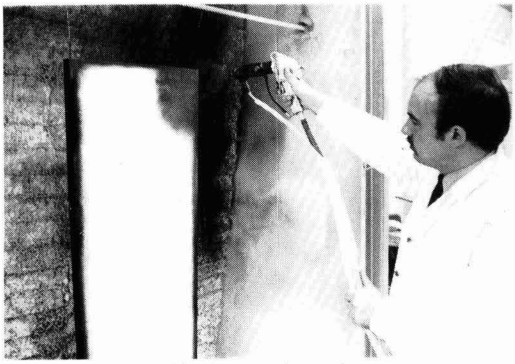


**Figure 4. Air electrostatic hand spray gun**

The draft "European Standard for Hand Held Electrostatic Spray Guns for Use with Flammable, Non-flammable Liquids and Powders" is now available for public comment. It is also intended to produce a new code of practice for the correct installation and use of equipment to replace the Guidance Note EH9 from the Health and Safety Executive, "Spraying of highly flammable liquids".

The manufacturers of electrostatic hand spray guns supply their equipment at different voltages, which range from 30 – 80 kV. To achieve the best application transfer efficiency, the paint must be within the resistance range recommended by the equipment manufacturer.

### 5.1 Air electrostatic hand guns

This equipment replaces conventional air spray guns to reduce the paint wastage and increase productivity. There is a certain amount of wrap-around, which reduces the time taken to paint a component. Unfortunately, the optimum efficiency is rarely obtained as the operator generally turns up the atomising air pressure higher than is necessary.

### 5.2 Airless electrostatic

Airless electrostatic, particularly the hot version, has established itself as the best application equipment for larger components, such as agricultural and earth-moving equipment, where "throw" is required to get the paint into the difficult areas, and the ability to apply a heavy coat in one application.

### 5.3 Airless-air electrostatic (airmix)

The principle of the airless-air system will be described in a subsequent section; it will be referred to as airmix not because it is a trade name and easier to use but because since its introduction in 1975 very many users know this method of atomisation as airmix. There is also no generally accepted technical name, it having been referred to as airless-air, air-airless, low pressure airless with air, and hybrid airless.

The addition of electrostatic charging gives a better transfer efficiency; as the velocity of the paint droplets is slower than with air or airless electrostatic, a good wrap-around is achieved when they reach the article being painted.

### 5.4 Airmix

Over the last few years the airmix spraying system has become accepted as a spraying system which will reduce finishing costs by reducing paint wastage, spray booth maintenance and improving the working conditions of the operator by the reduction in bounceback and overspray.

The system consists of an air operated pump (Figure 5) for pressurising the paint as in the airless system. The paint becomes atomised as it leaves the tungsten carbide tip, again similar to airless spraying. The fluid pressure is much lower which results in a non-uniform paint fan (Figure 6).

The additional air jets are directed from the "ears" of the aircap at the nozzle and are deflected to surround the paint fan. The effect of the air jets is to make uniform the paint fan, keep the nozzle clean by the sweeping action of the air along the surface, and to surround the paint fan with a small amount of low pressure air.

The result is a properly atomised paint fan with the "feathered edge" of the conventional spray gun pattern. This pattern greatly assists the operator in overlapping and blowing in small areas, which would not be possible with airless as the edge of the spray pattern is much more defined.

The reduction of bounceback and overspray is due to the lower forward velocity of the paint droplets as they leave the spray gun:

| | |
|---|---|
| Conventional air spray | 10 metres/sec |
| Airless | 1 metre/sec |
| Airmix | 0.5 metre/sec |

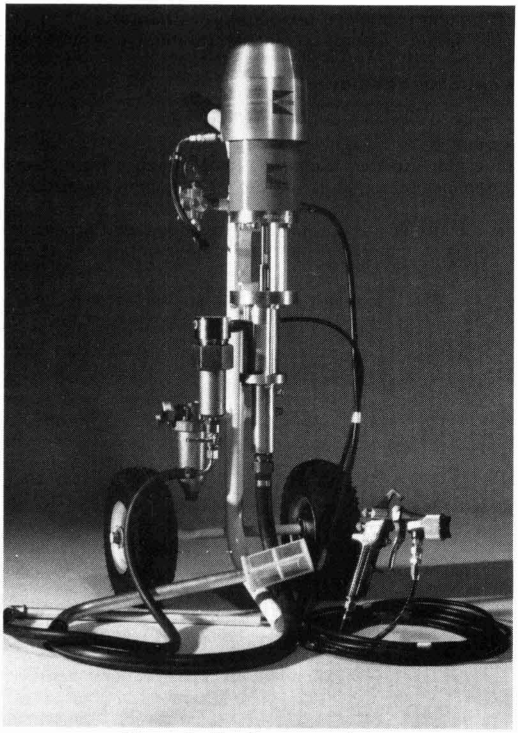
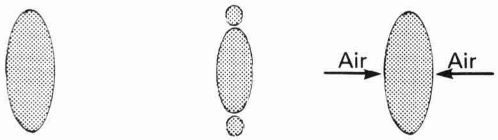


Figure 5. Airmix pump and gun



Airless–200 bars

Airmix – 40 bars without additional air

Airmix – 40 bars with 1 bar additional air

Figure 6. Spray-out pattern of airless and airmix

Figure 7. Airmix being used in a furniture factory

The Paint Research Association[1] has also tested airmix and found that the amount of paint fog was reduced by a factor of 11 times when compared with a conventional air spray gun. They also confirmed that the amount of paint fog returning onto the operator was considerably reduced.

Material savings in the region of 20-30 per cent over conventional air spray systems are generally obtained. As the majority of systems are manual systems, the cost saving calculation is based on the number of articles which can be painted with a given amount of paint/lacquer. When compared with airless in factory conditions, worthwhile savings have been achieved. These appear to be related to the distribution efficiency due to a reduction in excessive film thickness from better operator control.

With the lower forward velocity of the paint droplets the operator has to stand nearer the workpiece; this is not acceptable to the on-site operator, where the additional "throw" of the airless is more important than any material savings.

As the paint output of airmix is not so dependent on the tip size, unlike airless, the output can be varied by adjusting the fluid pressure with the same size of nozzle. A reduction in output pressure with airless will result in tailing which, as there is no additional air, cannot be eliminated.

Airless spray guns have the advantage of a turnaflo tip cleaner (the spray tip is reversed by turning a wingnut, the pressure of the paint blows out the obstruction, and the spray tip is then turned back to the spraying fan position) which is very useful for on-site painting.

### 5.5 Typical users of airmix hand systems

The main market for airmix has been the furniture industry (Figure 7), where electrostatic systems have not proved successful due to the poor conductivity of wood and the operators' dislike for the equipment. The aircraft industry and large-vehicle manufacturers have found the reduction of bounceback and overspray a great advantage in improving the conditions of work for their operators. Many of the larger spray booths were not designed for the bigger vehicles and aircraft now being built.

The limitations of the airmix system, when compared with a conventional spray gun, are that even with the smallest unit a litre of material is needed to prime the pump and hoses. For the vehicle refinishers with frequent colour changes, the wastage of material and cleaning thinners would far outweigh any material savings during application. Also, the cost is another problem for the smaller paint user. To replace a suction feed conventional spray gun for vehicle refinishing or a pressure pot and gun on a production line with airmix would be approximately five times more expensive. At present the improvement in working conditions is not considered sufficient to justify the cost of an airmix unit.

## 6. Additional advantages of using more efficient hand spray equipment

It was estimated[2] in 1979 that 40 per cent of the companies spraying paint employed insufficient or no extract at all. The Guidance Note EH9 from the Health and Safety Executive for the "Spraying of highly flammable liquids", already referred to, recommends a standard exhaust ventilation in the spray booth of minimum air velocity of 0.7 m/s at the work opening, and this may need to be increased to 1.5 m/s if particularly toxic materials are used.

When using an electrostatic hand spray gun, the air velocity can be reduced to 0.4 m/s which would reduce the factory heating bill. Very few companies who change from conventional air spray guns to hand held electrostatic systems have reduced their extraction rates. It is not clear why this is so but it may be that their existing system was only working at the lower exhaust velocity or that it was not possible to modify their existing spray booth.

The whole question of exhaust air velocity in spray booths for manual operators is very complex. The existing guidelines have not considered either the effect of the size and shape of the workpiece in the spray booth or the amount of paint which is being atomised by the spray gun.

The greatest reduction in exhaust air velocity and volume is possible with automatic systems within a totally enclosed spray booth, where the air volume required can be calculated to keep the solvent level concentration below danger level. This is dependent on the type of solvents and the emission rate of the spray guns. The air velocity must be sufficient to take the overspray into the treatment tank of the spray booth.

### 6.1 Reduction in spray booth maintenance

A 25 per cent reduction in the amount of paint going into a spray booth will considerably reduce the cleaning time, especially for dry back spray booths. Pollution of the atmosphere will also be reduced.

With the lower velocity spraying systems, less neat paint will go into the atmosphere as it is not being blasted into the spray booth.

## 7. Automatic systems

Automatic paint application offers many advantages:

1. More efficient paint application, transfer and distribution efficiency
2. Consistent finish quality and fewer rejects
3. High solids materials can be used which
    (i) reduce costs due to solvents
    (ii) reduce atmospheric pollution
4. Lower labour costs

The use of computers in the paint shop is now a reality for the control of a painting sequence as, for instance, with robotics and the control of the high speed bell paint application systems in the car industry. This information can be fed into a master computer to provide production and stock control information.

In order to reach this level of automation the best application system has to be found and economically justified. The economic considerations determine the degree of automation which is warranted. A more efficient application system will, in theory, give the lowest finishing costs, but in practice it is often found that unless there is good operator control the painting costs will be higher than had been estimated. The more sophisticated the automatic controls in the plant the better the efficiency but the higher the initial cost.

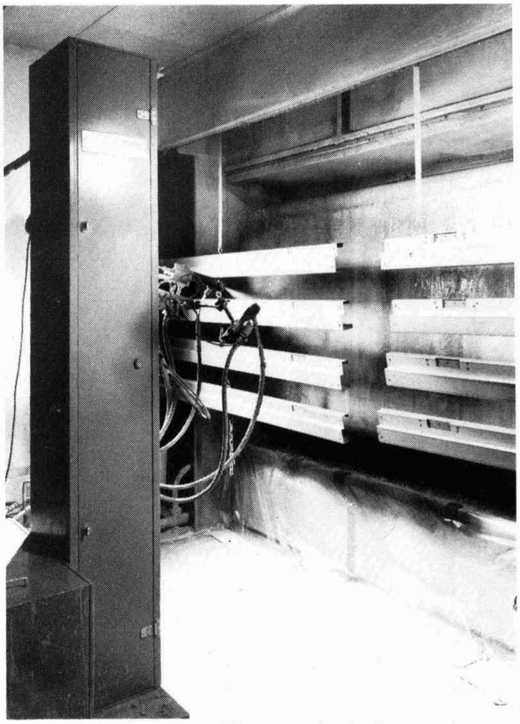


Figure 8. Reciprocator with automatic air electrostatic guns

Rather than describe the types of automatic spray equipment in detail, it is intended to deal mainly with the factors which affect their application efficiency.

### 7.1 Reciprocators with automatic electrostatic guns

These automatic systems have been in use for many years. The parts to be coated are carried on a conveyor through the spray booth and in front of the moving spray guns. The spray guns are generally automatic air electrostatic but in recent years have been replaced with high speed electrostatic rotators and airmix electrostatic units.

Reciprocators with electrostatic guns offer an automatic plant at a relatively low capital cost (Figure 8). Due to the higher forward velocity of the atomised paint particles, better penetration can be achieved with the air electrostatic than with other electrostatic systems. The efficiency of the system is dependent on the degree of gun control, i.e. the spray gun cut on and off, so that the article is painted with the minimum of overspray and good distribution efficiency.

The control mechanisms for only height or width are very simple and inexpensive but, with differently shaped articles, will be very wasteful of paint. The majority of these plants with only height and width control are for flat panels of different shapes and sizes. Good distribution efficiency can be achieved by matching the reciprocator painting speed to the speed of the conveyor.

Both horizontal and vertical reciprocators with automatic conventional air guns are used for the application of metallic paints in car plants, as the more efficient electrostatic high speed rotators do not give the same lay-down of the metallic particles in the paint. This causes matching problems on the hospital lines, where rectification spraying is done with air spray guns.

For profile control, the shape of the workpiece is detected by photoelectric cells or a video camera, and this information is memorised and activates solenoid valves to cut the guns on and off according to the shape of the workpiece.

This type of self-programming control is necessary for random batch size production. It will also take care of products which have been put on the conveyor the wrong way round, upside down, etc. In addition to providing the information for switching the spray guns on and off, the sensors should be able to measure the surface area of the products to check the paint mileage and in the future possibly change the shape of the spray pattern and control the paint output.

### 7.2 Programmable robots

From the statistics of the British Robot Association[3] there are now 124 robots in use for the application of surface coatings; 36 were installed in 1982. These robots are fitted with automatic electrostatic, airless and conventional air spray guns, so the transfer and distribution efficiency can only be considered as good as the experienced sprayer who produced the program. However, once programmed, the repeatability of the application efficiency is constant.

The economic justifications for the use of robots are in the reduction of labour costs, improved quality, fewer rejects and increased productivity. There are also cost savings to be had in the areas where robots are used, in reducing spray booth extraction rates and the consequent energy savings on heating the replacement booth air. Robots will fit into an automatic electrostatic system for painting inaccessible parts such as car engine compartments (Figure 9) and van interiors, which are very unpleasant for a manual operator due to the paint fog created by the bounceback and overspray in a confined area.

If more than one robot is used, they can be linked via the central plant computer so that in the event of a robot breakdown, production can still continue but at a reduced rate.

### 7.3 High speed electrostatic rotary atomisers (discs and bells)

The traditional rotational speeds of electrostatic discs and bells of 1,500-3,000 revolutions per minute atomised the paint partially by centrifugal force but largely by electrostatic forces, so that the main variable for improving the atomisation was by increasing the electrostatic voltage.

A new generation of high speed turbine-driven electrostatic atomisers with speeds of over 50,000 rpm are now being increasingly used, particularly in the domestic appliance and automotive industries. The increased speed has meant that paints with higher solids, viscosities and surface tension can be finely atomised. Also, a greater paint output can be atomised at these higher speeds. The effect of rotation speed on atomisation[4] can be seen in Figure 10. The transfer efficiency of these high speed atomisers is very high, and 90 per cent plus is claimed.

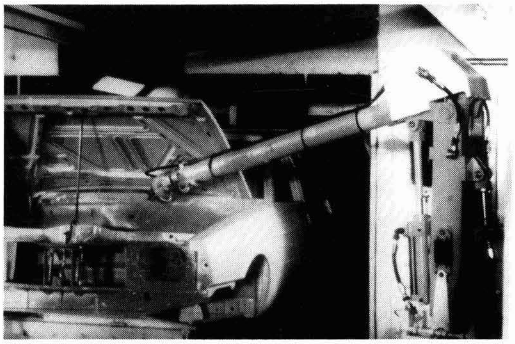


**Figure 9. A Programmable robot spraying the inside of a car engine compartment**

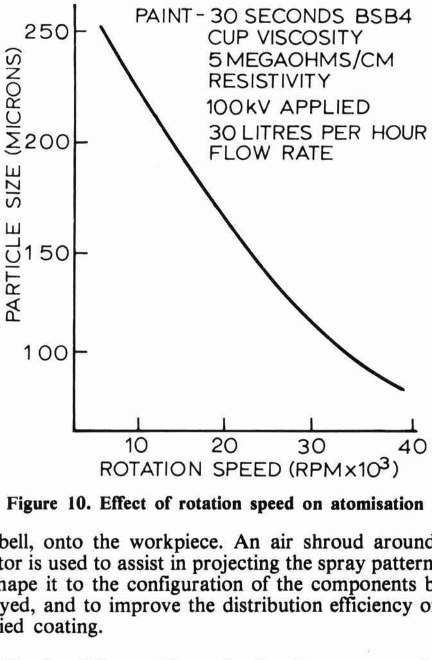


**Figure 10. Effect of rotation speed on atomisation**

Electrostatic forces are not sufficient on their own to attract the paint, which is spun tangently from the edge of the bell, onto the workpiece. An air shroud around the rotator is used to assist in projecting the spray pattern and to shape it to the configuration of the components being sprayed, and to improve the distribution efficiency of the applied coating.

With disc (Figure 11) application the components are passed round the reciprocating disc on a U-shaped conveyor. They can be rotated or indexed as they pass round the disc. Bells (Figure 12) can be mounted as fixed units or on reciprocators which can follow the profile of the component as with the painting of a car body.

These high speed rotary electrostatic atomisers considerably improve the application efficiency, because by giving finer paint atomisation and improved distribution efficiency less paint is wasted as the minimum film thickness to achieve coverage can be reduced.

Higher solids materials can be atomised so less thinning solvent is necessary, thus reducing atmospheric pollution. Faster application at higher film thicknesses can be achieved. A typical example of the higher solids materials[5] which can be used with the high speed electrostatic disc, as compared with the conventional electrostatic disc, is an acrylamide acrylic white stoving enamel. With the high speed electrostatic disc, a solids content of 40-60 per cent can be used. However, with the conventional disc the

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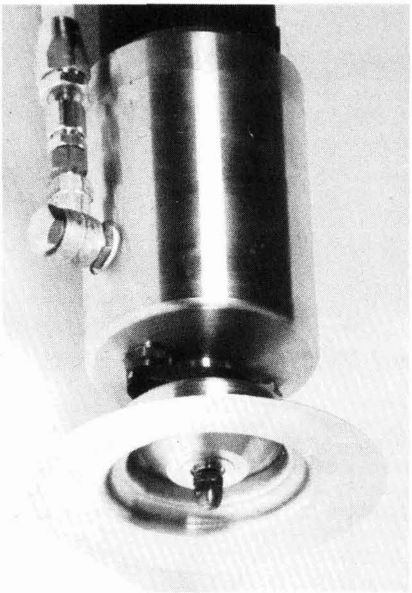

Figure 11. High speed rotary electrostatic disc

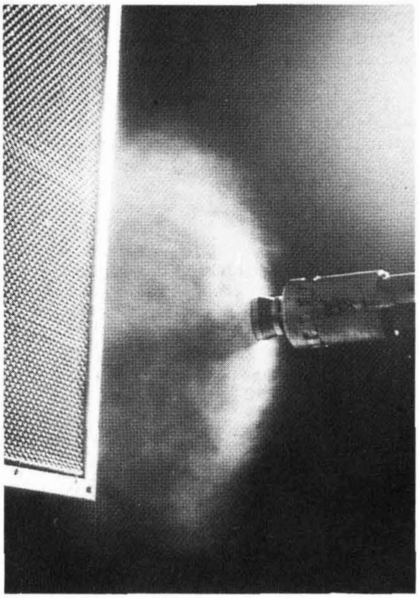

Figure 12. High speed rotary electrostatic bell

solids content would need to be reduced to 30 per cent to achieve satisfactory atomisation.

## 8. Conclusion

It will be realised from what has been said that there is no perfect piece of spray painting equipment. Each of the systems mentioned has advantages and disadvantages. The ideal plant installation should combine the advantages of various types of equipment to obtain the best application efficiency with the ability to put the paint where it is needed.

Over the coming years paint chemists will be striving to formulate paints with improved chemical and functional properties. They will be looking for energy savings by reducing stoving temperatures and producing two-component materials with faster curing times. Higher solids materials will be further developed to reduce the wastage of thinning solvents and to lessen atmospheric pollution.

It is in the long-term interest of the paint and spray equipment manufacturers that they encourage their customers to use only atomising application systems that give the best possible application efficiency. For, as we have seen over the last few years in the UK, some of the traditional paint markets such as engineering foundries and automotive subcontracting are disappearing. Many components are now made of plastic and do not need painting. If the cost of painting is too high this will lead to the increasing use of alternative materials and processes.

Judging by the large number of conventional air spray guns that are sold each year there is still a lot of paint wasted.

## Acknowledgements

The author wishes to thank *Product Finishing* for permission to use the photographs in figures 11 and 12.

Also, the International Paint Company for allowing him to copy some of the slides which will be used to illustrate the presentation of his paper.

*[Received 22 April 1983*

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## next month's issue

The Honorary Editor has accepted the following papers for publication in the January issue:

**Further collaborative experiments on testing the mould resistance of paint films** *by A. F. Bravery, S. Barry, M. Pantke and W. Worley*

**Glycidyl ether-based maleopimaric esters** *by H. Panda and R. Panda*

**Impedance measurement on zinc rich paints** *by T. Szauer and A. Brandt*

# Fire retardant paints*

**D. M. Bishop, D. Bottomley and F. G. R. Zobel**

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**Summary**

Aesthetically acceptable fire retardant paint and varnish processes are required for refurbishing the interiors of railway passenger rolling stock. Assessment of application properties and indicative fire tests were followed by suitable paint processes being subjected to fire rig tests carried out in a modified railway coach. This paper discusses the recent developments in fire retardant paint technology within British Rail based on realistic fire tests.

## 1. Introduction

### 1.1 Historical development

Many of the earliest references to fire prevention were to the chemical treatments of various cellulose derivatives such as wood, paper and textiles. Sustained efforts to improve the fire retardancy in the latter can be traced back over three centuries[1]. The use of ammonium phosphate, which is still an important ingredient in fire retardant compositions for paints and wood treatment today, was first suggested by Arfrid[2] in 1786. By the turn of that century most of the suitable inorganic salts had already been recognised as fire retardants.

Although fire retardants had been used for several centuries in the textiles industry, the first reference to the use of inorganic salts as fire retardants in paints was in a patent taken out by Louis Paimboeuf[3] in 1837. It was claimed that the addition of lime, potash, alum and common salts (and molasses could be added if so desired) to a water-based or linseed oil paint would produce a fire retardant paint suitable for protecting buildings against fire. In 1948 Ware and Westgate published a review of United States patent literature on fire resistant and fire retardant coatings, which covered 111 years during which time at least 339 patents were issued. The survey enabled the historical development of certain types of fire retardants in that country to be studied, although not all the entries refer to coatings in the modern sense[4]. The review covered various categories of fire retardants such as chlorinated hydrocarbons, borates, phosphates, silicates and antimony compounds. The concept of replacing only part of the normal paint pigments with a fire retardant, such as ammonium magnesium phosphate, was patented by two Frenchmen[5] in 1909.

### *1.1.1 Flame retardant paints*

Antimony compounds were first mentioned as fire retardants in the patent literature[6] in 1884, and antimony trichloride[7] was used in a fire retardant paint in 1921. However, it was not until 1936 that antimony trioxide, which is widely used today as a fire retardant pigment in conjunction with a halogenated organic compound, was mentioned in a patent covering a nonflammable paint based on chlorinated rubber medium[8] for electrical apparatus. Probably the delay in the use of antimony trioxide as a fire retardant pigment was that quality grades of the pigment[9] were not commercially available until 1919. Borates were proposed for use in fire retardant paints for walls, ceilings and buildings[10] in 1898, but silicates[11] and chlorinated hydrocarbons[12] were proposed at later dates, in 1933 and 1940 respectively.

All these materials have been used in a class of fire retardant paints known as "non-intumescent". Those paints utilising fire retardants based on the elements chlorine, bromine, antimony, phosphorus and boron are known as flame retardant because the gaseous species produced on heating interfere with the flame propagating reactions. There have been few major developments in non-intumescent paints because the fire retardants generally used have been available for a long time[54]. Developments during the sixties included a range of flame retardant emulsions and gloss paints based on antimony trioxide and a medium containing a chlorinated paraffin[13], also an emulsion paint based on a vinyl emulsion, sodium borate, chlorinated paraffin, leafing aluminium and pigment[14]. Further developments included chlorinated alkyds based on chlorendic acid[15,16], an antimony oxide coated silica pigment[17], a special sodium borate[18] and halogenated plasticizers[19], and the use of brominated compounds in the production of fire retardant media[20]. There is little in the literature on smoke suppressants but certain molybdenum compounds are claimed to be both smoke suppressants and flame retardants in the presence of halogenated organic compounds[21-23].

### *1.1.2 Intumescent paints*

In 1952 a patent was issued for a type of fire retardant paint known as "intumescent", in which the coating, on being subjected to heat, produced a physical barrier between the flame source and the substrate[24]. The original paint was a two-component system containing, typically, urea, monoammonium phosphate, starch and pigment, to which was added formaldehyde or paraformaldehyde and water before application; similar paints were later patented[25-28]. The high levels of water-soluble inorganic salts necessary to impart good fire protective properties, together with the unsuitability of water-resistant oxidising systems for this type of coating can result in deterioration of the fire retardant properties in humid conditions. However, some improvement was reported by stoving the coatings[29] and then overcoating with a chlorinated rubber/dehydrated castor oil paint[30].

These early developments were followed by attempts to obtain intumescent paints with improved film properties. These were emulsion-based paints incorporating materials such as ammonium phosphate, urea and starch in synthetic lattices such as homopolyers or copolymers of vinyl acetate, styrene or acrylic esters, or vinyl chloride/vinylidene chloride copolymers[31-35]. Another approach was to use solvent-based intumescent paints[36-41], and patents were issued in the sixties based on intumescent fire retardants and chlorinated rubber media, which itself is claimed to have fire retardant properties[42,43].

One early approach to formulating intumescent paints was to use ongokea (isano) oil. This contains a fatty acid with an unusual constitution which produces a violent chemical reaction on heating[44]. Sources of ongokea oil were in short supply and a comprehensive investigation of the various components of an intumescent paint resulted in formulations based on modified tung oil, chlorendic acid and toluene diisocyanate blended with pentaerythritol polyurethane, melamine phosphate and dibromopropyl alcohol[45].

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*Paper presented at the Association's York Conference, 15-18 June 1983, session IV. Following presentation of the four papers of this session, general discussion took place which was not recorded.

Although substantial improvements have been made in intumescent paint formulations there are major weaknesses such as the water solubility of the fire retardant inorganic salts, shelf stability, and because of the necessary high fire retardant pigment loadings these paints tend to be matt or very low gloss[46]. There have been only a few references to clear intumescence coatings as the blend of essential inorganic salts tends to produce "milky" films, but clear lacquers based on moisture curing polyurethanes were developed[47].

### *1.1.3 Fire retardant paints*

There are few reviews on the state of the art, but several papers were published in 1945 on fire retardant paints for steel surfaces[48,49], and the American Chemical Society published a paper in 1953 on the proceedings of a symposium on fire retardant paints[50]; discussions on fire test methods have been a prominent part of the literature. Fire retardant paints have been used on the railways since the fifties, when a formulation based on sodium silicate/china clay/water was used to paint the undersides of wooden floorboards of passenger rolling stock. Intumescent fire retardant paints were introduced in the sixties for the painting of timber components; flame retardant paints have not been used on the interiors of vehicles. Fire retardant impregnated timber for use in the interior of railway vehicles was introduced in 1979.

### 1.2 Role of fire retardant paints

In severe fire conditions, fire retardant paints would be of little or no significance in influencing the conflagration. Around the edges of the fire or under conditions of isolated fires such as where combustion may start from cigarettes, matches, electrical short circuits or spontaneous combustion then fire retardant paints can play very important roles[50]:

(i) If the paint is flammable with a low ignition point then it may materially assist the spread of fire.

(ii) If the paint is inert then it may have little or no influence on the fire propagation.

(iii) If the paint is of a heat reflecting nature then it may keep the temperature of the combustible substrate and the paint itself below the ignition temperature. Therefore it will either prevent the spread of flame or reduce the rate at which it spreads.

(iv) If the paint is of an insulation type then it may keep the temperature of the combustible substrate below the ignition point.

The rate of flame spread was considered to be the most important factor in saving lives and minimising property loss. This led directly to the development of the 25 foot tunnel test by the American Underwriters Laboratories in 1950, which can accurately measure the spread of flame and has been incorporated into many codes of practice[51]. Properly formulated fire retardant paints can significantly reduce the spread of flame and prevent further ignition of combustible materials in the vicinity, thus minimising the size of the fire.

A fire retardant additive operates by interfering with at least one of the individual stages of the burning process[52]:

(i) The heating of the flammable substrate.

(ii) Its subsequent degradation and decomposition.

(iii) The ignition of the flammable gases evolved.

(iv) Their continued combustion with sufficient nett heat sustaining and continuing the flame propagation.

An efficient fire retardant will affect more than one of those steps by either physical or chemical means in a variety of ways[4]:

(i) Formation of a glassy coating by low melting inorganic compounds with low thermal conductivity or high reflectivity, which seals the underlying surface from the flames.

(ii) Replacement of combustible organic pigments and resin by non-flammable materials.

(iii) Formation of a thick carbonaceous foam which physically and thermally insulates the substrate from the flame source; this type of coating is known as intumescent.

(iv) The fire retardant can by its own degradation liberate non-combustible volatiles which interfere with flame propagating mechanisms and reduce the flame spread; this type of coating is generally known as flame retardant.

(v) By chemically affecting the thermo-oxidative decomposition of the flammable substrate and reducing the concentration of combustible gases produced. This can be achieved by promoting char formation, dehydrogenation or dehydration, which limit the production of combustible hydrocarbon gases.

### 1.3 Types of fire retardant paint

Fire retardant coatings can be defined as those intended for application to combustible (and occasionally non-combustible) surfaces for the purpose of reducing the fire hazard as required by the fire safety codes[53]; they fall into two categories:

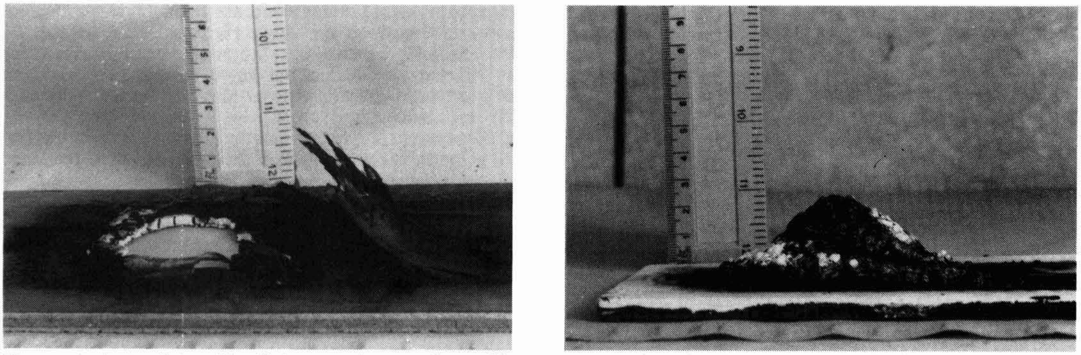
(i) Intumescent paints, which protect a flammable substrate by physically and thermally insulating the substrate from the flame source. These coatings can provide excellent fire protection with a marked reduction in the heat transmitted to the substrate.

(ii) Flame retardant paints, which provide decorative properties without contributing to the fire propagation and are formulated to be self extinguishing on removal of the flame source. These coatings offer little protection to a flammable substrate under constant exposure to fire.

Although both types of paints are formulated to reduce the spread of flame, the modes of fire retardancy are very different.

### *1.3.1 Intumescent paints*

Intumescent paints are characterised by the ability to rapidly swell or foam to form a stable, inert, carbonaceous



Flame retardant paint – offers little protection to a flammable substrate under constant exposure to fire

Formation of carbonaceous char with intumescent paints

**Figure 1. Types of fire retardant paint**

char when subjected to heat. This char thermally insulates the substrate from the heat source, reduces the surface spread of flame and prevents substrate combustion, as shown in Figure 1. Conventional commercial paints normally require large quantities of three basic ingredients (as part of the pigmentation) to produce the char, namely a polyhydric alcohol, a phosphate salt and a blowing agent. The char is formed by the dehydration of the polyalcohol, such as pentaerythritol which has a high carbon content[55], by an acid which is normally phosphoric acid produced within the coating from various ammonium and amine phosphate and phosphate esters on heating (see Appendix A). The materials which actually cause the char to expand are known as blowing agents and are selected for their decomposition to volatile products at the required temperatures, such as melamine and chlorinated paraffins which decompose at 250°C and 197°C respectively. If the blowing agent decomposition temperature is too low then the gases will escape before the char is formed; if the temperature is too high the char will be merely lifted off or blown apart by the released gases. For many formulations two blowing agents with slightly different decomposition temperatures are used in order to extend the time of the release of volatile products – the low temperature blowing agent usually being an amide or amine and the higher temperature one a chlorinated paraffin[60]. The char must be tough and adherent to resist the violent draughts arising in fires, and occasionally other ingredients are added to improve the char toughness, such as urea or melamine formaldehyde, which are believed to form a tough skin over the cellular mass. Most of the ingredients in an intumescent paint fulfil more than one function since some will release gas on heating and can be considered as blowing agents and many will contain carbon which will contribute to the char; the ingredients have to be selected with all these factors in mind[55].

Considerable technical effort is required to optimise the level of intumescence and good formulating techniques are necessary to obtain a paint that not only has excellent fire retardant properties but also excellent decorative qualities. Any change in the ingredients of an intumescent paint must take into consideration the effect on paint stability in the can, brushing characteristics, sag and flow properties, overcoating, resistance to moisture and scrubbing etc., as well as on the fire retardant properties. It is necessary to incorporate large amounts of active pigment ingredients into these paints to give 60-80 per cent w/w pigment on the dry film. Consequently there is little free volume to incorporate coloured or tinting pigments and the paints tend to be white or pastel shades[46]. Work has established that the three major components of an intumescent paint should be within the following ranges[56]:

| | |
|---|---|
| Polyhydric alcohol | 25 – 30 per cent w/w |
| Phosphate ester | 45 – 55 per cent w/w |
| Blowing agent | 20 – 25 per cent w/w |

Pigment volume concentration has a definite effect on fire retardant properties as based on the height of the intumescence formed and the flame rating in the two-foot tunnel test. Maximum fire retardant properties are achieved at pigment volume concentrations of at least 70 per cent[55]. There are many published papers on the most effective resins for intumescence formation and hence fire retardant properties[55,57,58]. The resin should be sufficiently flexible so as not to stifle the formation of the intumescence and should contribute to the containment of the foam. Oxidising media, in general, are not suitable for intumescent paints as there is a reduction in their fire retardant properties on ageing due to the films oxidising and becoming more inflexible and tough, which stifles the intumescence[59]. Thermosetting resins, which harden on heating, do not produce good intumescence[60]; thermoplastic resins, which soften on heating, are generally preferred because structurally sound chars are formed[61].

Although intumescent paints can be solvent-based, only the water-based paints have been available in these tests, and although these have excellent fire retardant properties, they have several disadvantages:

(i) Poor rheological properties result in severe brush marking in the residual dried films. (Overcoating with high gloss paints only highlights the defect.)

(ii) The necessary high loading of relatively coarse ingredients limits these paints to matt coatings which are highly porous.

(iii) The active ingredients are often water-soluble, so these paints cannot be used externally, in areas of high humidity or where frequent cleaning is necessary.

(iv) Limited shelf life.

Intumescent fire retardant paints are normally applied as two or three coat processes, each coat being applied at 150-200 microns wet film thickness to achieve the maximum fire retardant properties. For internal use where a high standard of decorative appearance is not required, intumescent paints are highly effective in minimising the surface spread of flame and protecting the substrate from fire.

### *1.3.2 Flame retardant paints*

Flame retardant paints are characterised by their ability to produce gaseous products on heating which interfere with the flame propagating reactions and reduce the flame intensity. The most widely used flame retardant pigment is antimony trioxide, although alternative pigments are commercially available such as zinc borates (which are claimed to have better fire retardant properties[50]), barium metaborate and antimony silico-oxide.

Antimony trioxide by itself is an ineffective flame retardant[48], but in combination with halogenated organic compounds (such as chlorinated rubber, chlorinated paraffins and chlorinated alkyds, although bromine is claimed to be more effective[61]) a synergistic effect occurs producing highly effective flame retardant properties[52]. The exact mechanism of the flame retardant reaction is not known. However, several theories have been proposed (based on the reaction between halogens and antimony trioxide to produce antimony trichloride, $SbCl_3$, and antimony oxychloride, $SbOCl$, on heating) such as a "blanket" effect[62], "wall" effect[63], or interference by halogen-free radicals on the flame propagation reaction[64,65]. The mode of action depends on the formation of volatiles, and in the violent draughts that occur in fire situations the flame retardant properties could be seriously reduced.

The optimum formulation for flame retardant paints based on antimony trioxide and chlorinated hydrocarbon would appear to be determined by[66]:

(i) The antimony trioxide/chlorine ratio.

(ii) The total amount of antimony trioxide and chlorine present in the formulation.

An extensive programme of work was carried out on antimony trioxide/chlorinated paraffin in a number of media, ranging from linseed oil to emulsions such as polyvinyl acetate, polystyrene-butadiene, acrylics and neoprene, it was found that[67,68]:

(i) Antimony trioxide is less effective at high concentrations of chlorine than at low concentrations.

(ii) The maximum fire retardancy was obtained at equal amounts of antimony trioxide and chlorine.

(iii) High levels of antimony trioxide reduced the hiding power whereas high levels of chlorinated paraffins adversely affected the drying properties.

In a test programme on fire retardant paints for steel involving various pigments and media, antimony trioxide/chlorinated organic compounds performed well with regard to flammability, the general results were(48,49):

(i) Emulsion paints had better fire retardant properties and flashed less easily than solvent-based paints.

(ii) The paints with the best fire retardant properties had pigment volume concentrations of not less than 48 per cent for emulsions and not less than 60 per cent for solvent-based paints.

(iii) At pigment volume concentrations of 60 per cent or more, none of the single pigment paints ignited. At these pigment volumes no advantage was shown for antimony trioxide but at lower pigment volumes antimony trioxide showed some advantage in preventing flashing.

In a study specifically on antimony trioxide/chlorinated paraffins in an alkyd medium, it was found that the addition of chlorinated paraffins (70 per cent w/w chlorine) enabled the antimony trioxide level to be greatly reduced at a given pigment volume concentration[69]. It was found that the lower the pigment volume concentration the greater the level of chlorine required to give the same level of flame retardancy; at a pigment volume of 20 per cent the antimony trioxide/chlorine ratio was 1:8 whereas at 40 per cent this was reduced to about 1:1, but in general it is claimed that flame retardant paints require a ratio[61] of about 2:1. Some of the commonly used flame retardant coatings are based on[56]:

(i) Chlorinated alkyds

(ii) Epoxies

(iii) Polyurethanes

(iv) Polyvinyl chloride

(v) Polyvinylidene chloride

In general, flame retardant paints are solvent-based and provide good decorative coatings suitable for interior and exterior use in a wide range of colours. They are formulated so as not to contribute to fire propagation and to be self extinguishing on removal of the flame source. Flame retardant paints are normally applied as a two or three coat process depending on the substrate and the level of fire retardancy required, with one or two coats of flame retardant undercoat and a gloss decorative flame retardant finish; each coat is applied at about 50 microns wet film thickness. However, under continued exposure to the flame source, flame retardant paints give little protection to flammable substrates and are inferior to the higher build intumescent paints in this aspect (Figure 1).

### *1.3.3 Fire retardant timber*

Although out of context in a paper on fire retardant paints, the performance of fire retardant timber was included in the research programme because it is specified for new build passenger rolling stock and it was necessary to compare its performance in a "real fire" with that achieved with fire retardant paints.

The earliest reference to fire retardants for wood reported in *Chemical Abstracts* occurred in 1905 and referred to a mixture of ammonium phosphate and boric acid[70], a process which is widely used today, although over the years many fire retardants have been proposed for wood using various techniques[52]. Some degree of fire retardancy can be achieved by simple surface application or immersion methods but in general these techniques are largely unsatisfactory. In most cases the wood is impregnated by placing the wood in the treating vessel, evacuating to low pressure for a period of time and then introducing the impregnant into the vessel under pressure for several hours often at elevated temperature; the treated timber is then kiln dried. The increase in weight due to the retention of the fire retardants depends on the wood species and the chemicals used, but ranges from 1.4 – 33 per cent w/w[52]. Fire retardant timber must be evaluated for surface spread of flame, after glow, smoke generation as well as mechanical strength, resistance to decay, permanence of fire retardancy and so on. To achieve the required fire retardant properties of low flame spread, low smoke emission, minimum heat evolution and no after glow, a combination of salts is required and explains the variety of commercial mixtures used over the years. The mechanical properties of treated timber are affected by the impregnating salts and it was reported that the elastic modulus of treated wood could be reduced by 12 per cent or so and that the dynamic strength could be reduced by 20-40 per cent for laminated beams and plywood[71].

### 1.4 Fire retardant paint requirements for passenger rolling stock

All materials used in the construction of new passenger rolling stock, including plywood timber and paints, must have a surface spread of flame of "Class 1" when tested to British Standard 476 Part 7: 1971 "Surface Spread of Flame Test for Materials". In the modern railway vehicle most of the interior surfaces, such as ceilings and walls, are constructed of laminates such as moquette or polyvinyl chloride covered plywood, which should meet the above fire retardant requirements. There is little painting on the interiors of these vehicles and then only the application of fire retardant intumescent water-based paints to components that are not visible.

However, the major problem is to ensure that the fire retardant properties of the decorative painted surfaces in the interior of older passenger rolling stock meet the "Class 1" requirement. This applies to all vehicles built before 1979, and hence involves a large number of vehicles in which:

(i) The interior fittings were constructed of non-fire retardant plywood or timber.

(ii) The ceilings, compartments, corridors and lobby ends, and walls are coated with multilayers of paint or varnish of varying composition.

The cost would be prohibitive to replace all the existing materials with those meeting the fire retardant requirements and a programme of work was therefore initiated to find fire retardant paint and varnish processes which would:

(i) Enable the fire retardant requirements to be achieved with two or three coats of fire retardant paints, selected by suitable fire test methods, without recourse to paint stripping to bare wood, etc. Additional coats would necessitate serious consideration of replacing ceilings, etc. by the more expensive, but more durable, laminates.

(ii) Enable aesthetically acceptable brush applied decorative finishes to be obtained. Brush application is necessary because of the relatively small areas to be painted within a vehicle interior; spraying would not be economical due to the time consuming masking of windows, fittings, etc. that would be necessary. Paint spraying in confined areas also increases the safety problems.

(iii) Be easily accommodated into railway workshops' "open-shop" painting facilities, should be water- or white spirit-based (as are all paints currently in use for painting rolling stock), and have excellent brushing and overcoating properties comparable to those of conventional decorative paints.

(iv) Facilitate maintenance re-painting. Vehicle interiors are normally re-painted every two years or so, due to general wear and tear, often as single coat re-paints. Maintenance painting with three coats of fire retardant paints every two years would not be cost effective and could lead to premature paint adhesion failures.

## 2. Fire test methods

A number of laboratory procedures are available to evaluate the effectiveness of fire retardant paints and fire treatments[50,72], which vary according to which of the three stages of a fire the effective measurement is associated[73]:

(i) Ignition

(ii) Rate of spread of flame

(iii) The extent of the conflagration

While all the stages were considered important, the rate of spread of flame was considered to be the most important factor in saving lives and minimising property loss[51]. This led to the development of the 25 foot tunnel test by the Underwriters Laboratories Inc. (American Society for Testing and Materials Method E84-61), which was incorporated into most American and Canadian building codes of practice[51], and subsequently led to the development of several smaller tunnel tests[73-75].

British Standard 476 "Definitions for Fire Resistance, Incombustibility and non-Inflammability of Building Materials and Structures (including Method of Test)" was introduced in December 1932, and amended in 1942, for assessing the fire resistance of structural building components but using very different tests from those associated with this specification today. No references have been found in the literature to the development of this specification to include the surface spread of flame test in the first revision in 1953, probably due to the developments occurring during the war years. It has been strongly suggested, but not substantiated, that the surface spread of flame test was based on experiments carried out in a railway vehicle during the war years and the temperature gradients observed during the vehicle tests were incorporated into the specifications. This spread of flame test was officially introduced on to the railways in the fifties for the assessment of fire retardant coatings and prior to this the Schultz Fire Resistance tester had been used[79]. The latter was introduced early in the thirties and consisted of a cam driven by a spring motor which moved a gas burner towards and away from the test piece, making one approach every five seconds. The fire resistance was measured by the number of approaches required to ignite the test piece surface.

Although various methods of assessing the fire retardant properties of paints have been used by the railways over the years, the indicative fire tests used in this report were:

(i) British Standard 476: Part 7: 1971 "Surface Spread of Flame Test for Materials" using the large scale apparatus at the Warrington Research Centre; the method of test is for materials, which may be painted, and not specifically for paints. The test panels were held in the vertical plane and the test was considered as a possible test for assessing wall paints.

(ii) The two foot tunnel test (inclined plane test), in which

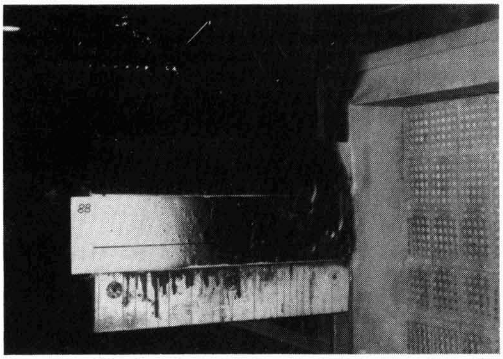


Figure 2. British Standard 476: Part 7: 1971, large scale surface spread of flame apparatus

the test panels were held at an angle to the horizontal plane. This test was considered appropriate for assessing ceiling paints.

Paints with satisfactory fire retardant properties were subjected to further fire tests carried out in a "real fire" in a modified railway coach, the test rig being based on large scale fire tests on railway vehicles[76]. All the indicative small scale fire tests and the railway test rig tests were carried out on untreated 6 mm gaboon plywood (which was widely used in the construction of railway vehicles) unless otherwise stated. The only other substrate used was fire retardant timber to Class 0 as defined in the Building Regulations.

### 2.1 British Standard 476: Part 7: 1971 "Surface Spread of Flame, Tests for Materials", using the large scale apparatus

This test assessed the ability of various paints to influence the spread of flame across their surfaces and classified "this in relation to exposed surfaces of walls and ceilings". The spread of flame classifications are shown in Appendix B and all tests were carried out at the Warrington Research Centre. The apparatus consisted of a vertically mounted radiation panel approximately 900 mm square with a refractory concrete surround. On one side of the radiant panel a specimen holder was hinged to the surround so that when the specimen was moved to the test position its face was flush with the inner face of the refractory surround and its front edge was shielded, as shown in Figure 2. Six representative samples of each specimen under test are required for a certified classification but an indicative test result can be obtained with two samples, measuring 230 mm × 900 mm. These were used and were painted at least four weeks prior to testing and conditioned at constant temperature and humidity prior to each test. Immediately the specimen was exposed to the radiated heat, a vertical luminous gas flame was exposed to the hot end of the specimen for one minute. As soon as the igniting flame was in contact with the specimen, the time of spread of flame was recorded by measuring distances along a line drawn parallel to the longitudinal axis 75 mm from the bottom edge of the specimen (see Appendix B). Each test was continued for ten minutes unless the flame reached the far end of the specimen in a shorter time. Any associated phenomena, such as surface flame flashing or the burning of delaminated paint layers, was noted.

The important factors highlighted during the spread of flame tests are shown in Figure 3 and the results are summarised in tables 1 and 2, having been separated into fire retardant paints and varnishes respectively.

#### *2.1.1 Fire retardant paints*

Table 1 summarises the results obtained over the last few years, with similarly painted panels being tested several times on different occasions over this period. The important factors are:

(i) The conventional three coat decorative finish gave a Class 3 rating, with the paints giving surface flame flashing as shown in Figure 3.1. The flame retardant process, although eliminating the surface flame flashing, only gave a Class 2 rating.

(ii) Two coats of intumescent paint, applied at 150 microns wet film thickness per coat, gave a Class 1 rating which was not reduced by overcoating with single coats of high build decorative (to BR Specification No. 70 Item 81) or flame retardant finishes, in spite of the intercoat adhesion failures between the intumescent paints and decorative finish (see Figure 3.2).

(iii) There was no difference in the fire retardant properties of the water-based and solvent-based intumescent paints, both giving a Class 1 rating.

(iv) Overcoating two coats of intumescent paint with two coats of decorative finish reduced the rating to a Class 2 or even lower, as shown in Figure 3.3.

(v) Overcoating two coats of intumescent paint with two coats of flame retardant paint did not affect the spread of flame rating.

(vi) Overcoating a three coat decorative finish (which had a Class 3 rating) with two coats of intumescent paint and a decorative finish indicated that the spread of flame had been sufficiently reduced to give a Class 1 rating.

Although the results clearly show that a Class 1 rating could be obtained on untreated 6 mm gaboon plywood using intumescent paints, maintenance painting with conventional decorative paints would produce a rapid deterioration in the fire retardant properties.

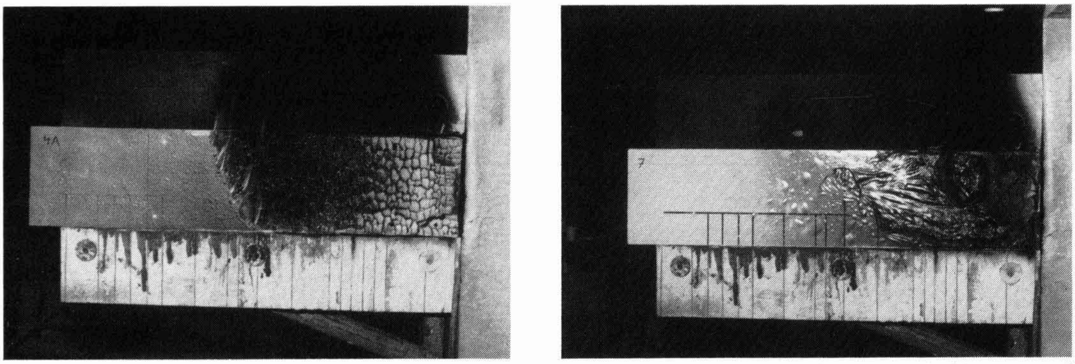
Surface spread of flame tests were carried out on impregnated plywood having a Class 0 fire rating to the Building Regulations and clearly showed that:

(i) The impregnated timber had a good Class 1 rate of flame spread rating.

(ii) Painting the impregnated timber did not materially alter the Class 1 rating, but only a few painted specimens were tested.

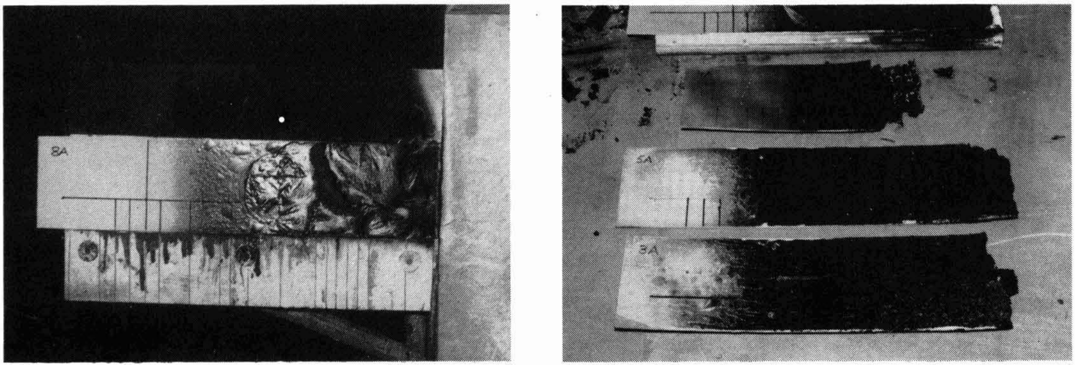
(iii) Although the impregnated timber did not burn, it readily charred and disintegrated and resulted in a significant loss of structural timber as shown in Figure 3.4. A similar effect was observed after the completion of the same fire tests on laminates based on the same plywood.

Overcoating the impregnated plywood with an intumescent fire retardant paint process greatly reduced the charring and disintegration of the substrate with the result that there was a significant reduction in the loss of structural timber; the Class 1 rating was not affected.



**1. Three coat decorative finish – spread of flame after 7 minutes, Class 3 rating**

**2. Two coats of intumescent paint overcoated with one coat of decorative finish – spread of flame after 7 minutes, Class 1 rating**



**3. Two coats of intumescent paint overcoated with two coats of decorative finish – spread of flame after 7 minutes, Class 2 rating**

**4. Effect of fire retardant impregnation on loss of structural timber. Impregnated timber (4A), untreated timber (5A and 3A)**

**Figure 3. British Standard 476: Part 7: 1971, "Surface spread of flame test for materials"**

### *2.1.2 Fire retardant varnishes*

Although fire retardant varnishes cannot be expected to be comparable in performance to the heavily pigmented intumescent paints (addition of the ingredients necessary to improve the performance would produce an opaque varnish), during the extensive evaluation of coatings an intumescent varnish process showed excellent fire retardant properties as shown in Table 2. The three coat process, consisting of two coats of water-based intumescent undercoat applied at 150 microns wet film thickness per coat and a white spirit-based finishing coat, gave a Class 1 spread of flame rating compared with the much lower ratings obtained for the three coat decorative varnish process and the other fire retardant varnish processes tested.

### 2.2 Inclined plane test[78]

Large scale tunnel tests require considerable expenditure of time and materials in the development of fire retardant coatings, which necessitate the testing of a large number of formulation variables. This led to the development of smaller versions of the 25 foot tunnel, such as the 18 foot[75], eight foot[74] and in 1967 the two foot tunnel test developed by Monsanto[73] and which was the version used to assess fire retardant coatings in this report. The two foot tunnel was designed to compare differing fire retardant treatments and to predict the rating when tested in the 25 foot tunnel. Although there have been many papers on the reproducibility of results and its correlation with the large scale test[77], it has been used successfully as a screening method during the current work.

The apparatus consisted of a two foot long tunnel inclined at 38° to the horizontal in which the painted surface was placed face downwards to form the roof of the tunnel as shown in Figure 4. Paints under test were applied at their recommended wet film thicknesses to 6 mm

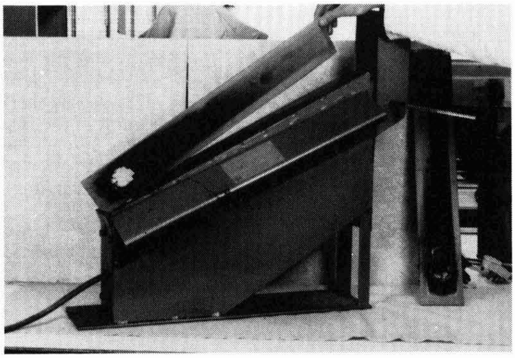


**Figure 4. Inclined plane test apparatus**

*Table 1*

*BS 476: Part 7: 1971*

*Surface spread of flame tests for materials – paint processes*

| Paint process | Travel at 1½ minutes | Final travel | Class rating |
|---|---|---|---|
| 1 ct wood primer<br>1 ct decorative undercoat<br>1 ct decorative finish | 240 mm | 390 mm | 3 |
| 1 ct wood primer<br>1 ct flame retardant undercoat<br>1 ct flame retardant finish | 100 mm | 430 mm | 2 |
| 2 cts water-based intumescent paint<br>1 ct high build decorative finish | nil | nil | 1 |
| 2 cts water-based intumescent paint<br>2 cts high build decorative finish | 75 mm | 190 mm | 2 |
| 2 cts water-based intumescent paint<br>1 ct decorative undercoat<br>1 ct decorative finish | 290 mm | 290 mm (stopped after 36 seconds) | 4 |
| 2 cts water-based intumescent paint<br>1 ct flame retardant gloss finish | nil | 75 mm | 1 |
| 2 cts water-based intumescent paint<br>1 ct flame retardant vinyl sheen | nil | nil | 1 |
| 2 cts water-based intumescent paint<br>1 ct flame retardant undercoat<br>1 ct flame retardant finish | nil | nil | 1 |
| 2 cts solvent-based intumescent paint<br>1 ct flame retardant finish | nil | nil | 1 |
| 2 cts two-pack epoxy intumescent undercoat<br>1 ct two-pack polyurethane finish | nil | nil | 1 |

Notes:
1. All tests were carried out on the large scale apparatus at the Warrington Research Centre.
2. All tests were carried out on untreated gaboon plywood (6 mm thick) obtained from British Rail Engineering Ltd, Litchurch Lane, Derby.
3. All panels were laboratory aged for one month before testing.

untreated gaboon plywood panels (unless stated otherwise) cut to the required 61 cm × 9.5 cm size. All panels were conditioned in the laboratory for at least four weeks after application of the final coat of paint before testing. The panels were heated near the lower end by a Meker pattern burner using natural gas at a flow rate of one litre per minute and producing a flame temperature in contact with the panel of around 950°C. Panels were exposed to the flame for five minutes and the maximum surface spread of flame during consecutive 15 second intervals was measured visually. Temperatures of the flue gases emitted from the top of the tunnel and at the back of the panel directly above the flame were measured by thermocouples. Although there was little variation in the flue gas temperatures unless there was rapid flame spread, the temperature at the back of the panel gave an indication of the thermal insulating properties of the surface coating.

Typical panels after completion of five tests are shown in figures 5-14, and the relevant results of several hundred tests are shown in tables 3 and 4 and will be discussed in detail.

### *2.2.1 Intumescent paints*

The level of intumescence obtained was dependent on the number of paint coats applied to the substrate (for a given paint formulation and wet film thickness per coat) as shown in Figure 5, and these differences were reflected in the inclined plane test data:

(i) There was a large reduction in the surface spread of flame with two coats compared with that obtained from one coat, i.e. from 6-7″ (inches) down to 3-4″.

(ii) There was little difference in the surface spread of flame obtained with two or three coats of intumescent paint. Care had to be taken with paints that produced high levels of intumescence because what could be measured was the *deflection* of the flame by the intumescence rather than actual spread of flame.

(iii) With one coat of intumescent paint the panel was scorched on the back indicating insufficient substrate fire protection, but scorching was significantly reduced with two or more coats due to the greater thermal insulative effect; this was reflected in the back of the panel temperatures slowly rising to a maximum of 200°C and 140°C for one and two coats respectively. With non-intumescent paints, the temperature rose steadily until about 200°C when the

*Table 2*

*BS 476: Part 7: 1971*
*Surface spread of flame tests for materials – results for varnishes*

| Varnish process | Travel at 1½ minutes | Final travel | Class rating |
|---|---|---|---|
| 1 ct clear wood sealer<br>2 cts clear interior satin wood finish | 215 mm | 570 mm | 3 |
| 2 cts solvent-based intumescent undercoat<br>1 ct gloss wood finish | 455 mm | 455 mm (test stopped after 36 seconds) | 4 |
| 2 cts solvent-based intumescent undercoat<br>1 ct satin clear top coat | 480 mm | 480 mm (test stopped after 30 seconds) | 4 |
| 1 ct clear wood sealer<br>2 cts satin wood finish<br>2 cts solvent-based intumescent undercoat<br>1 ct gloss wood finish | 525 mm | 525 mm (test stopped after 1 minute) | 4 |
| 2 cts water-based intumescent undercoat<br>1 ct top sealer | nil | nil | 1 |

Notes:
1. All tests were carried out on the large scale apparatus at the Warrington Research Centre.
2. All tests were carried out on untreated gaboon plywood (6 mm thick) obtained from British Rail Engineering Ltd, Litchurch Lane, Derby.
3. All panels were laboratory aged for one month before testing.

flame broke through the panel, which was indicated by a rapid increase in temperature to about 400°C.

At least two coats of intumescent paint applied at 150 microns wet film thickness per coat, which was considered a realistic film thickness for decorative fire retardant paints suitable for brush application, were required to minimise the surface spread of flame and ensure a good level of intumescence and, hence, substrate protection. There was no difference in the fire protective properties of the water-based and solvent-based intumescent paints, but the solvent-based paints had superior flow properties and gave a more aesthetically acceptable appearance.

### *2.2.2 Flame retardant paints*

The flame retardant paints, although having excellent brush application and flow properties, gave far inferior fire protection to the substrate than the intumescent paints, as shown by:

(i) The much greater surface spread of flame, i.e. 11" compared with 3-4" for the comparable two coats of intumescent paint.

(ii) The fact that the panel had completely burnt through whereas the intumescent paint had protected the substrate (cf. figures 5 and 14).

### *2.2.3 Effect of decorative finish on fire retardant properties*

The inclined plane tests have clearly shown that the type of finishing paint applied over the intumescent coatings, to improve the aesthetic appearance, can greatly influence the overall fire protective properties. All tests were carried out over two coats of intumescent paint applied at 150 microns wet film thickness per coat and showed that:

(i) Any conventional decorative finish produces an initial surface flame flashover, and the greater the number of decorative finishing coats the greater the surface flashover (see Figure 6).

(ii) The decorative finishes appeared to stifle the formation of the intumescence, and the greater the number of finishing coats the greater the stifling effect and the lower the substrate protection.

(iii) The high build decorative paints based on vinyl toluenated alkyd appeared to stifle the formation of the intumescence less than the conventional decorative paints based on alkyds, as shown by the greater substrate protection, although the surface spread of flame was the same in both cases. However, differences may also have been due to formulation variables from company to company and from paint to paint, as tests on white decorative finishes from four companies have shown a very wide range of surface spread of flame and substrate protection as shown in Figure 6.

(iv) Different coloured decorative paints from the same company can effect the surface spread of flame, although the effect was not so apparent as with the four white finishes from different companies, as shown in Figure 6. Again these differences were probably due to formulation variables such as pigment/vehicle ratios, the use of organic pigments for the bright colours, etc.

(v) The use of decorative flame retardant paints (as the finishing paint only) greatly reduced the surface spread of flame and increased the substrate protection; the spread of flame was 7" compared with 10" for a single coat of conventional decorative finish, with the elimination of charring at the back of the panel. However, the intumescence was stifled by the flame retardant finish.

Following the fire rig tests (see section 2.3.3 "Fire retardant paints"), collaborative paint companies submitted a "new generation" of highly decorative fire retardant processes based on two coats of intumescent undercoat and a modified flame retardant finish which would not stifle the formation of the intumescence:

(i) A decorative fire retardant process consisting of two coats of solvent-based intumescent undercoat at 150 microns wet film thickness per coat and a reformulated gloss flame retardant finish applied at 50-75 microns wet film thickness produced a very high level of intumescence with excellent fire retardant properties as shown in Figure 7, with a maximum surface spread of flame of 3-4" with no surface flame flashover or substrate charring.

(ii) The new generation of decorative fire retardant processes evaluated have indicated that the nature of the two top coats have a great influence on the overall fire retardant properties (as shown in figures 8 and 9).

(iii) Overcoating two coats of solvent-based intumescent undercoat with conventional decorative and flame retardant finishes significantly increased the spread of flame, and only with the reformulated flame retardant finish was there no increase in the spread of flame on overcoating (see Table 3).

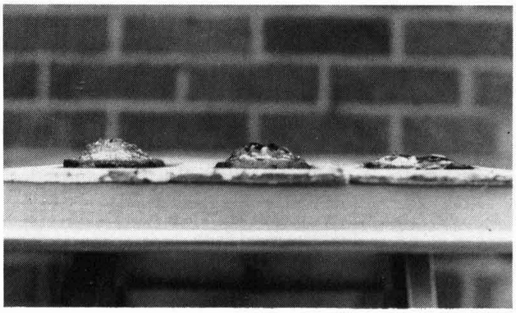
### *2.2.4 Maintenance painting*

The interiors of passenger rolling stock are re-painted every 2-3 years due to general wear and tear and it would be uneconomical to apply three coats of fire retardant paint at these time intervals instead of the normal one coat decorative paint. Although the three coat process gave greatly improved fire protection to ceiling panels taken from scrapped passenger stock, as shown in Figure 10, regular three coat maintenance painting could lead to premature adhesion failures.

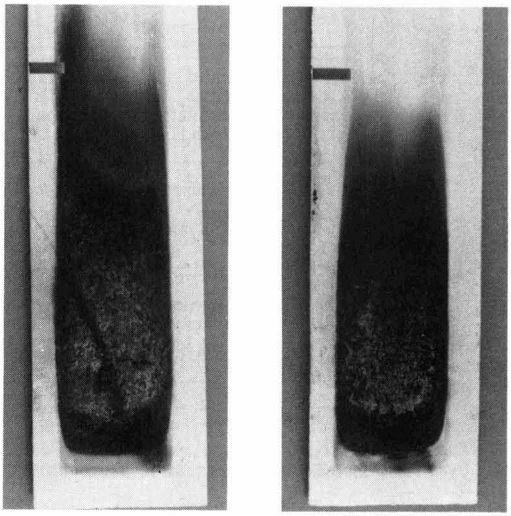
The inclined plane test clearly showed that re-painting with single coats of conventional decorative finish greatly increased the surface spread of flame from 10" with one coat of decorative finish to 17" with three coats of decorative finish. However, re-painting with flame retardant finishes greatly reduced the spread of flame compared coat-for-coat with that obtained with the conventional decorative finishes, i.e. from 3-4" with one coat of reformulated flame retardant finish to 5-6" with three coats of the flame retardant finish. The latter had a lower spread of flame than that obtained with two coats of water-based intumescent paint and one coat of high build decorative finish, which gave an excellent performance in fire rig tests.

### *2.2.5 Other fire retardant paint systems*

Two other processes, other than those based on the single pack intumescent paints already discussed, were evaluated

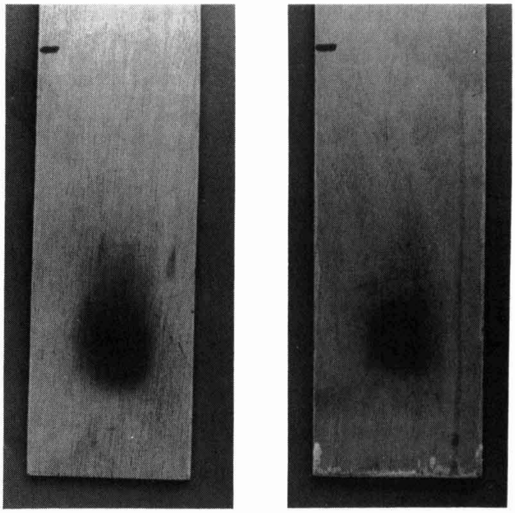


**1. Level of intumescence. Effect of number of coats of intumescent paint (left to right three coats, two coats, one coat)**



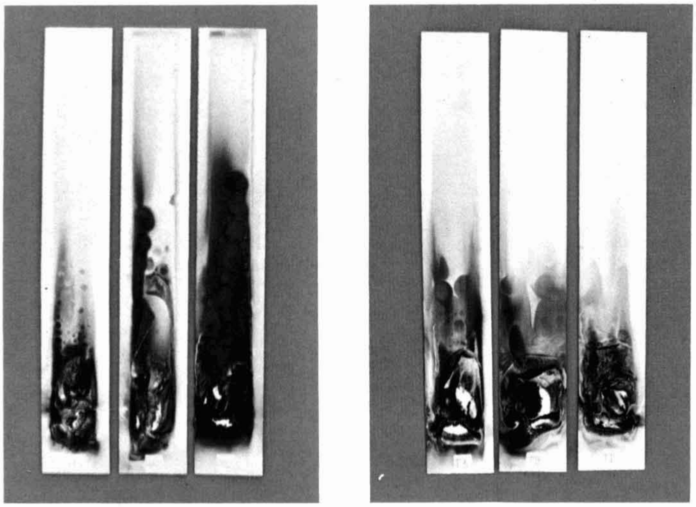
**2. Surface spread of flame**

**One coat intumescent paint** **Two coats intumescent paint**



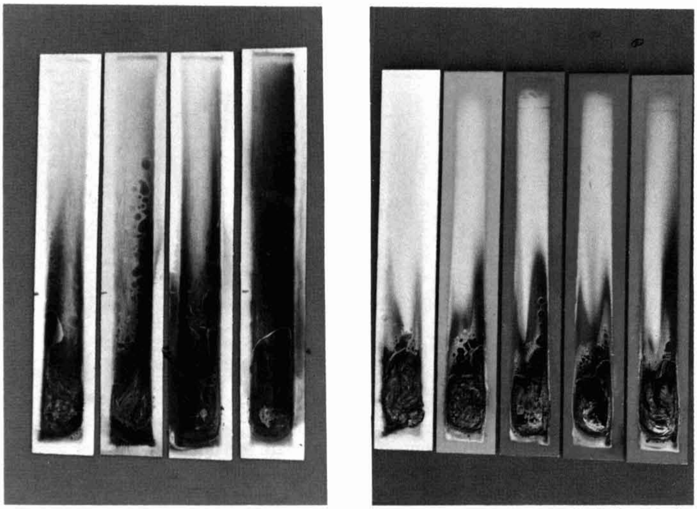
**3. Reverse of above panels shows substrate fire protection**

**Figure 5. Fire protective properties of intumescent paints**



1. Conventional decorative finish (left to right one coat, two coats, three coats)

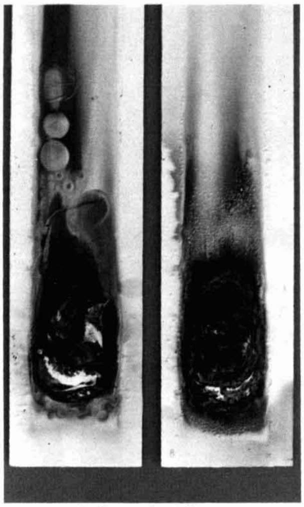
2. Decorative flame retardant paints (left to right three coats, two coats, one coat)



3. White finishing paints from different manufacturers

4. Different coloured finishing paints from the same manufacturer

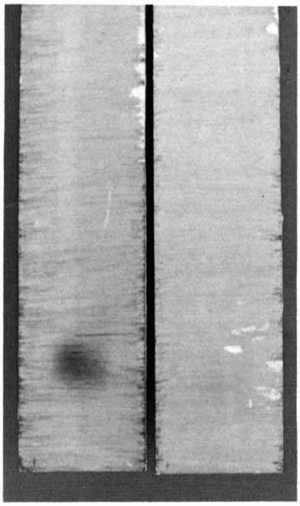
Figure 6. Effect of overcoating intumescent paints with decorative finishes



1. Spread of flame

Conventional flame retardant finish

"Modified" flame retardant finish



2. Substrate protection (back of above panels)

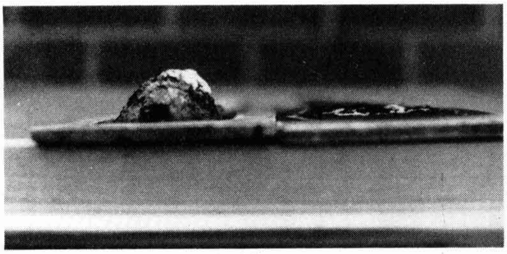
Figure 7. Effect of overcoating intumescent paints with flame retardant finishes

for use in the interiors of passenger rolling stock. Since the finishing coats in these processes are not fire retardant, further work is in hand to establish maintenance painting requirements.

*2.2.5.1 Two-pack epoxy intumescent paint* – Two coats of the intumescent paint were required to minimise the spread of flame and to maximise the substrate protection. The level of intumescence was far greater than that obtained for any other paint examined and this was reflected in the excellent substrate protection (see Figure 11). However, the spread of flame for two coats appeared to be greater than that for one coat but was due to the *deflection* of the flame by the large amount of intumescence formed.

Overcoating two coats of the intumescent paint with one coat of high gloss two-pack polyurethane finish did not significantly reduce the level of intumescence or the fire protective properties (see Figure 12). This process combining the excellent fire protective properties of the two-pack epoxy intumescent paint and the hardness and decorative properties of two-pack polyurethanes was considered suitable for painting areas subject to considerable wear and tear, such as interior surfaces of doors.

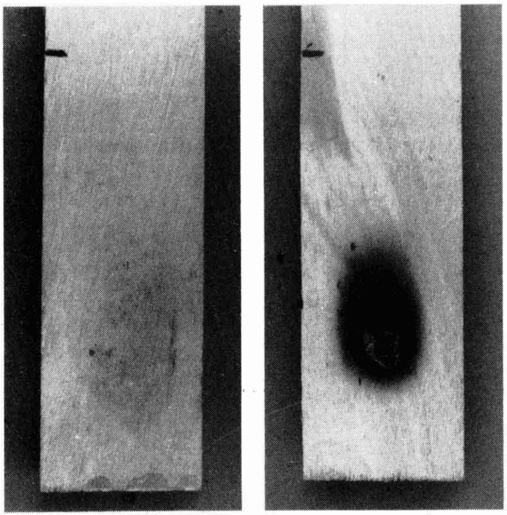
*2.2.5.2 Intumescent varnish* – As with the intumescent paints, the level of intumescence obtained with the water-based varnish was dependent on the number of coats applied (see Table 4), and two coats of varnish, applied at



1. Level of intumescence

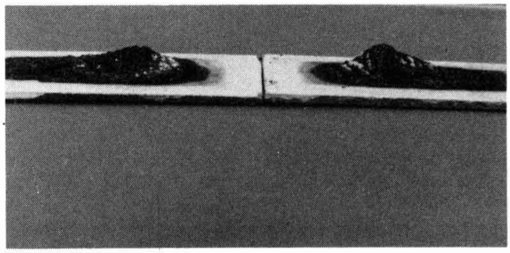
Modified flame retardant finish

Conventional flame retardant finish



2. Substrate protection (back of above panel)

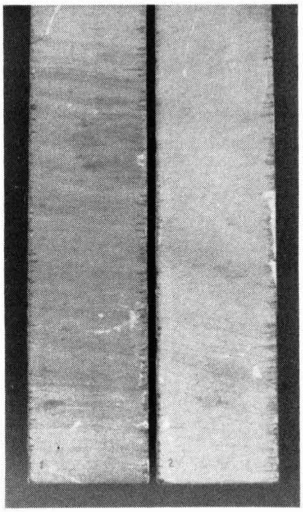
**Figure 8. Effect of type of flame retardant finish on intumescence and substrate protection**



1. Level of intumescence

Modified intumescent undercoat

Conventional intumescent undercoat



2. Substrate protection (back of above panels)

**Figure 9. Effect of intumescent intermediate coats on intumescence and substrate protection**

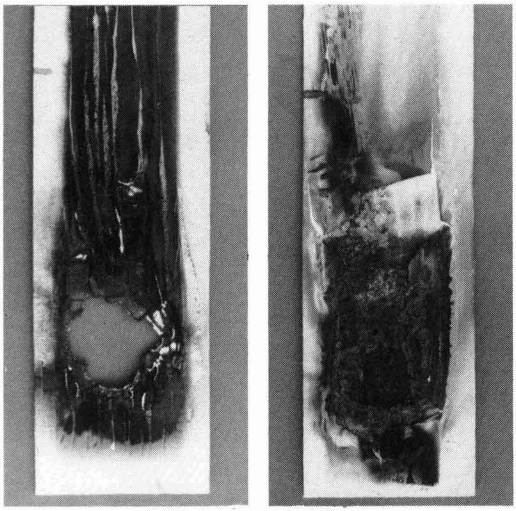
150 microns wet film thickness per coat, were necessary to minimise the surface spread of flame and ensure satisfactory substrate protection (see Figure 13). The maximum spread of flame for two coats of intumescent varnish was 2-3" whereas for the standard interior wood varnish process (consisting of a sealer and two coats of satin wood varnish) the spread of flame was 18", with initial surface flashover and no substrate protection.

The nature of the finishing coat was again found to affect the overall fire retardant properties and tended to stifle the level of intumescence. The best results were obtained using a thermoplastic white spirit-based top coat, which gave a spread of flame of 2-3" for a three coat process and with no surface flashover. Changing the finish to a conventional alkyd varnish stifled the formation of intumescence and increased the spread of flame to 6-7" with an initial flashover. Applying two coats of varnish finish, irrespective of its type, greatly increased the spread of flame, although the thermoplastic finishes gave no surface flashover.

The refurbishing of polished woodwork necessitates the removal of the existing varnish system in those areas that have been badly marked or where the finish has deteriorated to such an extent that a satisfactory standard of surface preparation cannot be obtained by re-varnishing. Consideration was given to a maintenance schedule that would eliminate the sanding/stripping procedures and replace it by a simpler process, involving tinting of the water-based intumescent varnish to various shades, e.g. rosewood, teak, walnut and pine to match the original woodwork colours. Inclined plane tests have shown that the introduction of the tints slightly increased the spread of flame from 2-3" to 3-4" or so depending on the level of tint (see Table 4) but these materials were far superior in fire retardant properties to the traditional three coat decorative varnish process.

### *2.2.6 Effect of timber pretreatment on fire protection*

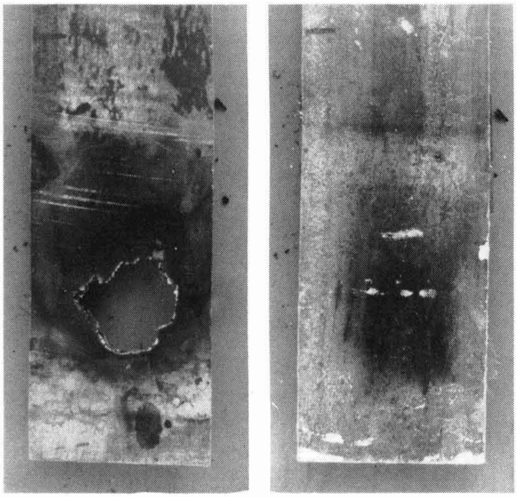
The effect of applying a three coat flame retardant paint process to both untreated and impregnated 6 mm gaboon plywood is clearly shown in Figure 14. The untreated timber burnt completely through with a high surface spread of flame of 12", whereas the similarly painted impregnated plywood had not burnt through with a significantly reduced spread of flame of 8". However, the degree of scorching on the back of the impregnated plywood panel was far greater than that obtained with intumescent paints applied to untreated timber (cf. Figure 5 and a surface spread of flame of 3-4" for two coats of



1. Surface spread of flame

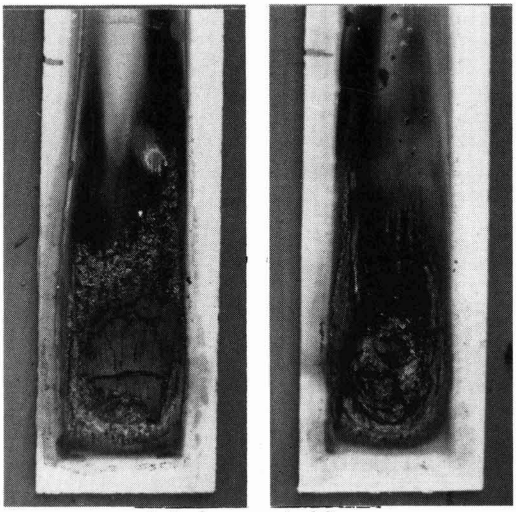
"As received" with 12-15 coats of paint

"As received" but coated with two coats of solvent-based intumescent paint and one coat flame retardant finish



2. Substrate protection (back of above panels)

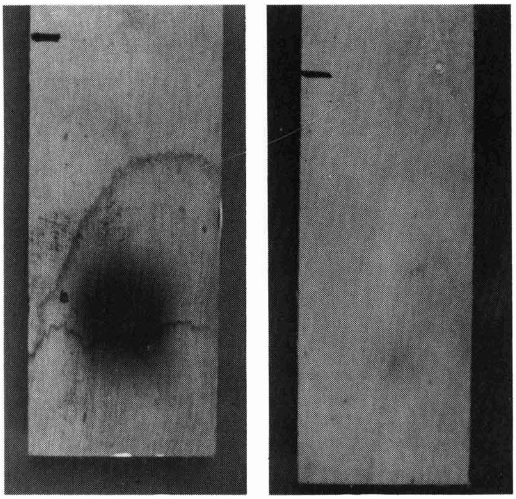
**Figure 10. Fire protection of ceiling panels from scrapped coach**



1. Surface spread of flame

One coat intumescent paint

Two coats intumescent paint



2. Substrate protection (back of above panels)

**Figure 11. Fire protective properties of intumescent two-pack epoxy paint**

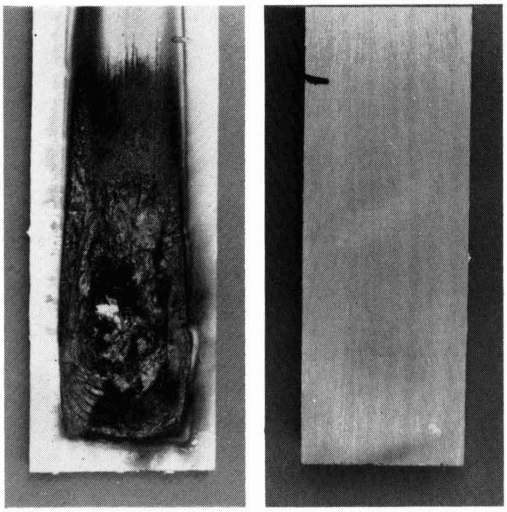
intumescent paint on untreated plywood) and was a reflection of the poor fire protective properties of flame retardant paints in these tests. Painting impregnated timber with two coats of intumescent paint eliminated the scorching on the back of the panel and reduced the surface spread of flame to 3-4" (see Table 5).

### 2.3 British Rail fire rig test

#### *2.3.1 Development*[76]

Although the number of serious fires involving passenger rolling stock is very small, the type of fires that occur suggest that materials for use in the interior of vehicles, normally selected on the basis of the indicative small scale fire tests, should be subjected to more realistic test methods. The ideal solution would be to carry out large scale tests in passenger rolling stock in "in service state", but apart from being expensive this would require both complex instrumentation and considerable data processing if the relevant factors were to be fully assessed. In a large scale test the contribution of an individual seat, wall panel, ceiling, etc. in the development of a fire was difficult to determine and attempts have been made to develop realistic fire test rigs.

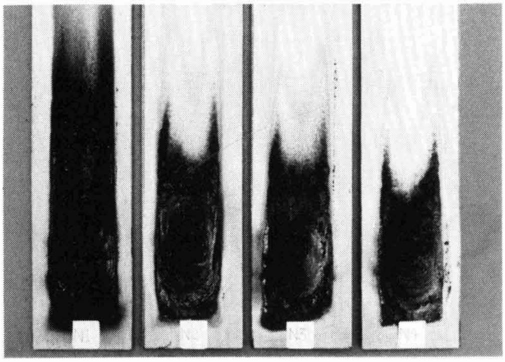
The Fire Research Station have successfully used a test rig for the examination of domestic and commercial fur-



Surface spread of flame

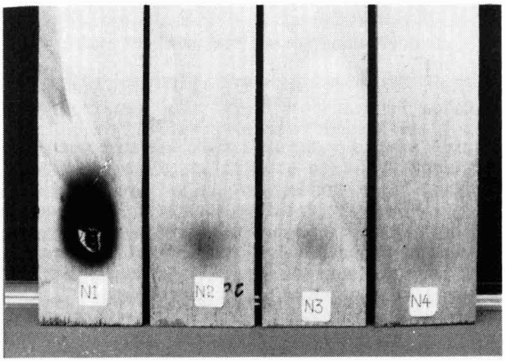
Substrate protection (back of panel on left)

Figure 12. Overcoating intumescent two-pack epoxy paint with two-pack polyurethane finish



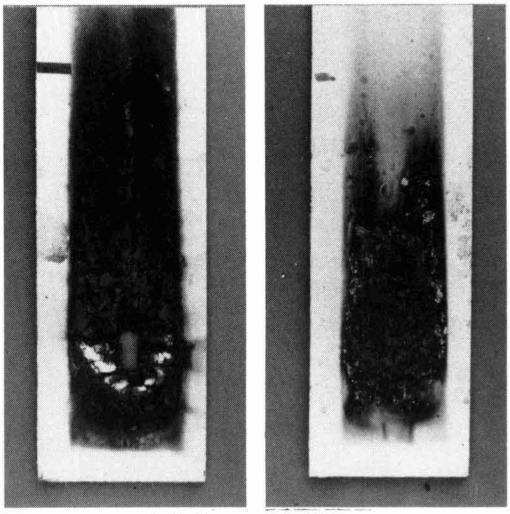
Surface spread of flame

(Left to right one coat, two coats, three coats, four coats)



Substrate protection (back of above panels)

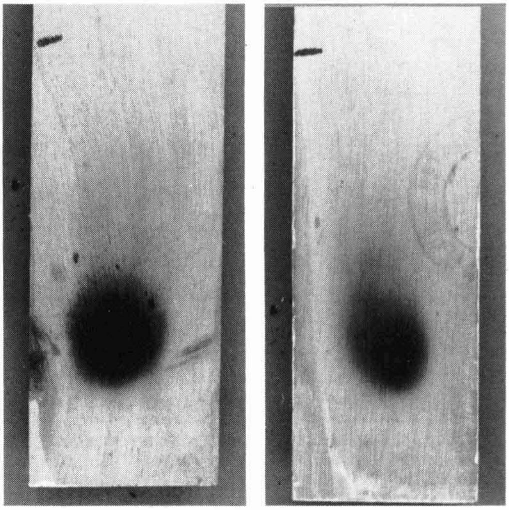
Figure 13. Fire retardant properties of water-based varnish



1. Surface spread of flame

Untreated gaboon plywood painted with three coats flame retardant process

Flame retardant gaboon plywood painted with three coats flame retardant process



2. Substrate protection (back of above panels)

Figure 14. Effect of timber pretreatment on fire protection

niture and fittings based on a typical ground floor in a house with a corridor (or hallway) off the room[78]. The items under investigation were subjected to pre-determined ignition sources and the room/corridor allows collimation and stratification of the hot gases produced and reduces the necessity of the multi-sampling involved in large scale tests. The test rig enabled materials to be subjected to different ignition sources often more relevant to a real fire, but in the large overall volume of the rig (20 m$^3$) the relatively small quantities of smoke, toxic gases and heat evolved would be difficult to detect.

*Table 3*
*Inclined plane fire test results – paints*

| Paint process | Maximum surface spread of flame | Comments |
|---|---|---|
| 3 cts decorative process | 17″ | No protection – panel completely burnt through |
| 1 ct water-based intumescent paint | 6-7″ | Substrate scorched at back. Moderate intumescence |
| 2 cts water-based intumescent paint | 3-4″ | Good intumescence and substrate protection. Poor decorative appearance |
| 1 ct water-based intumescent paint<br>1 ct decorative paint | 10″ | Initial flashover after 15 seconds. Poor intumescence and susbtrate protection. Poor decorative appearance |
| 2 cts water-based intumescent paint<br>1 ct decorative finish | 10″ | Initial flashover after 15-30 seconds. Intumescence was stifled decorative appearance |
| 2 cts water-based intumescent paint<br>2 cts decorative finish | 10-11″ | Initial flashover after 15 seconds. Intumescence stifled but good substrate protection. Poor decorative appearance |
| 2 cts water-based intumescent paint<br>1 ct high build decorative finish | 10″ | Initial flashover after 15 seconds. Intumescence was stifled but less than with decorative paint |
| 1 ct solvent-based intumescent paint | 7″ | Substrate scorched at back. Moderate intumescence |
| 2 cts solvent-based intumescent paint | 4″ | Good intumescence and substrate protection. Improved flow properties |
| 1 ct solvent-based intumescent paint<br>1 ct high build decorative paint | 13″ | Initial flashover. Intumescence stifled with poor substrate protection |
| 2 cts solvent-based intumescent paint<br>1 ct high build decorative paint | 10″ | Initial flashover. Intumescence stifled but good substrate protection |
| 2 cts flame retardant undercoat<br>1 ct flame retardant finish | 11″ | No surface flashover. Poor substrate protection – panel burnt through |
| 2 cts solvent-based intumescent paint<br>2 cts high build decorative paint | 13″ | Initial flashover. Intumescence stifled with fair substrate protection |
| 2 cts solvent-based intumescent paint<br>3 cts high build decorative paint | 17″ | Initial flashover. Intumescence stifled and back of panel scorched |
| 2 cts solvent-based intumescent paint<br>1 ct flame retardant paint | 7″ | No flashover. Good intumescence and substrate protection |
| 2 cts solvent-based intumescent paint<br>2 cts flame retardant paint | 8″ | No flashover. Fair intumescence and substrate protection. Intumescence slightly stifled |
| 2 cts solvent-based intumescent paint<br>3 cts flame retardant paint | 10″ | No flashover. Fair intumescence and substrate protection. Intumescence stifled |
| 2 cts solvent-based intumescent paint<br>1 ct modified flame retardant finish | 3-4″ | No flashover. Excellent intumescence and substrate protection.No stifling of intumescence |
| 2 cts solvent-based intumescent paint<br>3 cts "modified" flame retardant finish | 5-6″ | No flashover. Very good intumescence and substrate protection. Negligible stifling of intumescence |
| Scrapped coach ceiling panel "as received" with 12-15 paint layers | 12″ | Initial flashover. No substrate protection – panel completely burnt through |
| Scrapped coach ceiling panel as above with 2 cts solvent-based intumescent paint<br>1 ct flame retardant finish | 8″ | Initial flashover. Intumescence stifled but good substrate protection |
| Scrapped coach ceiling panel with 2 cts solvent-based intumescent paint<br>1 ct "modified" flame retardant finish | 3-4″ | No flashover. Excellent intumescence and substrate protection |
| 2 cts two-pack epoxy intumescent paint<br>1 ct two-pack polyurethane finish | 3-4″ | No flame flashover. Excellent intumescence and substrate protection |

*(See overleaf for notes.)*

Notes to Table 6 (on previous page):
1. Water-based intumescent paint to BR Specification 62B Item 12, applied at 150 microns wet film thickness per coat.
2. Solvent-based intumescent paint was a development sample to meet railway requirements, applied at 150 microns wet film thickness per coat.
3. Flame retardant paints to BR Specification 62B Item 13, applied at 50-75 microns wet film thickness per coat.
4. Decorative paints to BR Specification 56, applied at 50-75 microns wet film thickness per coat.
5. High build decorative paint to BR Specification 70 Item 81, applied at 75-100 microns wet film thickness.
6. All tests were carried out on untreated gaboon plywood (6 mm thick), obtained from British Rail Engineering Ltd, Litchurch Lane, Derby.
7. All panels were laboratory aged for one month before testing.

*Table 4*

*Inclined plane fire test results – varnishes*

| Varnish process | Maximum surface spread of flame | Comments |
|---|---|---|
| 1 ct clear wood sealer<br>2 cts clear interior satin wood finish | 18″ | Initial flashover. No substrate protection – panel completely burnt through |
| 1 ct water-based intumescent varnish undercoat | 5-6″ | No flashover. Fair intumescence but panel burnt through. Milky appearance |
| 2 cts water-based intumescent varnish undercoat | 2-3″ | No flashover. Good intumescence and substrate protection. Milky appearance |
| 3 cts water-based intumescent varnish undercoat | 2-3″ | No flashover. Excellent intumescence and substrate protection. Milky appearance |
| 1 ct water-based intumescent varnish undercoat<br>1 ct thermoplastic styrene butadiene finish | 5-6″ | No flashover. Fair intumescence but panel burnt through. Milky appearance |
| 2 cts water-based intumescent varnish undercoat<br>1 ct thermoplastic styrene butadiene finish | 4-5″ | No flashover. Good intumescence and substrate protection. Milky appearance |
| 2 cts water-based intumescent varnish undercoat<br>1 ct white spirit-based thermoplastic finish | 2-3″ | No flashover. Excellent intumescence and substrate protection. Milky appearance |
| 2 cts water-based intumescent varnish undercoat<br>1 ct clear interior satin wood finish | 6-7″ | Intitial flashover. Good intumescence but slightly stifled. Good substrate protection. Satisfactory appearance |
| 2 cts water-based intumescent varnish undercoat<br>2 cts clear interior satin wood finish | 13″ | Initial flashover. Intumescence stifled and scorching on back of panel. Satisfactory appearance |
| 1 ct clear wood sealer<br>2 cts water-based intumescent varnish undercoat<br>1 ct clear interior satin wood finish | 7″ | Initial flashover. Poor intumescence and scorching on back of panel. Satisfactory appearance |
| 1 ct clear wood sealer<br>2 cts water-based intumescent varnish undercoat<br>2 cts clear interior satin wood finish | 13″ | Initial flashover. Poor intumescence and scorching on back of panel. Satisfactory appearance |

Notes:
1. Clear wood sealer to BR Specification 71 Item 147, applied at 50 microns wet film thickness per coat.
2. Clear interior satin wood finish to BR Specification 71 Item 149, applied at 50 microns wet film thickness per coat.
3. All tests were carried out on untreated gaboon plywood (6 mm thick) obtained from British Rail Engineering Ltd, Litchurch Lane, Derby.
4. All panels were laboratory aged for one month before testing.

*Table 5*
*Inclined plane fire test results – fire retardant timber*

| Paint process | Maximum spread of flame | Comments |
|---|---|---|
| Unpainted, untreated plywood | 11″ | |
| Unpainted, Class 0 fire retardant plywood | 4″ | |
| 1 ct flame retardant primer<br>1 ct flame retardant undercoat<br>1 ct flame retardant finish | 7″ | Slight flashover. Substrate slightly scorched |
| 2 cts solvent-based intumescent undercoat<br>1 ct flame retardant finish | 6″ | Slight flashover. Intumescence slightly stifled and substrate slightly scorched |
| 2 cts solvent-based intumescent undercoat<br>1 ct "modified" flame retardant finish | 3″ | No flashover. Excellent intumescence and substrate protection |

Notes:
1. All tests carried out on Class 0, 6 mm gaboon plywood ex. British Rail Engineering Ltd, Litchurch Lane, Derby unless stated otherwise.
2. Solvent-based intumescent paints applied at 150 microns wet film thickness per coat.
3. Flame retardant paints applied at 50-75 microns wet film thickness per coat.
4. All panels were laboratory aged for one month before testing.

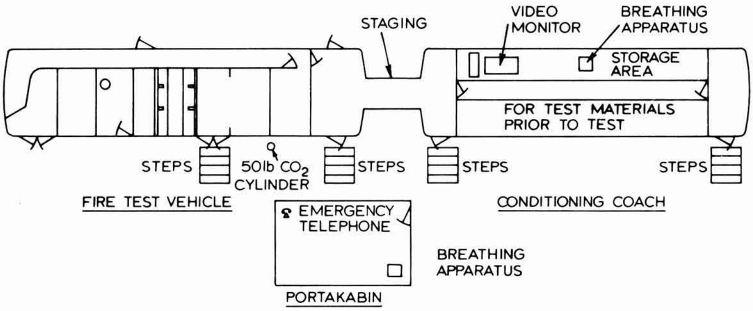
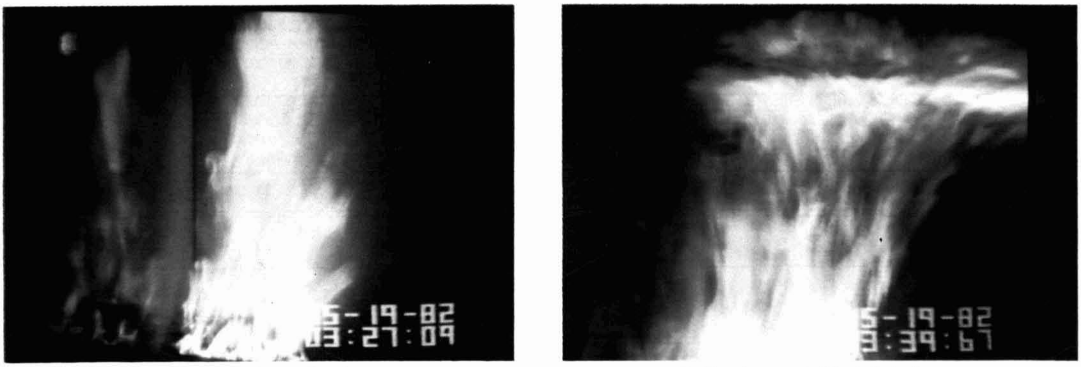


**Figure 15. General layout of fire test facility**

The Fire Research Station principle was used in modifying various compartments of a modern vehicle to construct a "room/corridor" fire test rig as shown in Figure 15. The volume of the rig was approximately 6 m$^3$ and was about the same size as a berth in a modern sleeper coach and a compartment in corridor stock. The instrumentation was installed alongside the test rig and the fires were video recorded. All materials under test, and the ignition sources, were conditioned with respect to temperature and humidity (20 ± 5°C and 50 ± 10 per cent respectively, giving a moisture content in the wood of about 10 per cent) for several weeks prior to each test in an air conditioned coach adjacent to the fire test vehicle. The general layout of the facility is shown in Figure 15 and ensured rapid transfer of the materials from the air conditioned vehicle to the test cell.

### *2.3.2 Assessment of fire retardant paints*

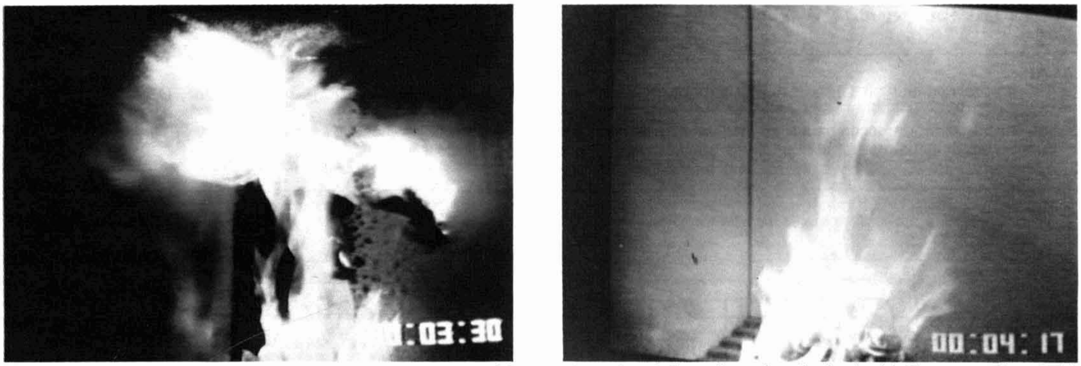
After laboratory assessment tests, which included brush application and overcoating tests as well as the small scale indicative two foot tunnel test (inclined plane test), satisfactory fire retardant paints were subjected to the British Rail fire rig test. The test rig consisted of three 1 metre square 6 mm untreated gaboon plywood panels (unless otherwise specified) coated with the fire retardant processes under consideration, brush applied at the recommended wet film thicknesses per coat, and erected in a corner configuration with the painted panels forming two sides and the roof, as shown in Figure 19. The ignition source for each test was a 2.8 kg wooden crib as described in Appendix C. The crib was ignited with 100 ml of industrial methylated spirit placed in a steel tray beneath the crib. All fire tests were video recorded through a polycarbonate window from the observation area (see Figure 15). The fire tests were terminated when the fire had "died" or when it was considered that the fire would become uncontrollable if allowed to continue, due to either the test cell being enveloped in flame or penetration of the flames to the back of the panels creating a tunnel effect with a rapid escalation in the flame intensity. The important fire rig test results are shown in figures 16-18 and summarised in tables 6-8. The results have been separated into fire retardant paints and varnishes.



1. Surface flame flashing

2. Envelopment of test rig in flames

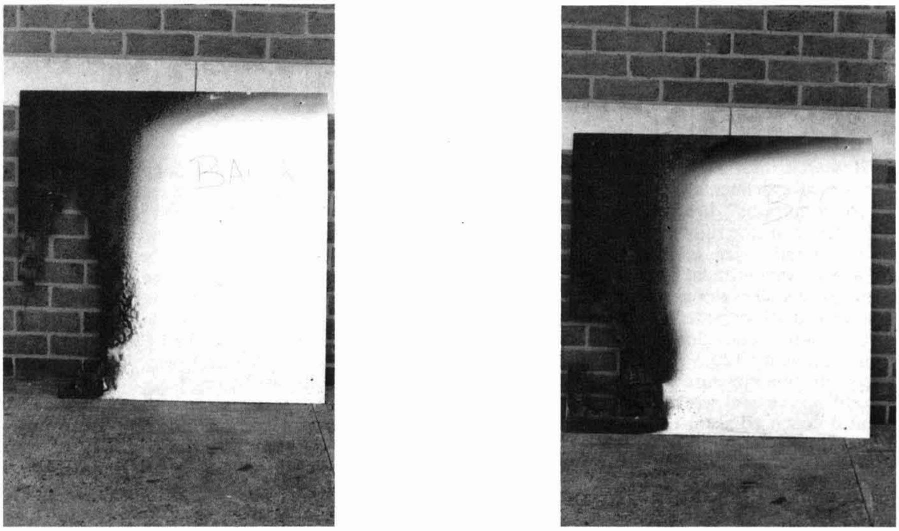
Figure 16. Fire rig test, decorative process



1. Delamination and ignition of conventional decorative finish

2. Reduced flame intensity obtained with flame retardant finish

Figure 17. Fire rig test, effect of overcoating intumescent paints with decorative finishes



1. Panel painted with two coats of solvent-based intumescent paint and high build decorative finish

2. Panel painted with two coats of solvent-based intumescent paint and one coat of modified flame retardant

Figure 18. Fire rig test, typical panels after termination of fire tests

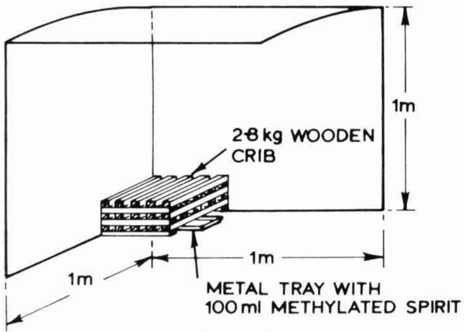


**Figure 19. Corner fire test rig**

### *2.3.3 Fire retardant paints*

The important highlights from the tests can be summarised as follows:

(i) The unpainted, untreated gaboon plywood lasted just over four minutes in the test, but overcoating with a three coat conventional decorative process significantly reduced the termination time.

(ii) There was flame flashover across the paint surface of the three coat decorative process after three minutes followed quickly by the whole of the fire test cell being enveloped in flames and the test being rapidly terminated (see Figure 16). The flashover was only a surface effect due to the ignition of the decorative paint and there was no scorching on the back of the panel.

(iii) The three coat flame retardant finish gave an improved performance over the three coat decorative and extended the termination time to seven minutes, with the elimination of the surface flashover.

(iv) Using a fire retardant paint process consisting of two coats of water-based intumescent paint and the high build decorative finish the fire was terminated after nine minutes. After four minutes the flame flashed across the whole "ceiling" and then the flame intensity decreased. There was blistering of the paint adjacent to the crib, which resulted in continuous delamination of the finishing coat and its spontaneous ignition (see Figure 17). The flame intensity again increased and the test was terminated after nine minutes.

(v) Because of the surface flame flashover and the ignition of the delaminated conventional decorative finish it was considered that these defects could be eliminated and reduced by the use of a decorative flame retardant finish. The flashover was eliminated and although the flame retardant finish did delaminate it did not ignite; the duration of the test was considerably increased to 15 minutes compared with the nine minutes when the conventional decorative finish was used. It was evident that the flame intensity was greatly reduced by the use of the flame retardant finish (see Figure 17).

The fire rig tests clearly highlighted the factors to be considered in improving the effectiveness of fire retardant paints for the interiors of rolling stock:

(i) Complete fire retardant paint processes are necessary based on two coats of intumescent undercoat applied at 150 microns wet film thickness per coat with a flame retardant finish; no previous references have been found to this composite process.

(ii) Delamination of the decorative finishes must be eliminated since delamination removed some of the intumescent coating, thus reducing the fire protective properties. It is obvious that since the delamination/fire retardant properties were highly dependent on formulation variables, and to ensure compatibilities between coatings, thus ensuring maximum fire protective properties, it is necessary to obtain three coat fire retardant processes from the same company.

(iii) Modifications to the fire retardant paint formulations were necessary because:

   (a) There was evidence of delay and stifling of the formation of the intumescence in some of the processes, due to the finishing coat, which allowed fire attack on the substrate. The flame retardant finishes required reformulating because the required properties in this type of fire retardant process are different from normal (where the heating of the paint film initiates a gaseous reaction which interferes with the flame propagation) in that the resin must soften and melt before the intumescence reaction occurs so as not to stifle its formation.

   (b) Some of the chars did not have the mechanical strength to withstand the conditions in the fire and cracked and disintegrated and exposed the substrate to the fire.

The collaborative paint companies submitted fire retardant paint processes based on these considerations and the results are shown in Table 6. It can be seen that there was a further improvement in the fire protective properties with the result that:

(i) The "defence-in-depth" fire retardant processes consisting of two coats of solvent-based intumescent and flame retardant finish gave improved performances with no flame flashover or paint finish delamination and ignition defects. The two coats of intumescent undercoat produced a high level of intumescence, with a stable char, which was not stifled by the flame retardant finish. This was reflected in the improved fire protective properties with the fire termination time being increased to over 20 minutes. It would appear that increasing the fineness of grind of the normal coarse pigment ingredients, to improve the decorative properties of the undercoats, produced higher levels of intumescence and hence substrate protection. The state of typical panels after termination of the fire test are shown in Figure 18 and it can be seen there was less loss of structural plywood than in the previous tests; the crib had completely ashed by the time the fire was terminated.

(ii) Replacing the "reformulated" flame retardant finish with a conventional flame retardant finish, but with the same solvent-based intumescent undercoats, significantly reduced the fire termination time from over 20 minutes down to around 15 minutes. Although the delamination of the flame retardant finish had been significantly reduced, it would appear to have stifled the intumescence with a consequent reduction in the fire protective properties.

(iii) The fire rig tests indicated that the fire retardant

*Table 6*
*British Rail fire test rig results – paints*

| Paint process | Test termination time (minutes) | Comments |
|---|---|---|
| Unpainted | 4½ | |
| Decorative 3 cts process | 6 | Flashover across "ceiling" after 3½ minutes. Flames rapidly engulfed whole of test cell |
| Decorative 3 cts flame retardant process | 7 | No flashover across ceiling |
| 2 cts water-based intumescent paint<br>1 ct high build decorative finish | 9 | Flashover across ceiling after 4 minutes. Decorative finish delaminated and ignited |
| 2 cts water-based intumescent paint<br>1 ct flame retardant finish | 15 | Flashover eliminated. Decorative finish delaminated but did not ignite. Panel burnt through |
| 2 cts solvent-based intumescent paint<br>1 ct flame retardant finish | 17 | Flashover eliminated. Decorative finish delaminated but did not ignite. Test stopped due to miscalculation of length of tape required. Crib had ashed |
| 2 cts solvent-based intumescent paint<br>1 ct modified flame retardant finish | 20+ | No flashover across ceiling and no decorative finish delamination |
| 2 cts two-pack epoxy intumescent paint | 30 | Excellent intumescence and substrate protection |

Notes:
1. All tests carried out on untreated 6 mm gaboon plywood obtained from British Rail Engineering Ltd, Litchurch Lane, Derby.
2. All tests carried out in British Rail fire test rig.
3. Intumescent undercoats were applied at 150 microns wet film thickness per coat.
4. All decorative finishes applied at 50 microns wet film thickness.
5. All panels were conditioned for at least one month prior to testing.
6. All tests were terminated when the fire "died" or when it was considered the fire would become uncontrollable or difficult to extinguish.

properties were greatly influenced by the nature of the two top coats, that is an intumescent undercoat producing a high level of intumescence and a decorative finishing coat which either enhances the level of intumescence produced or does not interfere in its formation. This does not infer that the first undercoat can be non-fire retardant, but it was found that significant changes in the formulations of the first intumescent undercoats did not significantly affect the overall fire retardant properties as did the formulation changes in the other two coats. It must be realised, however, that although there were significant formulation changes in the first intumescent undercoats evaluated, which resulted in differences in their individual fire retardant properties, they were all superior to most of the similar types of commercial intumescent paints evaluated over the last few years.

### *2.3.4 Two-pack epoxy intumescent paint*

The process consisting of two coats of the two-pack epoxy intumescent undercoat applied at 150 microns wet film thickness per coat confirmed the excellent results obtained in the inclined plane test, in which the level of intumescence and the substrate protection was the best of the processes evaluated. In the fire test cell the test was terminated after 30 minutes when the fire had "died away" and there were no signs of fire escalation.

The fire termination time was the longest achieved during this research programme and this, together with the excellent substrate fire protection, confirmed the excellent fire retardant properties of this paint.

### *2.3.5 Fire retardant varnish*

The intumescent varnish process consisting of two coats of water-based intumescent undercoat applied at 150 microns per coat and a top sealer, which showed considerable potential in the two foot tunnel test, was subjected to the fire rig test. The results are summarised in Table 7 and are compared with the performance of the conventional three coat decorative varnish system.

With the three coat decorative varnish system there was the familiar flame flashover across the paint surface after about three minutes, followed closely by the whole of the test cell being enveloped in flames and the test being rapidly terminated. The flames were entirely due to the ignition of the paint as there was no scorching on the back of the panel. The three coat intumescent varnish process, with a white spirit-based modified thermoplastic top sealer, produced a high level of intumescence with good fire retardant properties as shown by the fire termination time being considerably extended to 15 minutes, with no surface flame flashover or finish delamination/ignition defects. However, changing the top coat to a conventional

*Table 7*
*British Rail fire test rig results – varnishes*

| Varnish process | Test termination time (minutes) | Comments |
|---|---|---|
| 1 ct wood sealer<br>2 cts matt interior wood finish | 3½ | Flashover occurred. Flames rapidly engulfed whole of test cell |
| 2 cts water-based intumescent varnish<br>1 ct chlorinated rubber finish | 11 | No flashover. Intumescence was stifled |
| 2 cts water-based intumescent varnish<br>1 ct chlorinated rubber finish | 12½ (3) | No flashover. Intumescence stifled |
| 2 cts water-based intumescent varnish<br>1 ct white spirit-based thermoplastic finish | 15 | No flashover. Intumescence stifling was reduced |

Notes:
1. All tests carried out on untreated gaboon plywood (6 mm thick) obtained from British Rail Engineering Ltd, Litchurch Lane, Derby.
2. All intumescent undercoats were applied at 150 microns wet film thickness per coat.
3. Intumescent undercoats applied 225 microns wet film thickness per coat.
4. All finishing coats applied at 50 microns wet film thickness per coat.
5. All panels were conditioned for at least one month prior to testing.

*Table 8*
*British Rail fire test rig results – fire retardant timber*

|  | Test Termination time (minutes) | Comments |
|---|---|---|
| Fire retardant timber to Class 0 rating – unpainted | 20 | Wood cracked after 3-4 minutes. Although it did not burn it readily charred and disintegrated |
| 3 cts decorative paint process | 21½ | No flashover. Wood cracked after 4 minutes and charred and disintegrated |
| 2 cts solvent-based intumescent undercoat<br>1 ct flame retardant finish | 20 | No flashover across paint surface. Charring and disintegration of timber greatly reduced |

Notes:
1. All tests carried out on fire retardant gaboon plywood to Class 0 rating of Building Regulations: 1976 Section E15(1)(e)(11).
2. All panels were conditioned for at least one month prior to testing.

alkyd varnish produced a surface flame flashover after about 3 minutes and significantly reduced the fire termination time, due to the intumescence being considerably stifled, but the performance was still vastly superior to the three coat decorative process.

### *2.3.6 Effect of timber pretreatment*

The effects of applying both non-fire retardant and fire retardant paint processes to untreated and impregnated Class 0,6 mm gaboon plywood are shown in Table 8.

Three to four minutes after ignition of the crib, cracks appeared in both wall panels of the unpainted fire retardant timber, which gradually widened due to the charring and disintegration of the timber but which did not burn. The fire tests were terminated after about 20 minutes when the crib had died away, the test being repeated several times. The disturbing factor was the considerable proportion of treated timber in the wall panels that had completely disintegrated (about one third in each panel), and this included timber well away from the crib source. This loss of structural timber was greater than that obtained with untreated gaboon plywood coated with an intumescent fire retardent process. Painting the impregnated timber with an intumescent fire retardant paint process did not eliminate the timber cracking but confined it to an area in contact with or near the crib; the test was terminated after 20 minutes and the disintegration of the treated timber had been greatly reduced and was comparable to that obtained with the untreated timber painted with the same intumescent paint process.

During the tests a three coat conventional decorative paint process was applied to fire retardant timber, it being fully expected that the surface flame flashover and the rapid flame envelopment previously encountered with decorative paints would occur with rapid termination of the fire test. In fact the test was terminated after 21 minutes with no flame flashover across the paint surface, although there was extensive cracking/disintegration of the treated timber. The reason for the unexpected fire retardancy was that the impregnants from the treated timber had leached into the decorative paints and closer examination of the panels showed that the salts had even migrated to the finish surface.

The disintegration of impregnated timber was considered to be an undesirable effect since it would enable flames to get behind panels and could thus propagate the fire.

## 3. Rheological properties of fire retardant paints

Conventional flame retardant paints have excellent application and flow properties but do not meet the Class 1 fire retardant requirements. The water-based intumescent paints give excellent substrate protection and the Class 1 spread of flame rating but are not considered suitable for decorative interior surfaces because:

(i) Their poor rheological properties produce aesthetically unacceptable severe brushmarking in the dried films.

(ii) Overcoating with the high gloss paints would only highlight these defects.

However, water-based intumescent paints have good brush application properties and are easily overcoated after several hours drying time with no pick-up of the previously applied coats and no increased brush drag. The intumescent fire retardant varnish process, consisting of water-based intumescent undercoats and a non-fire retardant white spirit-based top coat, has satisfactory brush application and overcoating properties.

The fire tests have clearly shown that to meet the fire retardant requirements for the refurbishing of the interiors of vehicles necessitates two coats of high build intumescent undercoat and a flame retardant finish; the rheological requirements are:

(i) Good brush application properties with good flow and minimal visual brushmarking when the intumescent undercoats are overcoated with gloss fire retardant paints.

(ii) The paint viscosities/volume solids of each intumescent undercoat must be strictly controlled so that the essential wet film thickness of 150 microns per coat, and hence the fire retardant properties, can be achieved; the volume solids of each coat is normally above 50 per cent. The viscosities/volume solids of the domestic gloss fire retardant finishes are also important because, although these coats are normally applied at only 50-75 microns wet film thickness, the pigment volume concentrations in these paints are lower to enable the gloss requirements to be met and to reduce the migration of the fire retardant salts out of the paint films, but the intumescence of the undercoats could be stifled because of the higher cohesive strength of the finishing coat; in general, it would be preferential to have low volume solids for the finishing coats based on a suitable medium.

(iii) Each intumescent undercoat must be capable of being overcoated without being softened back (and increasing the brush drag) or excessive sinkage. It is possible that this could be achieved by slightly different resin/solvent formulations in subsequent coatings.

The new generation of fire retardant paint processes now under evaluation have in general been solvent-based with vastly improved surface appearance due to paint manufacturing techniques significantly increasing the fineness of grind of the normally coarse ingredients. These paints have good brush application and flow properties and the initial problems of softening back with increased brush drag have been overcome by reformulation. These processes combine the excellent application, flow and overcoating properties of conventional decorative paints and the excellent fire retardant properties of intumescent paints.

## 4. Conclusions

1. This work has clearly shown that few fire retardant paints commercially available at the start of this research programme met the fire retardant requirements for the refurbishing of passenger rolling stock, and none possessed the required decorative properties. Flame retardant paint processes, although highly decorative, cannot achieve the required fire retardant properties; intumescent paints had excellent fire retardant properties but were aesthetically unacceptable because of the residual brushmarks in the dried film. It became necessary to initiate a collaborative programme with the paint industry to achieve the railway objectives.

2. The small scale indicative fire tests used in this report are only suitable for eliminating the inferior fire retardant paints but cannot predict paint performance in a "real fire". This was better achieved by use of the fire test rig to simulate railway vehicle interior conditions.

3. Almost all of the fire retardant paints and varnishes evaluated in the fire test rig had the required Class 1 spread of flame rating to British Standard 476: Part 7: 1971, "Spread of Flame Test for Materials", but the fire test rig highlighted several serious defects:

(i) Rapid spread of flame across the decorative finish on the "ceiling" only a few minutes after the fire was initiated, followed by a reduction in the flame intensity.

(ii) Delamination and ignition of the decorative finishes, which could propagate further fires; delamination also removed some of the intumescent coatings and thus reduced the fire retardancy.

4. The decorative fire retardant requirements for the refurbishing of the interiors of passenger rolling stock can be achieved by a properly formulated three coat fire retardant process consisting of two coats of intumescent paint applied at 150 microns wet film thickness per coat, which provides the fire retardant and substrate protection

properties, and a "reformulated" flame retardant finish applied at 50 microns wet film thickness, which:

(i) Eliminates flame flashover across its surface.

(ii) Does not delaminate (thus eliminating removal of some of the intumescent coating) and contributes to the defence-in-depth fire retardant paint process.

(iii) Gives the required gloss level and reduces the leaching out of the soluble fire retardant salts from the undercoats but does not stifle the intumescence; the higher the gloss level the greater the possibility of stifling of the intumescence, which lowers the fire retardancy, although the reformulated finish was still superior to similar commercially available fire retardant processes.

These paints have excellent brush application, flow and overcoating properties and produce a high level of decorative appearance. Maintenance painting can be achieved by single coat repaints with the flame retardant finish instead of the full three coat fire retardant process. Any signficant stifling in the formation of the intumescence in the undercoats, and hence a reduction in the fire retardant properties, by the multi-coat layers of flame retardant finish will determine the number of repaints; this has still to be established.

5. The best fire retardant paint process evaluated was based on two coats of a two-pack epoxy intumescent applied at 150 microns wet film thickness per coat, which produced the highest level of intumescence achieved with any coating and this was reflected in the excellent fire retardancy and substrate protection.

6. The fire retardant varnish process consisting of two coats of water-based intumescent varnish, applied at the usual 150 microns wet film thickness per coat, and a white spirit-based non-flame retardant top coat has shown considerable potential for refurbishing work. The undercoats can be tinted to match the original wood colours.

7. The disintegration of the fire retardant timber during the fire tests was of concern as it could allow the flames to penetrate to the back of the panel with the possible further spread of the fire. Overcoating the impregnated timber with an intumescent-based fire retardant process greatly reduces the disintegration.

8. Although the fire retardant processes have been discussed for the refurbishing of the interiors of passenger rolling stock, it was realised at the outset of the research programme that these paints could be utilised equally for the interior painting of buildings where there was considered to be a fire risk; the varnish process could have potential in the furniture industry.

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The authors would like to thank the raw material and paint industries for the assistance and information that was given, especially the paint companies, whose collaboration brought the research programme to a successful conclusion. Special thanks are expressed to their colleagues in the Fire Section of the Hazards Unit at the Railway Technical Centre, Derby for the expertise in implementing the fire rig tests and the invaluable technical discussions. The authors acknowledge the permission of the Director of Research, British Railways Board, to publish this paper.

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## Appendix A

### Properties of some intumescent paint ingredients

*1. Possible sources of carbon for char formation*

| | Formula | Carbon content (% by wt) | Reactivity sites/100 g |
|---|---|---|---|
| *Sugars* | | | |
| Glucose | $C_6H_{12}O_6$ | 40 | 2.8 |
| Maltose | $C_{12}H_{22}O_{11}$ | 42 | 2.3 |
| Arabinose | $C_5H_6O_4$ | 45 | 3.0 |
| *Polyhydric alcohols* | | | |
| Erythritol | $C_4H_6(OH)_4$ | 39 | 3.3 |
| Pentaerythritol | $C_5H_8(OH)_4$ | 44 | 2.9 |
| dimer | $C_{10}H_{16}(OH)_6$ | 50 | 2.5 |
| trimer | $C_{15}H_{24}(OH)_8$ | 53 | 2.4 |
| Arabitol | $C_5H_7(OH)_5$ | 39 | 3.3 |
| Sorbitol | $C_6H_8(OH)_6$ | 40 | 3.0 |
| Inositol | $C_6H_6(OH)_6$ | 40 | 3.0 |
| *Polyhydric phenols* | | | |
| Resorcinol | $C_6H_8(OH)_2$ | 63 | 1.8 |
| *Starches* | $(C_6H_{10}O_5)_n$ | 44 | 2.1 |

*2. Typical blowing agents*

| Material | Gaseous by-products | Decom-position temp (°C) |
|---|---|---|
| Dicyandiamide | $NH_3$, $CO_2$,$H_2O$ | 210 |
| Melamine | $NH_3$, $CO_2$,$H_2O$ | 250 |
| Guanidine | $NH_3$, $CO_2$,$H_2O$ | 160 |
| Glycine | $NH_3$, $CO_2$,$H_2O$ | 233 |
| Urea | $NH_3$, $CO_2$,$H_2O$ | 130 |
| Chlorinated paraffin (70% Cl) | $HCl$, $CO_2$,$H_2O$ | 190 |

## Appendix B

### British Standard 476: Part 7: 1971 – Surface spread of flame classifications

| Classi-fication | Flame spread at 1½ mins | | Final flame spread | |
|---|---|---|---|---|
| | Limit (mm) | Tolerance for one specimen in sample (mm) | Limit (mm) | Tolerance for one specimen in sample (mm) |
| Class 1 | 165 | 25 | 165 | 25 |
| Class 2 | 215 | 25 | 455 | 45 |
| Class 3 | 265 | 25 | 710 | 75 |
| Class 4 | ——— exceeding Class 3 limits ——— | | | |

The flame-spread on any specimen of the sample shall not exceed the limit assigned for the class, with the proviso that for one specimen only in the sample the flame spread may exceed this limit by the tolerance shown.

## Appendix C

### Details of crib used as ignition source in fire rig tests

The cribs used were made of 30 sticks of Douglas Fir *(Pinus silvestris)*. Each stick measured 30.25 cm × 2.5 cm × 2.5 cm (12" × 1" × 1"). Each layer of the crib contained 6 sticks spaced evenly 3.05 cm (1.2") apart and parallel to each other. Alternate layers were at right angles and there were 5 layers. A small amount of PVA adhesive was used to enable handling of the crib.

Such a crib has a burning rate of 227 g/min, a maximum heat output of 53 kW, a flame length of 0.84 m, a burning time of 13.6 minutes and a total mass of approximately 2.8 kg.

The crib was ignited with 100 cc industrial methylated spirit placed in a steel tray beneath the crib.

# London Section

### Colour measurement and colorimeters

In his talk "Colour measurement and colorimeters" on 17 February 1983, Dr D. A. Plant said that in many industries the colour of a product and of its packaging was an essential part of its quality and appeal. In some cases control of appearance is not practised but in most cases visual controls are operated perhaps leading to feedback and adjustment. Colour measurement can offer greater precision and reproducibility, and can be extended to automated processing where visual methods cannot operate.

Methods of colour measurement were described. Firstly using spectrophotometers – which measure relative reflectance at defined wavelength intervals compared to a standard, generally barium sulphate, and are independent of illuminant. Secondly using colorimeters – which define a colour by determining the proportion of the three primaries which comprise it or will match it and are specific to a single illuminant, generally daylight.

Illuminants and colour specification were discussed and reference made to the CIE system and later Hunter, ANLAB and CIELAB systems. The value of the CIELAB system was stressed.

The application of colour measurement to manufacturing control, shade matching, batch correction, work-off of off shade batches and detection of metamerism was described. The control of product manufacture is the main area where colour difference measurements are used. Modern instruments avoid the disadvantages of visual control processes. Whereas colour measurements may be used in control of manufacture, customers may continue to use visual assessments and so satisfactory agreement between instrumental and visual methods is necessary. The development of colour difference units has been directed towards improvements of correlation with visual results.

Time was spent in describing the problems that can arise from metamerism, where a match under one illuminant is clearly not so under another.

Tristimulus colorimeters relate only to one illuminant but may be modified so that readings under a second illuminant can be made and metameric indices calculated.

This most informative talk was well illustrated with slides and concluded by saying that the present generation of colorimeters using microprocessors and spectrophotometers using mini-computers have a high degree of precision and are very robust. The accuracy of colour difference measurements in the case of colorimeters is so great that more problems arise due to the preparation of panels than from instrument errors. The preparation of panels must follow a carefully laid down procedure.

### The UK paint industry from the 60s to the 80s and beyond

At the meeting on 22 September the Chairman, Mr F. D. H. Sharp, was pleased to be able to introduce Mr L. Silver of Kalon Ltd as guest speaker. The title of Mr Silver's talk was "The UK paint industry from the 60s to the 80s and beyond" and in this he surveyed the changes in the fortunes of the larger paint companies and the industry generally during this period. It was shown that production rose to 739m litres in 1979 since which time a decline has occurred, in 1981 production being 653m litres. Profitability has been declining over many years, as have the numbers employed in the industry.

Of great significance in the area of decorative paints has been the decline in the number of outlets, mainly hardware stores, which fell from 16,000 to 5,500 within 20 years due to the growth of supermarket outlets. Also of note is the change from DIY one-third and trade two-thirds to the reverse within this period.

The second part of Mr Silver's talk was a most fascinating account of the development of Silver Paint Company founded in 1947 to the present company, Kalon. The development of the company had shown the virtues of informal meetings and quick decisions taking advantage of the needs of the day. This was shown in the decision to manufacture paint in 1947. At this time Mr Silver was acting as an agent for paints and when his source of supply was cut off he decided to manufacture himself to suit his own needs.

In the same way in 1973 when problems arose in the supply of emulsion polymers, laboratory work was started to develop these, leading to the founding of Kirklees Chemicals in 1975.

A key development was the entry into export marketing, particularly to West Africa, which has contributed to a ten-fold increase in exports in the last seven years and the need to open a new factory at a cost of £5.5m.

The extended period of questions for Mr Silver reflected the interest of those present. Mr Silver believed that innovation can only come from brand leaders who have high advertising budgets, but it was accepted that innovation could cover both technical and marketing innovation.

He outlined the recently announced technical agreement between nine overseas companies and Kalon, where exchange of information and development of new products would be mutually beneficial. He believed in the future of the UK paint industry and in particular of Kalon.

A vote of thanks was given by Mr Worsdall for the most interesting and revealing talk given by Mr Silver and congratulations on his personal leadership of one of the success stories of the industry.

*K. H. Arbuckle*

### Visit to the Laboratory of the Government Chemist

A small party from London Section visited the LGC headquarters at Cornwall House near Waterloo Station on the afternoon of Wednesday 28 September. We were treated to a fascinating demonstration of modern analytical equipment which is used to support the work of government departments, local authorities and other institutions.

Mr Terry Alliston, who organised our visit, began by explaining the history, functions and current status of the Laboratory of the Government Chemist. With origins dating back to 1842, when it was set up to analyse tobacco products for the Board of Inland Revenue, the LGC now employs 350 personnel, most of whom are based at Cornwall House, and operates on an annual budget totalling £8m. Some 90 per cent of their work is connected with government departments, including HM Customs and Excise, Ministry of Agriculture, Fisheries and Food, Ministry of Defence, the Department of the Environment and the Department of Health and Social Security; the LGC also acts as the Research Establishment for the Department of Industry. Recently they have been placing more emphasis on offering their services to the private UK business sector in such areas as the analysis of agricultural materials and oil spillages, advice on chemical nomenclature, analytical methods and dangerous goods.

During the visit the detailed techniques used in four main areas were demonstrated.

In the oil and fats part of the Food Section, capillary column gas chromatography is the standard technique employed to characterise the substance under investigation. This identifies the fatty acid components and also provides a quantitative assessment by means of computer-linked integration methods. For such materials as herbs with a similar distribution of organic acids, the supplementary use of headspace gas analysis is usually necessary.

In their Molecular Spectroscopy Division we were shown the latest sophisticated NMR equipment which has just been installed. In most cases, irradiation by C13 species is preferred for qualitative identification of organic compounds, this method involves the use of Fourier transformation techniques which I suspect very few of our party (including the writer) fully understood! Initial characterisation of the molecule is confirmed by comparing the infrared spectra. The LGC currently holds the reference spectra of 65,000 compounds for this purpose.

The oil pollution lab serves to identify the source of oil spillages and has developed techniques to differentiate between weathered crude oil and fuel oil using gas and thin layer chromatographic methods.

In the fourth and last lab of the visit, the analytical methods used for potable water were described. Initially this service was provided to those government establishments which have no direct mains supply and resort to wells, springs and borehole sources. Apart from anionic and cationic species, where high pressure liquid and ion exchange chromatography play a part, and heavy metals, where flameless atomic absorption spectroscopy is employed, the lab also checks other possible contaminants such as trace organic chemicals, sediment and bacteria. Topically the composition of "acid rain" is currently under investigation.

This was an extremely interesting visit and a clear demonstration of how rapidly analytical methods have developed and improved over the last 10-15 years. And, as one of our party remarked, "It's nice to think the Government cares!"

*K. A. Holt*

# Midlands Section

### Automation in the paint industry

The first meeting of the Midlands Section was held on 22 September 1983 at the Clarendon Suite, Stirling Road, Edgbaston, Birmingham. Members and guests heard Mr R. English of Mastermix Ltd give a talk entitled "Automation in the paint industry".

Mr English, a Midlands Section member, said that for a successful automated process there were three basic requirements:

1. Good materials handling.
2. Close, accurate control of the process.
3. Safety.

Referring to the equipment the speaker said that flowmeters were not considered to be accurate enough and load-cells were generally used. These are very robust and reliable being used for both liquids and solids. If the installation is very large then the solids may be stored in silos being transferred by air-blowing to the dispersion vessel. Big-bags are becoming more widely used but the more expensive organic pigments are still loaded by hand from sacks or fibre-board drums.

Cleanliness is very important and special cleaning processes are used. If the cleaning is efficient then very little trouble is encountered when changing from one colour to another.

The speaker said that the rate of pigment addition was very important to ensure good dispersion and his company had designed and developed a special vibrating discharge hopper for use when handling pigments from big-bags.

To conclude his talk Mr English demonstrated with the aid of a schematic diagram of a typical automated paint factory, a computer and a VDU screen how an automated process could be operated. By having control checks built into the computer program, the dispersion process can be controlled by the laboratory.

A lively question time followed the talk and the meeting was finally brought to a close with a vote of thanks proposed by Dr G. Lewis, endorsed by the audience in the usual manner.

*B. E. Myatt*

# Natal Section

### Preparation of steel substrates

On Tuesday 13 September Mr Dirk Pienaar of the SABS and Mr Fritz Weber of Plascon Evans Paints gave a lecture entitled "Preparation of steel substrates before application of paint and related products – the ISO Standard discussed".

Mr Pienaar outlined the work carried out by the ISO

Committees, of which SE12 had particular interest in South Africa. This sub-committee is divided into three main working groups he explained. WG1 deals with surface profile; WG2 deals with surface cleanliness; and WG3 deals with techniques of surface preparation.

Then Mr Pienaar explained in some detail the draft specification ISO 7167 which is to be circulated in the near future.

With the aid of slides, Mr Weber detailed a test method for measuring the cleanliness of a steel substrate using a test solution. The advantage of this test method is that it can be used on site. It involves an indicator system that when brushed onto a steel substrate gives a rapid colour change that quantitatively correlates with the soluble contaminants present on the surface.

An amusing vote of thanks was given by Professor David Williams-Wynn and the audience showed their appreciation in the normal manner.

### Aspects of modern paint technology

On Friday 23 September a one-day symposium entitled "Aspects of modern paint technology" was held at the venue mentioned above. A programme of six lectures especially tailored for technicians and laboratory staff in the paint and allied industries was given:

"The selection of coloured pigments for surface coatings" by G. A. Hughes – Ciba Geigy (Pty) Ltd.
"Titanium dioxide in alkyd media" by R. J. Archer – SA Tioxide (Pty) Ltd.
"Foam control in the surface coatings industry" by V. N. Mahilall – Bevaloid South Africa (Pty) Ltd.
"Biocides for use in water-based systems with particular reference to emulsions and paints" by A. G. Law – Thor Chemicals (Pty) Ltd.
"Surface preparation for heavy duty coatings" by P. A. Draper – consultant.
"Synthetic resins – some basic thoughts" by K. R. McDonald – BIP (SA) (Pty) Ltd.

To round off the day, Bevaloid sponsored a much appreciated cocktail party.

This initial venture was well supported and enjoyed by all participants and it is hoped to make this an annual event.

*R. Philbrick*

## news

### Cyanamid and Dyno announce joint venture

American Cyanamid Company and Dyno Industries AS of Norway have signed a letter of intent to form a 50 : 50 joint venture to produce and market crosslinking resins for the European coatings industry. The new company will offer the paint industry a complete range of high performance crosslinking systems which will be supported by the extensive research and technical expertise of the partners. The crosslinking resins are used extensively in industrial finishes and automotive applications. Major new products for these and related industries are now undergoing market evaluation.

The joint venture, which will launch operations early in 1984, will assume ownership of Dyno's amino resin production facility at Lillestrom near Oslo, Norway. This facility will continue to be operated by the existing plant organisation. Expansion plans for the existing facility will increase capacity to accommodate projected market demand.

Existing marketing organisations will form the nucleus of the new company's marketing force. Commercial and technical offices will be established to service the primary markets of Europe and the Middle East.

Dyno is one of Norway's major industrial companies with interests in chemicals, explosives, machinery and plastics. Cyanamid is a diversified multinational company which manufactures and markets medical, consumer and agricultural products, specialty chemicals, and formica brand laminates.
*Reader Enquiry Service No. 31*

**Signpost sales director, Alan Birrell, pours the celebration champagne for Peter Halfacre just minutes after he and two other Peterborough men, Ronnie O'Brien and Robin Jones, landed after free-falling over five miles into the record books**

### High flying Signpost Paints

A team of parachutists backed by Signpost Paints have succeeded in their attempt on the British civilian free-fall record.

The attempt had to be postponed several times because of adverse weather conditions. But as soon as the skies cleared the aircraft containing the three men complete with oxygen equipment and cold-weather clothing took off.

Following a half hour climb to 30,000 feet the three, Peter Halfacre, Ronnie O'Brien and Robin Jones, jumped. Then just over two and half minutes and five miles later they pulled their ripcords to make perfect landings at Sibson Airfield.

The aim of the jump was to raise money for a Norfolk children's home. Signpost provided cash backing to cover preparation expenses so that all the money raised would go to the charity.
*Reader Enquiry Service No. 32*

### Paint industry adviser for The Industrial Society

Peter Rose has been appointed as the first ever specialist adviser for the paint industry with The Industrial Society. Peter was formerly a manufacturing manager with Leon Frenkel in Kent. In addition to his advisory role he will also have responsibility for helping organisations in the East End of London.

Berger, International Paint, Ault & Wiborg and Blundell Permoglaze are just some of the many organisations in the paint industry that are turning to The Industrial Society for help. They have made particular use of the Society's training expertise in the areas of leadership and basic supervisory skills.
*Reader Enquiry Service No. 33*

### North American distributor for Torrance

Union Process Inc. has been designated exclusive North American distributor for Torrance & Sons Ltd. The agreement was jointly announced by Mr George Troughton, general manager of Torrance & Sons Ltd, and Mr Arno Szegvari, president of Union Process Inc.

Headquartered in Bristol, Torrance & Sons is a leading manufacturer of grinding and dispersion equipment. The firm was founded over 100 years ago and markets its products on a worldwide basis.

Torrance & Sons Ltd has been a licensee of Union Process's original attritor equipment since 1958. Both companies have maintained a technical working relationship since that time.
*Reader Enquiry Service No. 34*

### Datacolor representative

Datacolor of Zurich, Switzerland, manufacturer of colorimetric, colour matching and colour measuring systems, has appointed Westlairds Ltd as its exclusive representative for the UK and Ireland.
*Reader Enquiry Service No. 35*

## products

### Award winning chromatography system extended

Spectra-Physics is extending the LABNET local area network system by introducing the SP9200 LABNET Computer. This computer is designed to simplify the operation of chromatography laboratories. It allows the chemist to control and operate all chromatographic analysers and data systems from the SP9200 as well as being useful for general computing and laboratory management.

Many of the commonly used commands are pre-programmed into function keys for easy operation. An extended BASIC with special enhancements that allow easy access to all the set points, parameters and calculated results in the LABNET instruments is included as standard, together with a number of application programs for data systems and gas and liquid chromatographs.

The dual 8 and 16 bit processor product runs both CP/M and CP/M-86 operating systems, allowing the use of a wide range of popular software. Software included with the SP9200 includes both word processing and spreadsheet programs. Optional programs include a LOGBOOK program for the management of analysis samples and workload. Customisation of this program and the provision of special programs for individual systems is also supported.

In common with the rest of LABNET instruments, the computer is completely free standing and self supporting, it can be plugged into LABNET or removed without affecting the operation of the distributed network. No configuration or reconfiguration is required to allow addition or removal of any device.

The SP9200 contains 128K of RAM memory, a 630K floppy disk and a 5 megabyte winchester drive. The system is complete with a 12 inch, high resolution video screen and a detached keyboard. Input and output ports support serial and paralled printers, modems and communications to LABNET via a Communications Interface box (SP9500).

The LABNET chromatography system won the IR-100 Award, given by Industrial Research & Development, as one of the 100 most significant technical developments of 1982.
*Reader Enquiry Service No. 36*

### Foam control agents

A new system of identification for the selection of foam control agents has been introduced by Drew Ameroid. The system is specifically designed to eliminate the many problems currently associated with the selection process. It is based on the three key parameters of the mechanism of the product: carrier, hydrophobic agent and ease of emulsification. If the user has knowledge of these, foam control selection becomes a very much simpler exercise.

Each name in the company's range of Drewplus foam control agents contains a suffix relating to the hydrophobe(s) present, ease of emulsification, carrier and finally a number which is used to differentiate between products which are otherwise similar.
*Reader Enquiry Service No. 37*

### New digital colorimeter

New from Jenway is a digital colorimeter which received its first public airing at the Laboratory '83 exhibition. This new, compact instrument has eight switchable filters in the range 400 to 700 nm. It indicates 0-100 per cent transmittance, 0-1.999 absorbance (electronically linearised) and two concentration ranges which enable direct readings of concentration to be obtained. The sample system used by the instrument consists of 10 mm square disposable plastic cuvettes.
*Reader Enquiry Service No. 38*

### New hiding additive

Rohm and Haas is now marketing its unique non-pigmentary hiding additive under the name Ropaque OP-42. Following its successful introduction as Experimental Opaque Polymer E-1742, the product is now available in bulk tanker quantities.

Specially developed by Rohm & Haas, Ropaque OP-42 provides encapsulated air voids in the dry paint film which act as light scattering sites. This contributes substantially to the paint's hiding power, thus allowing a reduction in $TiO_2$ levels. The new product also acts as a spacer for $TiO_2$ particles, which enables this pigment to function more efficiently.

Ropaque OP-42 is also said to exhibit very low binder demand. This allows paints to be formulated at higher PVCs for optimum hiding without degrading film properties.
*Reader Enquiry Service No. 39*

### Two-component coatings spray equipment

Following last year's introduction of equipment for applying dual-component adhesives, sealants and jointing compounds, Kremlin Spray Painting Equipment Ltd has added another machine to the range. It is specially designed for spraying two-component paints and coatings such as pipe coatings, floor coatings, chemically resistant coatings, offshore coatings, and anticorrosion and marine coatings in general.

Suitable for solvent-free coatings, it operates on a 40:1 pressure ratio with a variable dosage ratio. A version fitted with in-line heaters can be supplied.

The key feature of the equipment is the specially developed dosage system. An air motor operates two hydraulic dosage pistons which draw the resin and the catalyst hardener direct from the original containers. Alternatively, pressure feed pumps with follower plates can be used to feed very high viscosity materials to the dosage pistons. The two metered materials are then fed in the correct proportions through a static mixer to the airless spray gun.

Cleaning of the equipment after use is achieved by a separate pump operated by a switch. Thus, if spraying is to be stopped for longer that the pot-life of the materials, the circuits can be rinsed by flicking the switch and pressing the gun trigger for a few seconds. To resume work the switch is set to "off" again and the gun trigger pressed. As soon as the mixed paint product flows out of the gun, work can be resumed.
*Reader Enquiry Service No. 40*

### New industrial anticorrosion paints

Goodyear's European Chemical Division and ESSO have announced that a new anticorrosion paint system based on Pliolite resins was applied during June 1983 to two industrial storage tanks at the ESSO Chimica plant, Vado Ligure, Italy.

The advantages offered by this new system are said to be: greater film thickness in fewer coats, increased corrosion resistance against atmospheric and chemical agents and ultraviolet radiation, and increased safety during application even indoors or in the presence of poor ventilation, thanks to the use of odourless and aromatic-free solvents.
*Reader Enquiry Service No. 41*

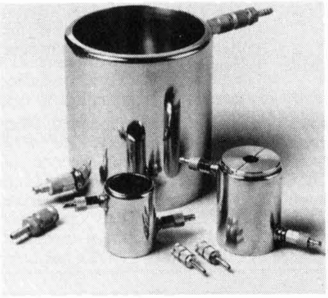
**The Leptoskop 2012 from Teledictor being used to check paint layer thickness**

### Coating thickness gauge

Teledictor Ltd has introduced into the UK the Leptoskop 2012 gauge for measuring electroplating, spray coatings and other non-magnetic finishes on steels and ferrous materials.

The instrument is said to be extremely accurate and, with the special microprobes available, is capable of measuring plating and coating thickness layers in awkward or otherwise inaccessible corners of finished components. Two thickness ranges are incorporated: 0 to 30 microns and 20 to 200 microns.

The 2012 system works on the magnetic induction principle. The high degree of accuracy is achieved by a simple two-stage calibration to adjust the zero reading of the instrument. Layer thickness measurement is set up with the aid of reference foils supplied in a variety of thicknesses.
*Reader Enquiry Service No. 42*



**Double-walled dispersion containers in stainless steel with capacities from 125 ml to 1 litre**

### Double-walled dispersion containers for lab and pilot use

VMA-Getzmann GmbH has developed stainless steel double-walled dispersion containers in 15 sizes (from 125 ml to 65 litres) for the control of temperature during dispersion, stirring or chemical reactions.
*Reader Enquiry Service No. 43*

## literature

### Croda Resins' new technical data manual

Croda Resins, manufacturer of synthetic resins for the paint, ink and adhesive industries, has produced a new technical data manual covering its comprehensive product range.

The manual is available by completing the Reader Enquiry Service form at the back of the *Journal.*
*Reader Enquiry Service No. 44*

### Ultrasonic homogeniser

Ultrasonics Ltd has published a new leaflet on the Minisonic Ultrasonic Homogeniser Type 4005.

The Homogeniser is described as a low cost laboratory and small batch production machine. It is said to be particularly suitable for making stable emulsions where particle size below five microns is required and for dispersing non-abrasive powders into liquids.

As well as the above leaflet, details of Ultrasonics' comprehensive range of ultrasonic homogenisers and the principles involved in ultrasonic homogenisation and dispersion may be obtained by completing the Reader Enquiry Service form at the back of the *Journal.*
*Reader Enquiry Service No. 45*

## meetings

### Call for papers

The 26th Annual OCCA Australia Convention is to be held in Western Australia at Mandurah (60 km south of Perth) from 13-15 September 1984.

Anyone interested in putting forward a paper for the Convention should contact either: the Director & Secretary, OCCA, Priory House, 967 Harrow Road, Wembley, Middlesex HA0 2SF, UK; or G. K. S. McManus, Convention Convenor, OCCAA, C/- PO Box 490, Cloverdale, Western Australia 6150.

## people

**Jack Macrae** has joined the O'Brien Corporation as technical manager for the Napko Protective Coatings Group. He will be headquartered in Houston.

Macrae has over 30 years of experience in the protective coatings business. He began with British Paints in England as a formulation chemist and later acted as technical director for Sherwin-Williams in Spain and International Paint in Canada. He was most recently director of International Paint in New Orleans.

A Licentiate of the Royal Institute of Chemistry, Macrae attended Kings College, the University of Durham and Rutherford College of Technology.

Mr Macrae is a member of the Ontario Section of OCCA and of the Chemical Institution of Canada.

★ ★ ★

**Mr Norman Lees** has been appointed to the position of director and general manager of Manchem Ltd, part of RTZ Chemcials Group.

Mr Lees will remain head of the Commercial Department with **Colin Taylor** and **Ken Lakin** – a member of OCCA's Manchester Section – continuing to report to him on sales and market development respectively.

**Dr Ian MacKinnon** has been appointed to the post of technical manager, assuming responsibilities in this area vacated by Norman Lees.

Michael Travers has joined the Export Department.

★ ★ ★

Croda Resins has announced that **Mr**

## news

**Roger Hawkins** has been appointed director in charge with effect from 1 December 1983.

Mr Hawkin's previous experience includes the director responsible for the Industrial Resins Division of Borden UK. His new appointment is due to the retirement of **Mr J. A. Lines,** who has been director in charge of Croda Resins for the past ten years.

★ ★ ★

**Mr W. M. Collins,** chairman of Berger Industrial Coatings and supervising director of the Berger Group UK Region, has announced the appointment of the chief executive and senior management of Berger Industrial Coatings:

**John Bailey** has been appointed chief executive of the company. He is a member of the Newcastle Section of OCCA. **Ken Bennison** has been appointed personnel director. **Brian Clifton** has been appointed operations director. **John Davey** has been appointed finance director. **Bruno Giordan** has been appointed technical director. **Bill Storey** has been appointed divisional secretary.

In addition to these appointments to the executive of Berger Industrial Coatings the following senior sales and marketing appointments have been announced:

**Pat Campbell** has been appointed business manager – automotive and general industrial. **Ken Forsyth** has been appointed business manager – protection. **Barry Knight** has been appointed business manager – vehicle refinishes.

## exhibition news

# 1-3 May 1984
# OCCA-35 Exhibition
# Cunard International Hotel

## *THE INTERNATIONAL FORUM FOR THE SURFACE COATINGS INDUSTRIES*

### Lecture series

Among the lectures already arranged (for exhibitors who wish to highlight commercial and/or technical aspects of their exhibits) is an important lecture on *A new concept in technical training for the Surface Coatings Industry* by the **Paintmakers Association,** which is collaborating with the **Paint Research Association** in a joint stand. Other lectures will include subjects such as colour instrumentation, viscosity measurement, pigments etc. and a full list will be published in *JOCCA* in the New Year.

It is stressed that the series of lectures given by exhibitors at the OCCA Exhibition, which was introduced successfully at OCCA-34 in 1982, is in no way intended to be a conference on a set theme but is purely an **extension of exhibition facilities,** allowing exhibitors to give talks on subjects of their own choosing.

The Association will make the arrangements for the lecture series without charge to the exhibitors, but all visitors wishing to attend lectures will be asked to apply for tickets at the Information Centre – the list of those attending each lecture will be made available on request only to the relevant exhibitor. It will be appreciated that the number of lectures which can be arranged in the three day period is necessarily limited and exhibitors who have not yet sent in an application form for inclusion in the lecture series are urged to do so without delay. It is not necessary at this stage to give the full title and summary of the proposed lecture, but an indication of the provisional title should be included on the application form in the space provided. The list of lectures will be published in the *Journal* in due course and, as in 1982, it will be possible for readers of the *Journal* to complete a form and send this in advance to ensure places at particular lectures, though tickets have to be collected from the Information Centre not less than half an hour before the stated time of the lecture.

### Special advertising rates

A further facility which is being offered as part of the package deal to exhibitors at OCCA-35 is the opportunity to advertise at 50 per cent of the normal space booking rate in the April 1984 issue of *JOCCA which will include the Official Guide* to the Exhibition; no separate *Official Guide* will be issued on this occasion. All members and subscribers to the *Journal* will, therefore, receive a copy of the *Official Guide* well in advance of the Exhibition since it is scheduled to despatch the April issue before the end of March 1984. Non-members attending the Exhibition will be charged £3 admission fee which will include the cost of a copy of the April issue of the *Journal* plus V.A.T. Exhibitors will understand that the advertising rate applicable will be directly dependent upon the number of advertisements which they place during the year since the Association operates concessionary rates at 3, 6 and 12 insertions.

### Exhibition Hall

The main part of the Exhibition will be situated in the Exhibition Hall of the Cunard International Hotel, Hammersmith, London W8 and since next year the Hall will be carpeted throughout, the stands will not have platforms, except where heavy machinery is being shown; in these cases the Association will provide platforms to spread the weight to the required loading.

### Free standing space

Some exhibitors have expressed a desire to have free standing space, ie space only, as distinct from either stands or complete rooms, and the Association has made arrangements on this occasion for free standing space at £50 per square metre in the Drake Suite on the mezzanine floor near the lecture hall. The free standing

# exhibition news

space is either 3 metres or 4.5 metres deep and the length of the stand would be at the choice of the exhibitor; the floor in the Drake Suite is carpeted.

**Audited attendance**

The Association completes the *Exhibition Data Form* of the Audit Bureau of Circulation and copies are obtainable on request. Not all exhibitions complete these important forms but wherever they do exhibitors are urged to compare them with the Association's, as it will be seen that a very wide spectrum of those in the industries from more than 30 countries are attracted to the Exhibition and the cost of contacting such numbers by other means would be far greater than showing their products and services at OCCA-35.

Any company requiring further copies of the Invitation to Exhibit and the Question and Answer leaflet, which was circulated with the Application form in July, should apply to the Director & Secretary, Oil & Colour Chemists' Association, Priory House, 967 Harrow Road, Wembley, Middlesex HA0 2SF, UK, Telephone 01-908 1086, Telex 922670 (OCCA G).

# bsi news

The standards listed below are available from: The Sales Department, British Standards Institution, Linford Wood, Milton Keynes MK14 6LE, Tel: 0908 32066, Tlx: 825777.

**British Standards**

3406:–
Methods for determination of particle size of powders
3406: Part 5: 1983 Recommendations for electrical sensing zone method (the Coulter principle) 32 page A4 size GR 8
Gives recommendations on a specific method, the electrical sensing zone method, for the determination of the particle size of powders, and facilitates comparison between size and analyses made in different laboratories. No current standard is superseded.
(ISBN 0 580 13244 7)

4254: 1983
Specification for two-part polysulphide-based sealants 8 page A4 size Gr 5
Requirements for two grades of two-part polysulphide-based sealant intended for use in general building and glazing applications excluding floors subject to vehicular traffic. Supersedes BS 4254: 1967. (ISBN 0 580 13430 X)

**New work started**

Hot applied thermoplastic road marking materials
Will amend BS 3262 in the light of road performance trials and will clarify test procedures. RDB/25

**Draft British Standards for public comment**

83/13096 DC Amendment No. 2 to BS 544: 1969. Linseed oil putty for use in wood frames. ECB/3

83/37718 DC Plastics – Liquid resins – Determination of density by the pyknometer method. (Revision of BS 2782: Part 6: Method 620E: 1980.) (ISO/DIS 1675) PLC/17

# occa news

## Report of Council meeting

A meeting of the Council took place on 26 October 1983 at the Great Northern Hotel, London N1. The President (Mr C. N. Finlay) was in the chair; 26 members were present.

The President welcomed Mr B. A. Canterford to his first Council meeting since his election as an Elective Council Member at the Annual General Meeting in June. Council noted with regret that Mr A. T. S. Rudram, who had served in many capacities on Council, including that of President 1975-77, had been forced through ill health to retire from his present office of Honorary Technical Education Officer. Council recorded its sincere thanks to Mr Rudram for his outstanding services over such a long period.

Following the July Council meeting, those appointed to Committees of Council or to represent the Association on other organisations, had been notified of their appointments and some replacements were required. Mrs E. Stretton had agreed to serve on both the BSI Committee LGL/9 Artificial Daylight for Colour Matching and the Colour Group. Mr A. C. Jolly would replace Mr J. R. Bourne, who had retired through business commitments from the Technical Committee. On the Professional Grade Committee, replacements for Mr Bourne and Mr Rudram were suggested and it was hoped that Mr P. Birrell, the representative of the Ontario Section, would serve in order to link the Professional Grade with that Section's Diploma course and a lecturer from a technical institute. Mr Peters had informed the Director & Secretary that his work was no longer related to either colour or surface coatings and Mr G. Robson had agreed, therefore, to serve as his replacement on BSI Committee PVC/1 – Pigments; this was agreed by Council.

Replacements were also required for Mr A. N. McKelvie, who currently served on the BSI Committees PVC/10, PVC/21 and C.17, and for the late Mr R. M. W. W. Wilson on the East Ham College of Technology's Consultative Committee for the Science Department. Mr G. Fowkes and Mr B. Gilliam agreed to approach members who it was thought would be willing to serve in these two capacities.

Reports were received on the Council Reunion Dinner, scheduled to take place later in the day. The arrangements for the Association's Biennial Dinner Dance at the Savoy Hotel on 11 May 1984 will be published both in the *Journal* and in the *Bulletin* and members are urged to support this prestigious event to which the Association invites as guests the principal officers of other learned societies.

The Honorary Secretary (Mr G. Fowkes) reported on the meeting which he, the Honorary Treasurer and the Director & Secretary had attended at Matlock in August with the British Colour Makers' Association to explain the new concept of the Association's Exhibition which had proved successful in 1982. Details of "package deals" (including special facilities to give lectures and to take advertising space in the April *JOCCA* preview issue at reduced rates) and the new facility of free-standing space were noted by Council.

The Honorary Treasurer introduced the half year accounts and estimates for the second half year which were adopted by Council.

Regarding the meeting of the Finance Committee, the President reported that in accordance with the wishes expressed at the AGM he and the Immediate Past President had both tried to see if it were possible for an outside financial adviser to give an opinion on the Association's finances (as reported in *JOCCA* page 255). Since this did not prove practicable it had been agreed that Coopers & Lybrand, the Association's auditors who had full knowledge of the accounts and the organisation of the Association, should be asked to submit a report. A meeting had, therefore, taken place with Coopers & Lybrand on 26 September and it was reported to the Finance Committee on 5 October that Coopers & Lybrand would undertake the work at a cost of £1,350. Dr F. M. Smith had been invited to attend both the meeting of Coopers & Lybrand and the Finance Committee meeting and it was then agreed that meetings of both the Executive Committee and Council would take place on 7 December to consider the report when received from Coopers & Lybrand.

It was reported that new advertising rates had been brought into operation, and the subscription rates for non-members to the *Journal* for 1984 would be £55 per annum and that the prices charged for the Association's other publications had been increased in line with other technical publications. It was noted that there had been an increase in income and a decrease in expenditure during the year which Council felt was a reflection of the enormous effort made by the Director & Secretary and his staff at Priory House in the most difficult circumstances of the recession.

Details were received on removals from the register and it was noted that there were many cases, particularly from overseas, where the names of members had been removed from the register, in accordance with the Articles, after June 30 and these members had then asked to be reinstated in the autumn. At present no charge had been made for this service but in 1984 members who did not pay their subscription by June 30 would be asked to pay a £5 reinstatement fee.

The Honorary Editor, Mr D. S. Newton, reported on the delays which had occurred in the despatch of the September and October issues which were outside the Association's control, since they involved industrial action at the printers and errors in transit to the despatchers. He reported that apart from the Conference papers, he had a good number of papers in hand but was always seeking short communications and other papers from sections. In particular it was stressed that it was hoped to produce a set of monographs on specific topics for which payment would be made and it had been hoped that members who had recently retired would be able to assist the Association in this way. It was felt that monographs of this kind would be of value, not only to those in developing countries, but also to young entrants into the industry. Section chairmen were asked, through section committees, to make this project as widely known as possible and if any member of the Association is able to offer his/her services to write a monograph on a specific topic, they should be asked to contact the Director & Secretary giving short details of the proposed subject and treatment.

The Honorary Research & Development Officer, Mr J. R. Taylor, reported that the Technical Committee would be meeting on 23 November to discuss the format and papers required for the Edinburgh Conference and details would appear in the *Journal* in due course. The call for papers would appear in the January issue. Mr Taylor also reported briefly on two other projects, a joint seminar with the Society of Dyers & Colourists and the proposal which had been received from the Macro Group of the SCI for a day meeting.

Mr Rudram was not able to attend the meeting, but he had reported to the Director & Secretary about a symposium which he had attended as Honorary Technical Education Officer and the suggestion that the Licentiateship should, in some way, be drawn to the attention of the Manpower Services Commission. This was remitted to the Professional Grade Committee.

The Director & Secretary reported that at the Professional Grade Committee meeting held earlier in the day, two Fellows had been admitted, one admitted to the Associateship Grade and two to the Licentiateship Grade. He had suggested to Licentiates that they should amplify the written evidence which they had provided in accordance with the regulations into short communications for the *Journal* which would automatically enable them to be considered for the Jordan Award; Mr S. R. Finn, the former Honorary Editor, had agreed to help any candidates prepare short communications if they wished to do so.

It was reported that the date for the AGM in 1984 had now been confirmed as 13 June at the Piccadilly Hotel, Manchester; further details would be announced in due course.

It was reported that OCCAA, who would provide the secretariat for the first three years of OCCA International, had nominated as International Coordinator for OCCA International Mr Tom Backous, a former President of the Australian Federal Committee, and this appointment was endorsed by the Council.

Reports were received from section chairmen on their activities. Following the section reports, the President gave a brief resume of his recent tour abroad which had started when he and his wife met members in the Singapore and Malaysia area. He felt that there was a possibility that interest would grow in the Association and there was a possibility that a branch could be formed. From there they had proceeded to Melbourne to the 25th Silver Jubilee Convention of OCCAA where he had the pleasure of presenting the scroll of Honorary Membership of the Association to Mr Brian Lourey, who had attended the York Conference as President of OCCAA, for his assistance in bringing to fruition the idea of OCCA International. The President had met several members from the New Zealand Division at Melbourne including Mr G. L. Willis, the Vice President, and, when they proceeded to New Zealand, they were able to meet the Auckland Committee and discuss Association affairs with them. After New Zealand the President and Mrs Finlay had proceeded to Montreal to the FSCT Paint Show and Convention where they had the opportunity to meet several office holders, both past and present, of the Ontario Section and a luncheon for the International Liaison Committee was held.

On all occasions he had expressed the good wishes of the Association and, as the Association's representatives, he and his wife had been very well received in each country.

The President then thanked the members for their attendance and declared the meeting closed at 4.30 pm.

## new members

The sections to which new members are attached are shown in italics together with the country, where applicable.

### Ordinary Members

Attwood, S. C. J. *(Transvaal)*
Baber, V. N. *(Cape)*
Crawford, R. McK. *(Wellington)*
Grose, G. A. *(Cape)*
Havemann, C. H. *(Transvaal)*
Heise, W. G. *(Transvaal)*
Mitchell, R. J. *(Ontario)*
Norris, F. N. *(Newcastle)*
Siddiqui, J. A. *(General Overseas – Pakistan)*
Stahel, D. I. *(Wellington)*
van Eyk, G. A. *(Cape)*
van Niekerk, L. R. *(Cape)*
Wickremesinghe, E., BA *(General Overseas – Sri Lanka)*

### Associate Members

Bloor, S. *(Zimbabwe)*
Christiansen, J. C. *(Auckland)*
Cryer, A. *(Transvaal)*
Munstermann, K. G. *(Natal)*

# professional grade register

At the meeting of the Professional Grade Committee held on 26 October 1983 the Committee authorised the following:

**Transfer from Associate to Fellow:**
Rampley, Dennis Neil *(London)*

**Admitted as Fellows:**
Arbuckle, Kenneth Harold *(London)*
Smith, Eric *(West Riding)*

**Admitted as Associate:**
Lister, Joseph William *(London)*

**Admitted as Licentiates:**
Birkett, Stephen *(West Riding)*
Redpath, Neil Douglas *(Newcastle)*

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

Several colleges in the UK are willing to help suitable candidates with the preparation of dissertations for Licentiateship and a list of these is available from the Association's offices.

### List of successful candidates

As laid down in the report of the Working Party on Education, Training and Qualifications which was adopted on the institution of the Professional Grade, a list of those members in the Grade is published in the December issue of the *Journal* each year. The 12th such list appears below and includes the names of members resident in 34 countries.

The sections to which members are attached are given in italics.

### Fellows

Addenbrooke, Brian John *(Midlands)*
Aitken-Smith, Frank Joseph *(Auckland)*
Anneveldt, Jan Johan Willem *(Transvaal)*
Apperley, Thomas William James *(West Riding)*
Arbuckle, Kenneth Harold *(London)*
Archer, Harold *(Manchester)*
Arnold, Michael Henry Miller *(London)*
Ashworth, Norman *(Manchester)*
Astfalck, Anthony Noel *(Transvaal)*
Atherton, Donald *(Scottish)*
Bailey, John Noel *(Newcastle)*
Banfield, Thomas Arthur *(London)*
Bayliss, Derek Arthur *(London)*
Bennett, Norman Arthur *(General Overseas – Malta)*
Bester, Lawrence Percy *(Transvaal)*
Bhumkar, Chidanand Jayram *(General Overseas – India)*
Birrell, Peter *(Ontario)*
Bishop, Eric Harold Abbott *(West Riding)*
Bohringer, Eberhard *(London)*
Boroky, Joseph Stephen *(General Overseas – Australia)*
Bosman, Herman Izak *(Transvaal)*
Bourne, John Robert *(Midlands – Trent Valley Branch)*
Bridle, Peter Frederick *(London)*
Brooks, Leo James *(London)*
Brown, Arthur Ernest Girdlestone *(London)*
Butcher, George Alfred *(Midlands)*
Butcher, Kenneth William George *(Manchester)*
Butler, Cecil *(West Riding)*
Calder, Robert Malcolm *(Auckland)*
Caldwell, David George *(Wellington)*
Campbell, George Alexander *(Manchester)*
Carr, William *(Manchester)*
Carter, Eric Victor *(London)*
Chatfield, Herbert Walter *(London)*
Chessman, Clifford Reginald *(Transvaal)*
Clarke, Harry James *(Midlands)*
Clement, Donovan Harry *(Midlands)*
Colborn, Douglas Charles *(Thames Valley)*
Cole, Derek *(General Overseas – Australia)*
Collier, Claude William *(Midlands – Trent Valley Branch)*
Collings, Arthur Geoffrey *(London)*
Coupe, Raymond Richard *(London)*
Courtman, Frank *(Manchester)*
Coverdale, Peter Frederick Muir *(Midlands)*
Cutter, John Outram *(London)*
Davidson, Sigismund Leonard *(General Overseas – USA)*
de Jong, Jan Lauwrens *(Transvaal)*
Dowsing, George Frederick *(London)*
Draper, Patrick Albert *(Natal)*
Duckworth, Samuel *(Manchester)*
Duligal, Eric Arthur *(Transvaal)*
Dunkley, Frederick George *(Midlands – Trent Valley Branch)*
Durrant, George Geoffrey *(Hull)*
Easton, James Douglas *(Ontario)*
Eglington, Roland Alexander *(Natal)*
Ellinger, Marianne Livia *(London)*
Entwistle, Thurston *(Newcastle)*
Finn, Stanley Russell *(London)*
Froggatt, Joshua John *(London)*
Fullard, John Edward *(Transvaal)*
Furuhjelm, Viktor Henrik *(General Overseas – Finland)*
Garratt, Peter Garth *(General Overseas – Austria)*
Gate, Peter Atholl Jackson *(Transvaal)*
Gay, Philip James *(Hull)*
Geddes, Kenneth Raymond *(Manchester)*
Gellman, Alexander *(London)*
Giesen, Mathias Franz *(General Overseas – Germany)*
Gillan, James Graham *(Manchester)*
Gollop, Percy Lionel *(London)*
Gooch, Colin *(Wellington)*
Gosling, Harry *(Manchester)*
Goyal, Ramkumar Bhanwarlal *(General Overseas – India)*
Graham, Thomas *(Manchester)*
Grainger, William Alan *(Irish)*
Gray, Denis Roy *(West Riding)*
Grover, Donald Henry *(London)*
Haken, John Kingsford *(General Overseas – Australia)*
Hamburg, Herman Rudolf *(London)*
Hanson, Robert Philip *(Newcastle)*
Hawkey, John Albert Lawrence *(London)*
Hill, Derek Alfred Wheeler *(London)*
Hill, Gilbert Victor Geoffrey *(Thames Valley)*
Hill, Lawrence Albert *(General Overseas – Australia)*
Hipwood, Hubert Allan *(London)*
Hodgson, Kenneth Vickerson *(Newcastle)*
Holbrow, Gordon Leonard *(London)*
House, Dudley James *(Natal)*
Hutchinson, Geoffrey Herbert *(Scottish – Eastern Branch)*
Inshaw, John Leslie *(Thames Valley)*
Iyengar, Doreswamy Raghavachar *(General Overseas – USA)*
Jacob, Basil *(Thames Valley)*
Johannsen, Ralf Peter *(Cape)*
Johnson, Roland Emanuel George *(General Overseas – Zimbabwe Branch)*
Jolly, Anthony Charles *(Manchester)*
Kalewicz, Zdzislaw *(General Overseas – France)*
Kane, Joseph Richard *(Newcastle)*
Keenan, Henry Wilfred *(London)*
King, Raymond John *(London)*
Kotwal, Hoshidar Peshotan *(General Overseas – Pakistan)*
Kut, Sigmund *(London)*
Landmann, Axel Wolfgang *(London)*
Lasser, Howard Gilbert *(General Overseas – USA)*
Lewis, Fred *(Manchester)*
Ley, John Barry *(London)*
Lunt, Walter Richard *(West Riding)*
Martin, Christian Pierre *(General Overseas – France)*
McKelvie, Archibald Neil *(London)*
McLean, Angus *(Scottish)*
McQuirk, Peter John *(London)*
Mitchell, John Edmund *(Manchester)*
Mitchell, Seward John *(Midlands)*
Moll, Ivor Stuart d'Anvers *(Manchester)*
Monk, Cyril James Henry *(Bristol)*
Moon, William Robert *(Manchester)*
Morgans, Wilfred Morley *(London)*
Morris, David *(General Overseas – Nigerian Branch)*
Munn, Raymond Henry Edward *(London)*
Munro, Hugh Anderson *(Scottish)*
Newnham, Herbert Alan *(London)*
Newton, Dennis Sydney *(London)*
Newton, Donald Stringer *(Bristol)*
Nutt, William Owen *(London)*
Oostens, Emile Elie Eugene *(General Overseas – Belgium)*

# professional grade register

Parfitt, Geoffrey Derek *(General Overseas – USA)*
Pienaar, Dirk Jacobus *(Transvaal)*
Piggott, Kenneth Elliot *(Natal)*
Polaine, Sidney Alan *(London)*
Prigmore, Maurice Henry *(Bristol)*
Raaschou Nielsen, Hans Kristian *(General Overseas – Denmark)*
Rampley, Dennis Neil *(London)*
Ray, Stanley Arthur *(Midlands)*
Rechmann, Heinz *(General Overseas – Germany)*
Reid, John Rodney Stanford *(Natal)*
Rileigh, Albert Kenneth *(General Overseas – Australia)*
Robson, Gordon Reginald *(Manchester)*
Roe, David Edwin *(London)*
Rose, Charles *(Manchester)*
Rouse, Robert Earnshaw *(Transvaal)*
Rubin, Wallace *(London)*
Rudram, Arthur Thomas Stephen *(London)*
Saunders, Laurence Frederick *(Natal)*
Seymour, Norman Henry *(Manchester)*
Sharpe, Eric Edward Victor *(Transvaal)*
Sharp, Peter Frank *(Auckland)*
Shepherd, Joseph *(Newcastle)*
Silsby, Denys John *(Midlands)*
Sim, Richard Alastair *(General Overseas – Australia)*
Simon, Raymond *(Irish)*
Slade, Harold Aitken *(Midlands)*
Slinn, Thomas Walter *(Wellington)*
Smith, Eric *(West Riding)*
Smith, Francis Mark *(Manchester)*
Smith, Harry *(Manchester)*
Smith, John George Nixon *(Newcastle)*
Sowerbutts, Franks *(London)*
Sreeves, John Ernest *(Midlands)*
Stoodley, Keith Herbert *(London)*
Stoyle, Francis Wilbert *(Irish)*
Stretton, Elizabeth *(Manchester)*
Tate, Donald Howarth *(Newcastle)*
Tatton, William Henry *(Thames Valley)*
Tawn, Alec Richard Hornsey *(London)*
Taylor, John Roberts *(Bristol)*
Thukral, Prem Sagar *(London)*
Tickle, Trevor Cyril Kenneth *(Manchester)*
Tooke-Kirby, John Theodore *(London)*
Tooth, John Henry Collins *(London)*
Turner, John Harry Wallice *(Manchester)*
Valentine, Leslie *(London)*
Walker, Alan Gordon *(Newcastle)*
Wall, Dennis Charles *(Manchester)*
Warner, Eric Albert Andrew *(Wellington)*
Watkinson, Leonard James *(West Riding)*
Westwood, George Ernest *(Hull)*
White, Robert Arthur *(Auckland)*
Whiteley, Peter *(London)*
Whitfield, Thomas *(Auckland)*
Wilkinson, Thomas William *(Hull)*
Willis, Gervase Hewitson *(Manchester)*
Wood, George *(London)*
Woodbridge, Richard John *(Bristol)*
Worsdall, Herbert Charles *(London)*
Yorath, Robert Stanley *(Wellington)*

**Associates**

Abel, Adrian George *(Manchester)*
Acey, John Arthur *(London)*
Adams, John Charles *(Midlands)*
Adams, Terry Ernest *(London)*
Adefarati, Francis Babasola *(General Overseas – Nigerian Branch)*
Allen, David Frank *(Irish)*
Anthony, Alan Sydney *(London)*
Armstrong, Edward *(Hull)*
Armstrong, Herbert Walter Maynard *(London)*
Arnold, Frank *(Manchester)*
Ashton, Ronald *(Manchester)*
Asiedu-Dompreh, Jonathan *(London)*
Assink, Jo *(Auckland)*
Asubonteng, Samuel Kofi *(General Overseas – Ghana)*
Awan, Mumraiz Khan *(General Overseas – Kuwait)*
Bains, Ranjit Singh *(London)*
Baldwin, George William *(Manchester)*
Bannington, Donald Bertram *(London)*
Barnes, Peter James *(London)*
Barrie, James *(Midlands – Trent Valley Branch)*
Batch, Alan James Edward *(London)*
Bax, John Charles *(General Overseas – USA)*
Beadle, Roy William *(London)*
Beckley, Albert Henry *(London)*
Bell, Brian Robert *(Midlands)*
Bell, Eric James *(London)*
Belsham, Barry Michael *(General Overseas – Cyprus)*
Bentley, Major Gordon *(West Riding)*
Berberi, Anwar Edmond *(General Overseas – Lebanon)*
Bird, George Donald Chaplyn *(Midlands)*
Bloomfield, Kenneth Vincent *(London)*
Bluck, Ross Steele *(Wellington)*
Bolam, Ion Barrow *(Newcastle)*
Borer, Keith *(Newcastle)*
Bose, Sunil Kumar *(London)*
Bowler, Kenneth Ernest *(Midlands)*
Boxall, John *(Thames Valley)*
Brooke, Leslie John *(Bristol)*
Byrns, Arthur Robin *(Cape)*
Caffery, George Francis *(London)*
Calderbank, John Thomas *(Manchester)*
Campbell, Douglas Shaw *(Transvaal)*
Campey, Leslie John Randall *(Ontario)*
Canterford, Barry Albert *(London)*
Cartwright, Jeffrey *(London)*
Catchpole, David Thomas *(Scottish)*
Catherall, Kenneth David *(Midlands)*
Chambers, Anthony *(London)*
Chebsey, Maurice *(Manchester)*
Chellingsworth, Horace Thomas *(Midlands)*
Chippington, Kenneth Alan *(Bristol)*
Churchman, Anthony Edward *(London)*
Clark, Laurence Norman *(London)*
Clark, Michael Denis Thomas *(Wellington)*
Clarke, Raymond John *(Ontario)*
Clayton, David Walter Norbury *(Manchester)*
Clausen, Hans Christian *(Natal)*
Coates, John Allen *(Manchester)*
Cole, Francis William *(Midlands)*
Constantinides, Erricos *(London)*
Cordwell, Terrence Allan *(Midlands – Trent Valley Branch)*
Cowie, Edward Bruce *(Natal)*
Cox, Garth Anthony *(London)*
Cromarty, Ronald Earling *(Transvaal)*
Craske, Anthony John *(General Overseas – Indonesia)*
Cunnington, Robin Roy Carol *(London)*
Daggett, Wilfred Francis *(London)*
Dalton, Frank *(General Overseas – Denmark)*
Davies, Frank Watkin *(Manchester)*
Davis, Brian Frederick James *(London)*
Davis, Reginald Albert *(Bristol)*
de Waal, Tielmann Johannes *(Cape)*
Dennis, Reginald Herbert *(London)*
Devine, James *(Transvaal)*
Donkersley, Brian *(London)*
Downham, Stephen Airey *(Manchester)*
Dunn, Paul Alan *(London)*
Dury, Ian Clifford James *(Thames Valley)*
Eaton, Michael George *(Thames Valley)*
Ekeh, Godwin Chukoemeka *(General Overseas – Nigerian Branch)*
Eltringham, James Norman *(Auckland)*
Eylers, Petrus Gerardus *(General Overseas – Zimbabwe Branch)*
Fell, Alan William *(Thames Valley)*
Fernades, Larry Raphael Francis Joseph *(London)*
Field, Lawrence Edward *(Natal)*
Finlay, Cecil Newton *(Newcastle)*
Fisher, Leslie Alexander *(General Overseas – Malaysia)*
Flood, Geoffrey Terence *(Manchester)*
Ford, Keith Sydney *(Manchester)*
Formanek, Leopold *(General Overseas – Czechoslovakia)*
Freund, Kurt Alfredo *(General Overseas – Ecuador)*
Fry, Jack Ian *(Wellington)*
Gascoyne, John *(Auckland)*
Gaynor, Helen MacDonald *(Transvaal)*
Gibson, Anne McArdle *(Scottish)*
Gibson, Frank *(Manchester)*
Gibson, John Carrington *(Hull)*
Gilliam, Brian Frederick *(London)*
Goodman, Robert John *(General Overseas – Spain)*
Green, Basil Ray *(General Overseas – Trinidad)*
Green, Brian James *(London)*
Greenall, Brian John *(Wellington)*
Greenfield, Eric *(Midlands)*
Griffiths, Henry James *(Midlands)*
Grime, David *(London)*
Gunn, David John *(Midlands)*
Gunn, Reginald *(Thames Valley)*
Hackney, Thomas *(Auckland)*
Hamilton, Alexander *(Scottish)*
Harrison, Cyril Geoffrey *(Hull)*
Harty, David Basil *(General Overseas – Australia)*
Hasnip, John Anthony *(Hull)*
Heald, Desmond *(Manchester)*
Herriott, Charles Edward *(London)*
Hickman, Edwin Peter *(Midlands)*

# professional grade register

Hill, Raymond Forsyth *(Scottish)*
Hitchmough, Rex Henry *(London)*
Holden, William Desmond *(Manchester)*
Holt, Clifford *(West Riding)*
Honiball, Alan Edward *(Scottish)*
Hopper, Derek Edgar *(Midlands)*
Horsfall, Anthony John *(Auckland)*
Howard, Eric *(Manchester)*
Howells, Barry John *(Hull)*
Howes, Edward John *(London)*
Hughes, Anthony Harold *(Manchester)*
Humphrey, Thomas Lawson Myles *(Scottish)*
Hutchinson, Martin Alfred *(West Riding)*
James, Tudor Herbert *(Irish)*
Jangbahadur, Shyam Sharan *(General Overseas – India)*
Jenkins, Brian Gordon Allan *(Auckland)*
Johnsen, Svend *(General Overseas – Denmark)*
Johnstone, James William *(Manchester)*
Jones, Derek Frederick Arthur *(Thames Valley)*
Jones, Geoffrey Peter *(Wellington)*
Kaye, Dennis David *(London)*
Kenna, Frank William *(Manchester)*
Kerr, Michael Anthony *(Manchester)*
King, Charles William Henry *(Midlands)*
Kirkwood, Thomas *(Scottish)*
Kirlew, Charles Wesley *(General Overseas – USA)*
Kitchen, John Robert *(Midlands – Trent Valley Branch)*
Laker, Bernard George *(London)*
Lakshmanan, P. R. *(General Overseas – USA)*
Lander, Wilfred Terence *(London)*
Lang, Robert *(Scottish)*
Langdon, Donald Robert *(Ontario)*
Langley, Robert *(Scottish)*
Lawrence, Simon Gayner *(Scottish)*
Lawton, Cyril Victor *(Midlands)*
Leathley, George Derek *(Auckland)*
Le Maistre, Paul Francis *(Midlands)*
Lever, Colin *(Manchester)*
Lewis, Geoffrey John *(Midlands)*
Lewis, John David *(Thames Valley)*
Lister, Joseph William *(London)*
Low, Charles *(General Overseas – Australia)*
Macdonald, Alan *(Auckland)*
Malik, Javed Haider *(General Overseas – Pakistan)*
Mandagi, Willy *(General Overseas – Indonesia)*
Mandelson, Jack *(Scottish)*
Maple, Donald Peter *(London)*
Marples, Peter *(Transvaal)*
Maynard, Albert William David *(Overseas)*
McCallum, Ian Robert *(Scottish)*
McCapra, Ronald *(Auckland)*
McClean, Michael Dennis *(London)*
McDonald, Kenneth Roy *(Natal)*
McDonnell, Christopher Robin Stack *(West Riding)*
McFetridge, John Henry *(Wellington)*
McKay, Alan Gordon *(London)*
McKay, John *(Manchester)*
McKean, James Newlands *(Auckland)*
McMillan, James *(Manchester)*
Mepham, Brian Edwin *(London)*
Mikucki, Wiktor *(London)*
Moore, Frank Roden *(West Riding)*
Moore, James *(Thames Valley)*
Moore, William Alexander *(Auckland)*
Morpeth, Frederick Johnson *(Manchester)*
Moss, Noel Sydney *(London)*
Mouallem, Mouhammad *(General Overseas – Syria)*
Mun-Gavin, Patrick William James *(Natal)*
Myers, Gordon *(Natal)*
Mynett, Raymond John *(Midlands)*
Naess, Erik *(General Overseas – Norway)*
Ness, Robert Alexander *(Auckland)*
Newman, Derek George *(Thames Valley)*
Norton, Douglas Kent *(Midlands)*
Notley, Malcolm Anthony Leslie *(London)*
Oakley, Ernest *(Newcastle)*
Ohene-Kwadade, Kofi *(General Overseas – Ghana)*
Pace, Graham *(Thames Valley)*
Parry, Martin Gerald *(London)*
Patel, Shirish Manibhai *(Ontario)*
Patrick, Alan Clive *(Irish)*
Payne, Edward James *(Manchester)*
Payne, Kenneth *(Bristol)*
Pemberton, Joseph James *(London)*
Pessall, Robert George *(Midlands)*
Piper, Norman William *(Manchester)*
Porteous, Barrie Milroy *(Ontario)*
Potter, Arnold John *(Hull)*
Potter, Francis *(General Overseas – Zimbabwe Branch)*
Proudley, Philip Miles *(West Riding)*
Provan, Andrew Wilson *(Wellington)*
Pyett, Albert Lawrence *(Manchester)*
Quorn, Peter James *(Transvaal)*
Rackham, John Michael *(Newcastle)*
Redman, Frank Benson *(Manchester)*
Reeve, Frank Nicholson *(Transvaal)*
Roberts, Peter David Mynwy *(London)*
Robinson, Arthur Graham *(Manchester)*
Robinson, Francis Derrik *(Hull)*
Rothwell, Gerald William *(London)*
Rout, Peter George *(West Riding)*
Routley, Alan Francis *(London)*
Russell, Frederick Charles *(London)*
Saggar, Anoop Kumar *(General Overseas – Kenya)*
Scheinost, Bernd *(Natal)*
Semple, James William *(London)*
Sewell, Anthony Robert *(Auckland)*
Sharpe, David *(London)*
Shepherd, David William *(Bristol)*
Silverwood, David *(Manchester)*
Smith, Brian James *(London)*
Smith, Harry Bertram *(London)*
Soman, Chettiparambil *(General Overseas – Spain)*
Sowerby, Alan Hope *(Auckland)*
Spaargaren, Albert Arend *(Natal)*
Spargo, Robert *(Auckland)*
Springett, Robert Arthur Edward *(London)*
Staples, Peter Graham *(London)*
Stephenson, Robert Perry *(Auckland)*
Stone, James Bryan *(London)*
Stott, Raymond *(Manchester)*
Surinphong, Julian Suriya *(General Overseas –Thailand)*
Talwalkar, Vinayak Sakharam *(London)*
Tape, Brian William Charles *(General Overseas – USA)*
Taylor, Richard Anthony John *(London)*
Taylor, Terence *(Manchester)*
Thomas, Anthony *(General Overseas – Brazil)*
Thornton, Philip Joseph Martin *(Irish)*
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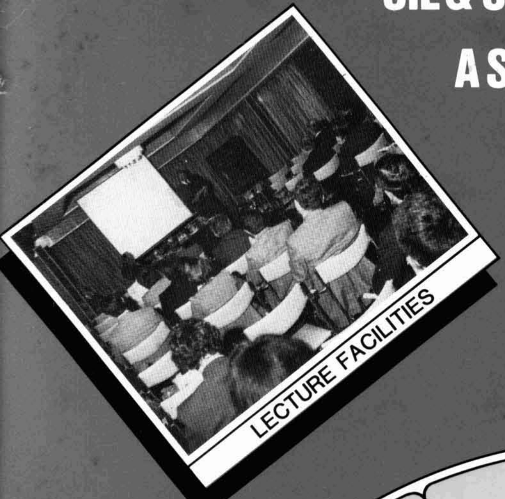
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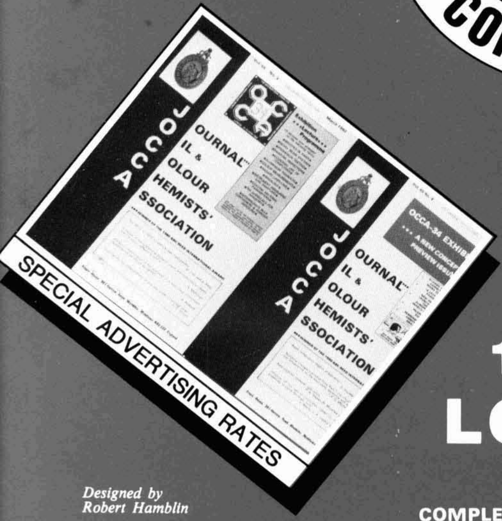
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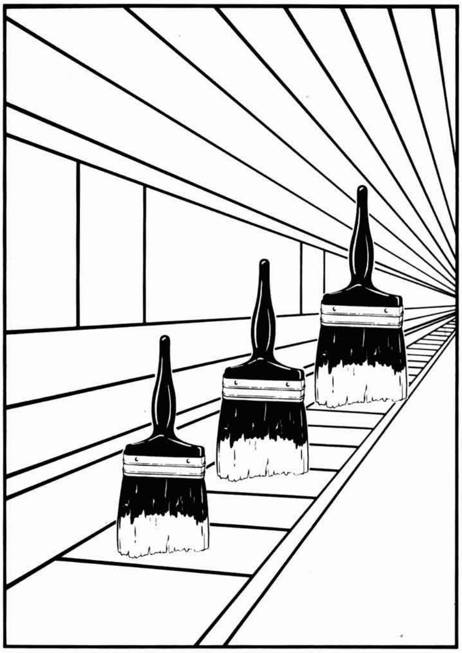

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