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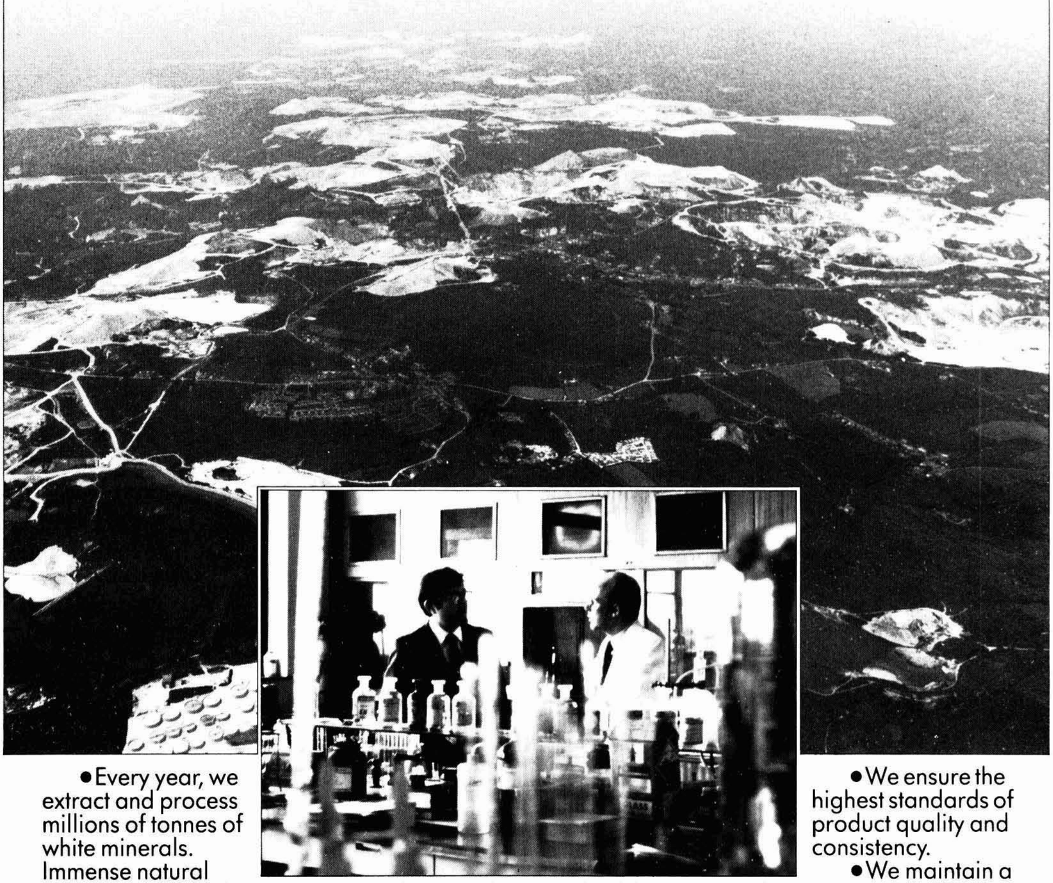

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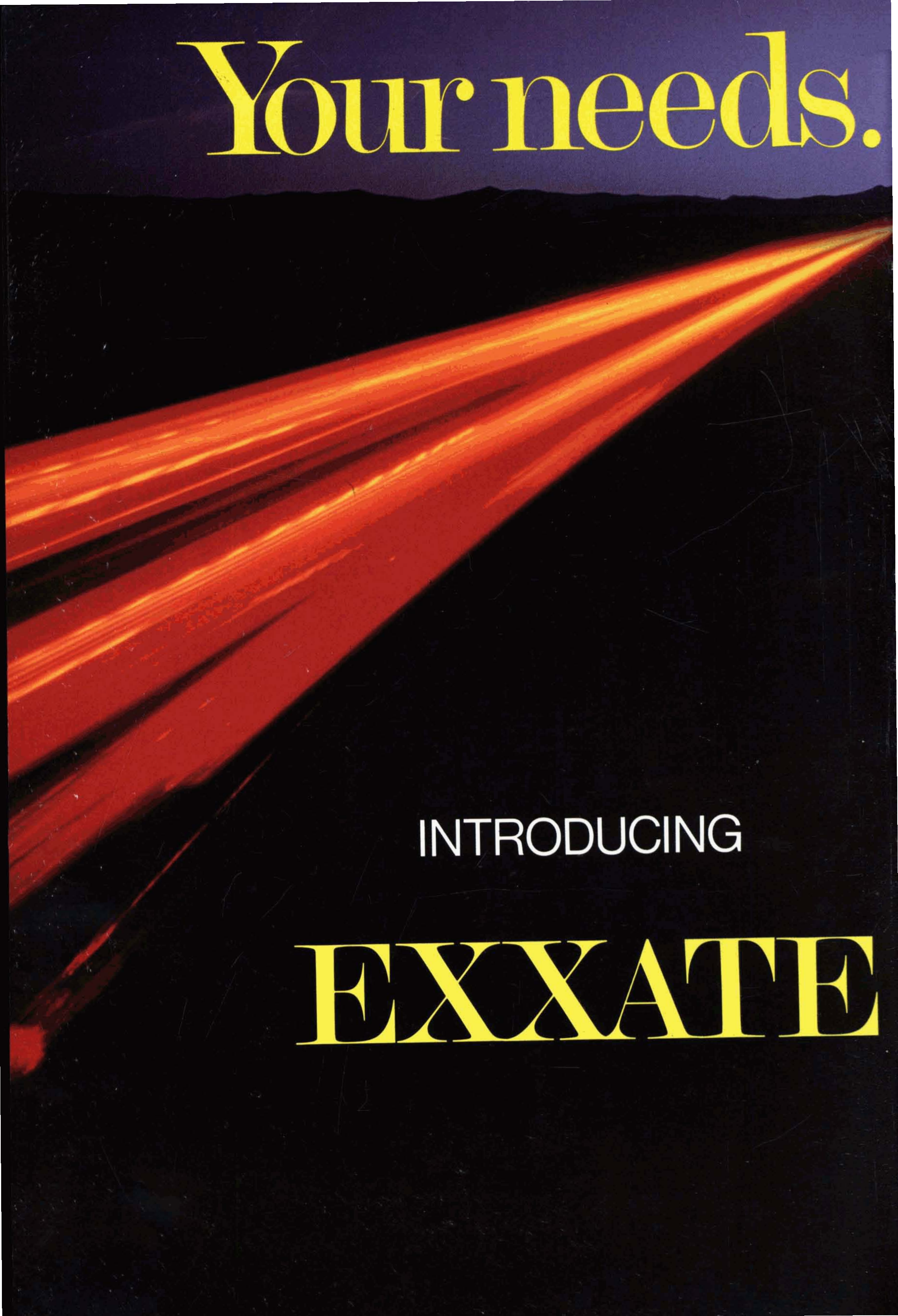

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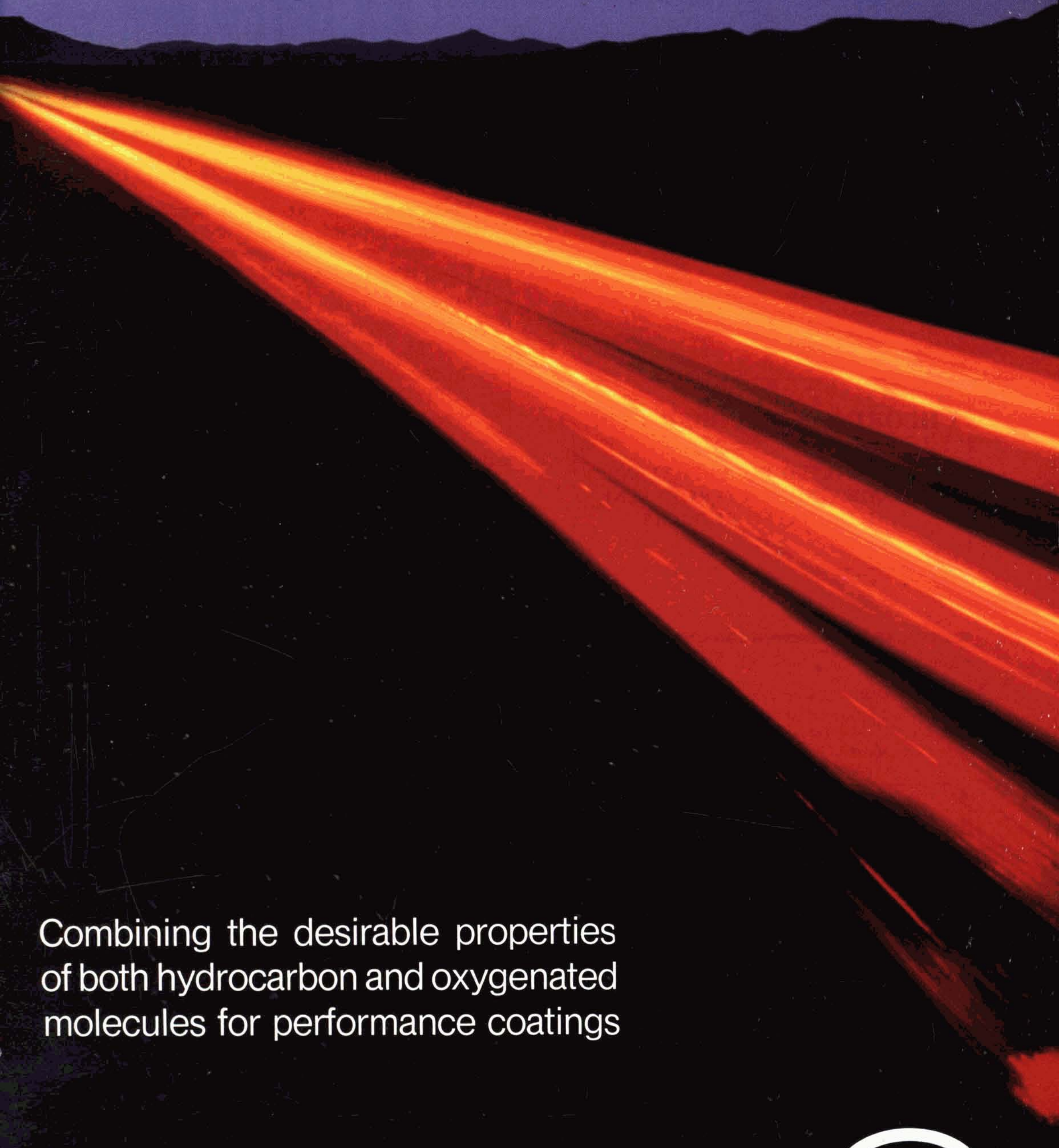

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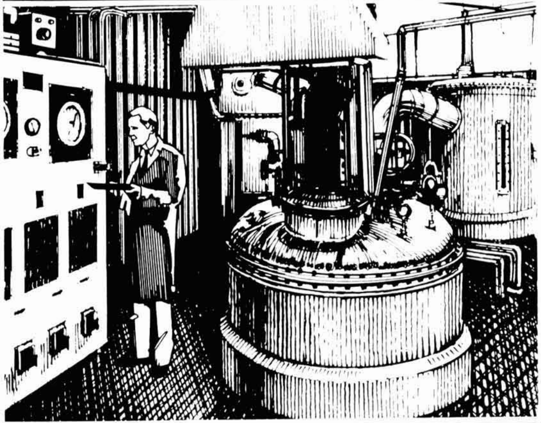

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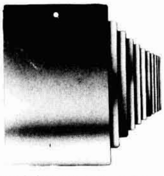

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Progress in timber finishing in Great Britain

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Summary

The nature of wood and its reaction to water vapour and liquid water, with particular reference to the British climate, are considered in depth. Other weather effects, such as sunlight, temperature change and wind are briefly reviewed.

Basic requirements for protection of timber are considered, from the point of view of design of joinery and the finishing system.

Composition of the various timber finishes are discussed and advantages and disadvantages of aqueous versus solvent thinned systems considered, together with other factors which must be taken into account in selecting the right system.

Results of flexibility and permeability measurements are reported and discussed in more detail.

1. Introduction

The where, why, which and how of timber use in Britain as in most places is a mixture of tradition, design (scientific and otherwise), availability, economics and fashion. So it is with finishes. Consequently, each country, sometimes each region within a country, is a little or a lot unique in the way timber is used and finished.

Recently there has been a major change in Britain in the fashion for timber and timber finishes, especially as used on the outside of building.

Timber is one of the two great building materials. It has strength and durability yet is easily worked. Whenever visible, it is preferred decorated. Used out of doors it will give much better service if protected against our climate and the consequences thereof. It is readily available and economical. Much is used for hidden constructional elements that are not finished, although they may be preserved against fungal decay and insect attack.

Half-timbered houses with exposed timber frames were widely built from the late 13th to 18th Centuries — many survive. Many houses during this period and most houses up to about 1950 used wood externally only for window frames, doors, minimal bargeboards and the like. The wood on half-timbered houses was often left unfinished or blackened with tar or paint. Other external woodwork was universally painted.

From 1950 to the present, major building programmes associated with greater affluence and a will to be better or be different, have led to major changes in the use and finishing of wood.

Window frames are still mainly wood, either large or small paned, predominantly softwoods (European Redwood in England and Wales, Whitewood in Scotland), but the use of hardwoods is significant and increasing. Bargeboards, soffits and the like are still almost entirely softwood, but are often larger and more of a feature. In new buildings, perhaps 50 per cent of these components are now stained. Doors, once painted or varnished, may now be stained. Wooden cladding on the outside of a house, either as a feature on a masonry wall or as part of a wood frame house, are common for houses, flats and tenements. Most commonly these are stained. Britain is just beginning to follow Scandinavia and North America in using sawn timbers in this situation — stains last at least twice as long as on prepared timber.

Crudely, modern finishes can be grouped,

1. Traditional paints giving an opaque, relatively impermeable film 80-100 microns thick.
2. Vapour permeable paints. Two or three coats giving an opaque film with medium to high vapour permeability. Film thickness approaching traditional paints.
3. Stains — Coloured transparent finishes. Degree of transparency and film thickness varying widely. Most are vapour permeable, some highly so.
4. Traditional varnishes — A thick film, colourless but relatively impermeable.

Basic to the absolute and comparative performance of these materials are the intrinsic properties of the wood and its reaction to its environment.

2. Wood, water and weather

Most of the things that determine the performance of wood in situations with which we are here concerned, stem directly or indirectly from its relation with water.

Wood is a cellular material. Cell walls are mainly cellulose and hemi-cellulose. Cells are joined by lignin. Cellulose is in effect a linear polymer of glucose, each molecule being one glucose unit wide and about 10,000 long (in wood). Hemi-cellulose is similar but from other basic sugar units. These chains lie more or less parallel to each other in the cell wall, partly in tightly bonded crystalline regions, partly in looser amorphous regions[1].

In green or saturated wood the cell wall is saturated with "bound" water and the cell cavity is full of "free" water. In seasoned wood there is no free water, but some water remains bound in the cell wall, how much depends on the surrounding humidity and temperature.

Cell wall water is bound to the cellulose by hydrogen bonds on the inner surface of the cell and is interspersed between individual molecules within the wall (especially in the amorphous region). The separation between the two adjacent cellulose molecules must allow for a water molecule stericaly held by hydrogen bonds to both celluloses.

When the cell wall dries out, i.e. the water is removed, cellulose molecules move closer forming hydrogen bonds directly with each other. Understandably, this affects the size of the cell wall and when it is happening in many cells, leads to gross shrinkage of the wood. This reaction is reversible. Drying out of "free" water does not affect dimensions so long as the cell wall remains saturated.

Movement of timber with changes in moisture content differ for different timbers (Table 1) and in different directions, being greatest tangentially approximating to 2 per cent for a change in moisture content of 10 per cent in pine.

2.1 Water vapour

Timber freely in contact with the air, but isolated from liquid water absorbs or desorbs water vapour from the air until its moisture content is in equilibrium with the air. (Table 2).

Temperature and humidity are constantly changing features of the British climate (Table 3), although the range is small.

Typical daily temperatures in summer are 10-18°C in the colder parts and 11-20°C in the warmer, with winter 1-6°C and 4.5-9.5°C. Midday humidity 60-75 per cent in summer, 80-85 per cent in winter with night humidity 85-94 per cent in summer, 81-92 per cent in winter (little seasonal variation).

Timber en mass only reaches equilibrium slowly and it does not follow daily changes, moisture content approximating to a seasonal mean of 18 per cent in winter and 16 per cent in summer. At or near the surface (if unprotected) response is much more rapid, so that if not fully, at least partly, daily changes in the atmosphere will be reflected in the timber, causing frequent small dimensional changes. Any timber finish must have sufficent film elasticity and flexibility to accommodate the natural movement of the wood. These diminish with age and unless renewed beforehand, will reach a point where the film is no longer able to move with the wood. Cracks will be formed. Once formed, water enters through the cracks accelerating the deterioration to flaking. The repeated changes in dimensions in the surface layers also set up strains between the surface and the bulk contributing to ultimate surface deterioration.

Seasonal changes are reflected in dimensional changes in the whole piece of wood, leading to sticking of doors, windows etc.

Timber in the air, but isolated from wetting by rain, mist etc., is unlikely to get much above 22 per cent moisture. Since a moisture content of around 30% is necessary to saturate the cell walls (fibre saturation point), its capacity for bound water within the wall is only partially satisfied, and it contains no free water. In this state, moisture movement within the wood is mostly by diffusion within the cell wall. Net losses or gains result from air exchange with the atmosphere, either by gaseous diffusion or air movement necessary to compensate for volume changes due to changes in temperature and to a lesser extent, atmospheric pressure.

Near the surface, in bright sunlight the wood temperatures may reach 60°C. Following rain evaporation cooling can reduce temperature by 10°C below ambient. With an ambient temperature of 15°C and intermittent sun — showers, frequent temperature changes of up to 50°C can occur. Such a change will cause expansion or contraction of the air by 18 per cent — air being sucked into or expelled from the wood accordingly.

Table 1

Movement of wood from 90% to 60% Relative Humidity[1]
(11-20% moisture content = Extreme seasonal normal)

Wood species	Tangential (mm/m)	Radial (mm/m)
Teak	12	7
Whitewood	15	7
European Redwood	22	10
Western Hemlock	19	9
European Oak	25	15
European Beech	32	17

Changes due to atmospheric pressures can be as high as 10 per cent but normal daily change at any one place is below 1 per cent.

Air moves readily in wood; none-the-less changes in wood moisture as a result of changing atmospheric humidity are slow. The amount of water in air is small compared to that in wood, one cubic metre of air, at 80 per cent relative humidity and 15°C only holds 10 grammes of water. Exchanging this cubic metre for a cubic metre at 70 per cent RH only exchanges one gramme of water. One cubic metre of wood, like pine, at 18 per cent moisture contains 84 kilogrammes water. To increase or decrease the moisture content by 1 per cent needs an exchange of 4,000 grammes water.

Wood will take up or give up water through these mechanisms. There is another and more damaging way in which it takes up water. There is no other way in which it can give up water. Interference with this process helps keep wood wet.

An important aspect of coatings is the extent to which they affect exchange. It is stopped by impermeable films but with permeable films will continue dependent upon the degree of permeability.

2.2 Liquid Water

Wood absorbs liquid water by capillary action. Penetration is greatest through the end grain, longitudinal permeability being up to 20,000 times lateral. Even in the end grain penetration is slow but if it goes on long enough the wood will become totally saturated. Moisture content can then be over 100 per cent (on the dry weight of the wood).

The mechanism of absorption is in principle simple capillarity, but as water penetrates, it must saturate the cell wall before it penetrates further. The cell and pores through which it must penetrate are small.

The ways in which liquid water gets to wood are well illustrated by a window frame (Figure 1).

Table 2
Equilibrium moisture content of wood*[2]

°C	°F	Relative humidity (%) 60	65	70	75	80	85	90	95
0	32	11.3	12.4	13.5	14.9	16.5	18.5	21	24.3
10	50	11.2	12.3	13.4	14.8	16.4	18.4	20.9	24.3
20	70	11	12	13.1	14.4	16.0	17.9	20.5	23.9

* % on dry weight

Table 3
Rainfall and humidity, monthly averages[3]

	Temperature (°C) Min	Max	Mean Daily Range °C	Humidity Mid-Day	% RH Night†
January	1 - 4.5	6 - 9.5	4.5 - 6	80 - 85	81 - 92
February	1 - 4.5	6.5 - 9	4.5 - 6.5	75 - 85	81 - 93
March	1.5 - 4.5	7.5 - 10	5.5 - 8.5	65 - 80	81 - 93
April	3 - 5.5	9 - 13.5	6 - 9.5	60 - 75	79 - 93
May	6 - 8.5	13 - 18.5	6 - 10.5	60 - 75	79 - 93
June	8 - 11	16 - 20.5	6.5 - 10.5	60 - 75	82 - 93
July	10.5 - 13	18 - 22.5	6 - 10.5	60 - 75	85 - 93
August	10 - 13.5	17.5 - 22.5	6 - 10	65 - 80	85 - 94
September	7.5 - 12	16.5 - 19.5	6 - 10.5	65 - 80	85 - 94
October	5 - 8.5	11.5 - 14.5	6 - 8.5	70 - 80	83 - 93
November	2.0 - 5	8 - 11	5 - 7.5	80 - 85	83 - 94
December	1 - 4.5	6.5 - 9.5	4.5 - 6	80 - 85	82 - 92

*Average mean of daily min./max. over England, Scotland and Wales — Excluding mountains and extreme tips

† A few observations only. (Note minimal seasonal change in night humidity)

2.2.1. Rain

The average annual rainfall over Britain is between 625 and 2,500mm for the whole country, but excluding less populated mountainous regions, lies between 625 and 1,500mm. This is not high by world standards, but it is uniformly distributed throughout the year so that we have no such thing as a dry season. (Table 4).

The country averages 175 to 225 rain days per year (48-61 per cent of all days) over a period. The wettest month or the dryest month may fall on any month of the year, with

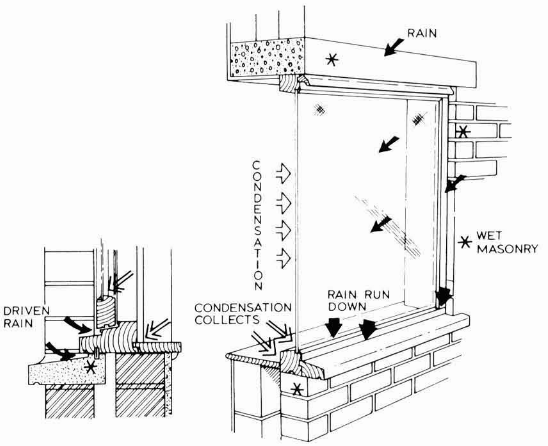

Figure 1. Wetting of window frame

very little variation in the average rainfall or number of rain days month to month. The annual average rainfall for England is 861mm but the record low is 533mm and high 1,168mm. Rainfall for Scotland averages 1,143mm.

Average figures are a poor representation of British weather, for the key word is change. Several changes can occur in one day. Settled spells of more than a few days are infrequent, although the greatest number of consecutive days without rain recorded, lie between 30 and 60 for different parts of the country and consecutive days with rain, between 20 and 50. There is a small but significant (10 per cent) occurrence of months where rainfall is below 25 per cent or above 150 per cent of average with a small occurrence (0.5 per cent) where it is up to 300 per cent.

Local variations, even on the same day, can be considerable. (Table 5).

After only two days rain, unprotected wood (European Redwood Sapwood) can reach 54-58 per cent of moisture[5].

Not all wood takes up water so readily; in the same trial European Whitewood only reached 24-31 per cent — even this is detrimental. Unfortunately the main British building timber is European Redwood and it always contains a fair proportion of sapwood.

On finished wood, rain absorption through the finishes depends on the porosity. Even where they minimise liquid absorption the high humidity (100 per cent?) at the surface will cause an increase in the wood moisture.

2.2.2 Condensation

In misty or similar weather there may be direct condensation onto the outer surface of the wood, but the biggest problem of this nature is condensation on the inside of windows and the like. This occurs when the outside temperature is low enough to cool the glass below the dew point of the internal air. (Table 6).

Occurrence of condensation conditions varies from place to place, but over a substantial part of the country night minima are low enough to give condensation for eight months of the year, day maxima may be below for four months.

Kitchen and bathroom condensation may only occur for one or two hours a day, but it can be at any time of the year and the pools of water produced are often left to soak into the wood.

2.3 Other Weather Effects

Weather effects on wood other than those related to water are of little significance, except at the surface where they have a detrimental effect on the wood and even more so on the finish.

Photo-chemical breakdown of wood substance, especially lignin, is caused by ultra-violet and visible light. Initially this is seen as a darkening of light coloured woods and it contributes to the separation of fibres.

Sunlight degrades coatings. Discolouration and fading depend on formulation. It also causes embrittlement. When embrittlement has reached a stage where the coating can no longer withstand the natural movement of the wood, the coating will break up.

Strong sunlight is hot. German data[6] indicates that in that country the surface temperature of stained wood can reach 60-80°C (dark colours, higher temperature). Britain has less strong sunlight but it seems reasonable to expect wood here to get to over 60°C.

Annually there is an average of 275-305 days on which there is some bright sunshine. Average daily sunshine in June is six-eight hours for most of England and Wales, falling to five in Northern Scotland. In December there is between one and two hours in England and Wales and between half and one hour in Scotland.

Blistering is caused by expansion of water vapour due to hot sun where there is wet wood under an impermeable finish.

The effect of temperature change on air movement and hence water up-take has already been discussed. Thermal movement of timber is small compared to other materials. Expansion is greatest in the transverse direction where the co-efficient of linear expansion is 34×10^{-6} for spruce, and 54×10^{-6} for oak per degree centigrade. Nonetheless a temperature change of from 10 to 60°C caused by intermittent bright sunshine would cause 1 metre width to expand by 1.7mm. With the very rapid changes of temperature that can occur in Britain this cannot be neglected, even though it is only one-tenth the typical moisture movement (spruce changing from 60-90 per cent relative humidity swells 15mm per metre).

Wind speeds inland are generally below 30 mph (13.4 metres per second) — Beaufort scale 6 strong breeze, large branches in motion, umbrellas used with difficulty. Gales (34-40 mph) and stronger are experienced but infrequently inland. Over most of inland England average frequency is only two days a year, getting above 10 days a year only within a few miles of the coast. Strong winds associated with driving rain or more rarely hail, or other solid particles, may contribute to abrasion, but the most important effect of the wind is likely to be the fact that even at low speeds it blows rain onto walls and the like, even

Table 4
Rainfall, and rain days — Monthly average[3]

Month	Average* Rainfall (mm)	Average Number Rain Days	Wettest† in	Driest† in
January	50 - 150	17 - 23	1928	1880
February	50 - 150	14 - 17	1923	1932
March	50 - 150	14 - 20	1903	1929
April	50 - 100	14 - 17	1882	1938
May	50 - 100	11 - 17	1924	1896
June	50 - 100	11 - 14	1872	1925
July	50 - 100	11 - 17	1936	1913
August	50 - 150	14 - 17	1917	1940
September	50 - 100	11 - 17	1918	1910
October	75 - 150	17 - 20	1903	1879 1922
November	50 - 150	14 - 20	1940	1896
December	50 - 200	17 - 23	1896 1914	1933
Annual	625 - 1500	175 - 225	1872	1887

Excluding mountains, *1901 - 1930 †1869 - 1940

Table 5
Local variation in rainfall

Town A	Rainfall*	Town B	Rainfall*	Distance A to B
Bridport	12mm	Yeovil	228mm	17 miles
Bedford	50mm	Norwich	203mm	85 miles
Carlisle	25mm	Edinburgh	76mm	70 miles

*On the same day for each pair

Table 6
Condensation[4]

Situation	Internal		Dew Point °C	Outside Temperature to Cause Condensation* °C
	Temp °C	Humidity % RH		
Well heated houses	20	53	10	5.7
Poorly heated houses	13	82	10	8.7
Hot Kitchen - cooking	22	95	21	20.5

*Single Glazing

where protected by overhanging eaves and so exposes the surface to a washing action.

3. Wood deterioration

When wood gets wet it is liable to be attacked by various types of fungus (Table 7) damaging or destroying it and/or any coatings. The development of any one of these is closely related to the moisture content of the wood.

Transparent or semi-transparent finishes such as stains are easily spoiled if any of them develop and the inclusion of a fungicide is most desirable.

4. Basic requirements for protection

The foregoing highlights that one of the main hazards facing timber in Britain is water, particularly liquid water which can raise moisture content to a level where deterioration of the timber and coating becomes likely.

One of the main functions of finishes, therefore, is to protect the timber from liquid water. In any situation where design and construction was such that water could only enter the timber through the finish, it would be logical to aim for a totally impermeable finishing system.

Such a situation is rarely achieved, especially in modern construction and design. This was particularly evident in the immediate postwar construction of the 1950's, when many instances were recorded of failure of the joinery within a few years of building, particularly around lower joints of window frames and doors.

Equally, there is no such thing as a totally impermeable paint system. However, except for low build systems with very high permeability, the amount of water transmitted through the film will be insuffícent to cause problems.

The real problem facing decorative/protective finishes is the liquid water entering the timber through areas other than the finish, i.e. open joints, unsealed end grain, defective glazing putty or beads etc., either from constructional moisture, driving rain or condensation. In such circumstances more permeable coatings are required to allow the excess moisture to escape without damage to the film — in other words, we must 'let the timber breathe'.

4.1 Prerequisites

The responsibility for successful finishing does not rest totally, therefore, on the paint manufacturer or decorator. The joinery manufacturer and builder must also play their part. The essential prerequisites are listed in Table 8. Recognition of these essential requirements has slowly been achieved during the last 15-20 years and comprehensive guidance notes have recently been produced for its members by the British Woodworking Federation, in conjunction with the Paintmakers' Association. Inevitably there are conflicts of interest between designing for ideal performance and cost and it must be recognised that some UK joinery falls far short in quality of the standards achieved in many countries in Western Europe. This identifies yet another reason why the finishing of timber in the UK presents problems not encountered, or of a greater severity than that experienced in Europe.

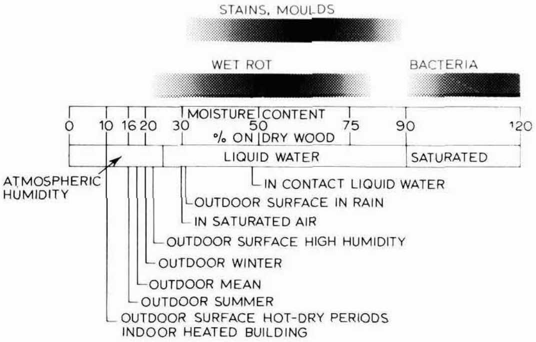

Figure 2. Wood — moisture — fungi

4.2 Finishing Systems

The main requirements of the finishing system, if it is to face up to these challenges and give satisfactory performance without gross failure, are summarised in Table 9.

Overall durability is dependent on having good adhesion to the substrate, adequate flexibility to withstand normal wood movement, and a composition which fails beyond the expected life of the finish by erosion rather than blistering, flaking or cracking. The latter forms of breakdown require removal of existing coatings before redecoration whilst failure by erosion requires only a thorough wash down, followed by repaint.

In the context of control of moisture movement, the finish should be water resistant, to minimise water uptake, whilst having sufficient permeability to allow release of excess moisture from the substrate. Clear finishes should have resistance to UV to prevent degradation of the underlying wood surface, and all products should have resistance to disfiguration by microbiological growths.

In any performance testing it is essential that tests are carried out on films of the expected applied film thickness. Variations in film thickness can have a significant effect on most film properties. Figure 3 shows the influence of the coatings percentage volume solids content and natural spreading rate on dry film thickness. Typical figures for conventional solvent thinned gloss and undercoat are compared with those obtained from aqueous matt and gloss finishes and a low build stain product. In the latter case the influence of the substrate on natural spreading rates and hence film thickness is indicated. An indication is given of the range of film thicknesses regarded as coming within the definitions of low build, medium build and high build.

The figures quoted are for one coat only and in most cases a normal system would consist of two or three coats. In practice, over the wide range of percentage volume solids contents and natural spreading rates of different finishes, dry film thicknesses vary around 22 micron ± 10 micron (0.5-1.5 thou.) per coat.

It is also important, in testing, to consider the total system rather than the individual components.

Table 7
Wood attacking micro organisms

Organism	Effect	Growth
Decay fungi (Wet Rot)	Destroy Wood	Most rapid 40 - 60% moisture around 20°C but will continue down to 20% moisture or 0°C.
Bluestain fungi (Sapstain)	Discolour sapwood. Fruiting bodies disrupt paint or stain films	Moisture content above fibre saturation (30%) and below complete saturation.
Mould	Various, may damage film or may just be superficial	High Moisture content at surface
Bacteria	Increases permeability causing over-absorption of preservatives. Affected timber very easily gets very wet with paint application problems	Fully saturated
Algaes	Superficial discolouration	Damp shaded timber

Table 8
Basic requirements for protection - prerequisites

1. Correct selection of wood (grade/quality)
2. Correct design of joinery/joints
3. Correct choice of glazing system in windows
4. Adequate preservation of timber
5. Use of correct primer in factory
6. Adequate sealing of end grain

Table 9
Basic requirements for protection - finishing system

Finishing system must have:
1. Good adhesion to substrate
2. Flexibility to withstand movement
3. Durability - within expected life of system
4. Optimum level of permeability
5. Water resistance - to minimise water uptake
6. Resistance to u.v. degradation of timber
7. Mould/algae resistance

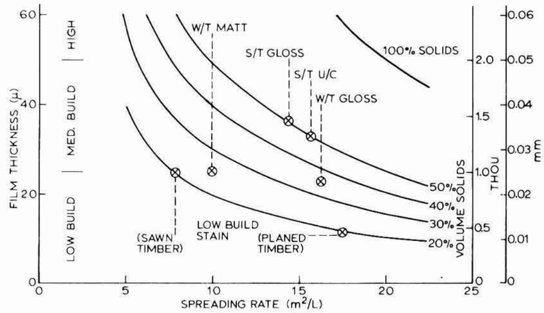

Figure 3. Relation between spreading rate/film thickness (1 coat)

Performance of finishes can be influenced substantially by the type of primer and undercoat used.

5. Types of finishes available

One of the main problems facing the specifier is to distinguish between the various specialised finishes offered for timber finishing. Within an overall grid ranging from low to high solids, transparent to opaque and matt to high gloss, most combinations are possible, and many are offered. Further, no agreed definitions yet exist to differentiate between the main groups of products within this grid. British Standards are attempting to bring some clarity into this field by establishing a guide to the selection and specification of exterior wood coatings.

In practice the choice can be greatly simplified and a realistic classification is as shown in Table 10. Here the main groups of products, i.e. low solids stains, medium solids stains, high solids stains, opaque stains, paints and varnishes are positioned within an overall grid of finish and build.

5.1 Composition

A further complication is that most of the finishes, if not all, can be formulated using aqueous or solvent based technology. A summary of essential composition is given in Table 11. With the exception of the resin system used, most other constituents are common to both technologies.

Table 10
Types of finish available

Build	Transparent	Semi-transparent	Opaque
Low	Low solids stains		
	Med. solids stains		
Medium			Opaque stains
High	Varnish	High solids stains	
	Coloured varnish		Paints

Table 11
Basic composition

Pigmentation:	Stains	— Iron Oxide
		(Transparent Iron Oxide)
	Opaque	— TiO_2
		— (Extenders)
		— (Coloured Pigments)
Additives:		— Synthetic wax water repellent
		— Fungicide/Algicide
		— (Blue stain inhibitors)
		— (Wood preservatives)
Resin system:	Solvent	— Long oil modified alkyd/Oleo resinous
	Aqueous	— 100% Acrylic copolymer
		— (Oil/Oleo resinous emulsions)

Table 12
Aqueous versus solvent thinned - Key differences

	Aqueous	Solvent
Specific permeability:	High	Low
Retention of flexibility:	Good	Moderate
Drying in high humidity:	Poor	Moderate
Use over putty:	Not suitable	Satisfactory

Table 13
Influence of choice of system on repaint cycle

1.	Low Build	e.g. Stains	2 - 3 Years
2.	Medium build	e.g. Stains/Opaque matt	3 - 7 Years
3.	High build	e.g. Opaque sheen/Gloss	5 - 10 Years

In the stain type products, iron oxide pigments are preferred for maximum lightfastness, transparent grades being preferred for the high build stains for hardwoods to enhance the natural grain of the timber. Evidence exists that the use of such transparent iron oxide contributes to the resistance to wood degradation by UV.

In opaque finishes, titanium dioxide is normal as the main opacifier, using grades appropriate to the resin system selected. Selection of extenders for the lower sheen products is critical in obtaining optimum flexibility, permeability and resistance to erosion.

Additions of synthetic waxes can contribute to the initial water resistance of coatings, and fungicides/algicides are necessary to inhibit biological growth on the surface. In stain products, a blue stain inhibitor is essential to prevent unsightly discolouration of the timber. In lower build preservative stains, a penetrating preservative is required to enhance the resistance of the timber to decay, particularly in situations where moisture content may rise above 25 per cent.

Choice of resin in the solvent bourne coatings can be wide, but most products are based on long oil modified alkyds or other oleo resinous systems. One of the key factors in choice is retention of flexibility on ageing. In aqueous coatings 100 per cent acrylic emulsions are preferred on grounds of adhesion, lower permeability and retention of flexibility with excellent durability. Some use is also made of oleo resinous emulsions, either as the sole binder or as modifer for synthetic emulsions.

5.2 Aqueous versus Solvent Thinned (Table 12)

The choice between solvent bourne and water bourne systems is influenced by both performance requirements and application conditions. Extremely durable systems may be produced from both technologies, for use on dimensionally stable, sound, dry substrates. In taking the broad requirements of modern timber finishing into account, the water bourne systems can show benefits over the solvent bourne equivalents. The most significant is the higher specific permeability of the aqueous system which permits the development of higher build films with desired permeability.

The second benefit of these aqueous systems is their higher initial flexibility and retention of this flexibility on ageing. They have the additional benefit of any absorbed water acting as a temporary plasticiser. This increases the film's extensibility quite significantly at a time when the wood itself is expanding due to moisture absorption. Thus they are much more able to follow the dimensional changes in timber as it absorbs water and subsequently dries.

The main disadvantage of aqueous coatings is their dependence on evaporation of water, as the first stage of film integration and coalescence. If applied under adverse weather conditions, i.e. low temperature, condensation or high humidity, drying will be protracted. Under such conditions coalescing solvent can evaporate prior to loss of water, leading to inadequate coalescence of the film when the water subsequently evaporates. Aqueous coatings are also unsuitable for use over oil based putties and bead glazing is essential if such finishing systems are specified.

The benefits of aqueous systems lend them particularly well to full factory finishing where drying conditions can be controlled. Many examples now exist of such full factory finished components performing extremely well in practice after 10 years' service with no subsequent maintenance repainting. Similar performance can be achieved by "on site" application providing due note is taken of their drying requirements.

The main benefit of solvent based systems is their greater penetration into the timber, especially important in low build stains, or basecoats, containing wood preservatives or blue stain inhibitors.

They also have a positive drying advantage in cooler and more humid conditions as can be experienced for a substantial part of the year in northern districts. This aspect is equally important in the higher build stains and opaque coatings.

5.3 Other factors influencing choice

Consideration must also be given to the anticipated maintenance schedule as indicated in Table 13. Low build stain finishes will normally require an additional coat or two after two to three years. Otherwise natural erosion will increase permeability to the point that excessive uptake of moisture will lead to wood splitting. In situations where maintenance costs are high, for example on high rise buildings where scaffolding may be needed, longer life high build coatings are essential. For such situations, alkyd based sheen products, aqueous gloss systems or high build stains are the obvious choice.

Ultimately the key factor influencing choice is the aesthetic consideration of required visual appearance of the finished work. This can also be influenced by the condition of the timber prior to decoration, and the nature of the joinery.

On new preserved hardwood high build transparent stains are the obvious choice, whilst on equivalent softwood joinery, semi transparent stains or opaque finishes may be preferred. On repaint work, or where the timber is disfigured, opaque finishes are more appropriate, the higher build finishes being required where dimensional stability is essential such as on windows/doors.

6. Performance Considerations

6.1 Flexibility

If the coating system is to meet the durability requirements previously considered, it must maintain an adequate level of flexibility throughout its expected life.

Indications of flexibility performance can be obtained by conventional tests such as bend, extensibility, impact etc., particularly if repeated on films subjected to accelerated weathering or even by low temperature stoving. A useful additional test for the fatique behaviour of coatings systems using a vibrational technique has been developed by Tioxide UK. Their work[7] has shown that increase in film thickness normally results in a decrease in fatique life. Figure 4.

Their work in three coat (primer, undercoat and gloss finish) systems also shows that the order of results may differ if the undercoat is tested alone or as part of a system. The presence of a gloss coat can modify the relative fatique behaviour of the undercoat. This work has also shown that low PVC alkyd based undercoats and acrylic based undercoats can contribute to an alkyd based finishing

Table 14
Durability testing of three coat gloss systems over various preservative pretreatments

	45° Exposure - 5½ years					Horizontal Exposure - 3 years			
System	Preserv.	Mould	Blist.	Adhesion	Overall Appearance	Mould	Edge Crack	% Film Removal	Overall Appearance
Alkyd based Primer - BS 5358	1.	G	M	M	M	M	M	0	P/M
	2.	M	M	M	V.P.	P	P	15	P/M
+ Alkyd based Undercoat	3.	-	-	V.P.	V.P.	P	P	60	P
+ Alkyd based Gloss	4.	G	G	M	P	P	P	50	P
	5.	G	V.P.	M	P	P	P	75	P
	6.	-	-	V.P.	V.P.	M	P	10	M
	7.	G	G	M	P/M	P	P	75	P
Acrylic based Primer	1.	G	E	E	E	G	G	0	E
BS 5082	2.	G	E	G	M	M	G	0	G
+ Acrylic based Undercoat	3.	G	E	E	G	G	E	0	E
+ Alkyd based Gloss	4.	G	E	E	E	G	E	0	E
	5.	G	M	P	P	G	G	0	E
	6.	G	M	M	P/M	M	M	0	G
	7.	G	G	M	P	M	G	0	G

Key: E = Excellent. G = Good. M = Moderate. P = Poor.

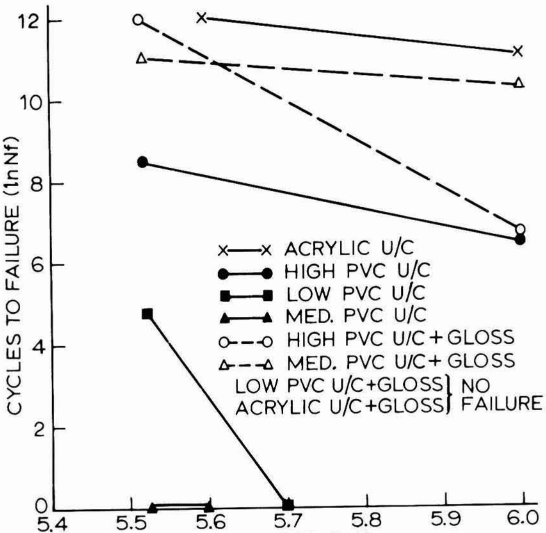

Figure 4. Flexibility—Fatigue crack resistance

system with no cracking on ageing. Two coat aqueous gloss systems also show this extremely good performance.

Results from this strain fatique testing have been supported by an extensive natural exposure test programme, in which an alkyd gloss finish was tested over various preservative pretreatments, primers and undercoats. All tests were over Baltic Redwood, selected for minimum heartwood content and no ponded sapwood. Each system was tested on horizontal grooved panels (PRA test) exposed for three years, and more conventional 45°C exposures for 5½ years.

Results of only a small section of this work are summarised in Table 14. Not only does this highlight the improvements in both mould resistance and durability attainable by use of an acrylic emulsion based primer and undercoat, but also the influence of the preservative pretreatment.

Similarly, the good results shown by the all aqueous gloss system have been confirmed by practical exposures of such a system on joinery used by the Method Consortium. Full factory finished joinery has now been in use for over 10 years; in many cases with no subsequent maintenance painting, and yet still showing extremely good protection with only very minor failures. The exceptional performance of this system has also been extensively reported by Miller[8] and others, based on the results of trials at the BRE in their window frame test house.

6.2 Permeability

Apart from these significant differences in results due to varying levels of flexibility, another factor equally important is permeability to moisture. Insufficient permeability may result in blistering or flaking of the coating during summer months, when maximum drying out occurs, particularly with uncontrolled ingress of liquid water. Too high a permeability, however, can have equally adverse results due to excessive absorption through the film, leading to dimensional changes during wetting and drying out with resultant wood splitting.

Dooper[9], in 1975, reported that to avoid wood cracking,


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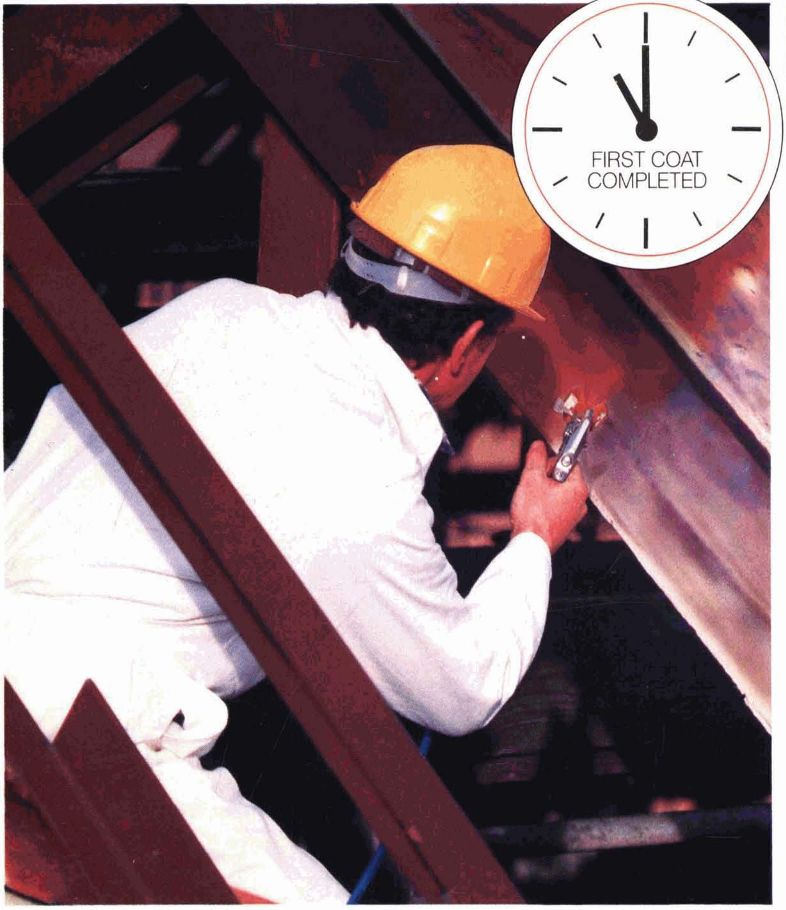

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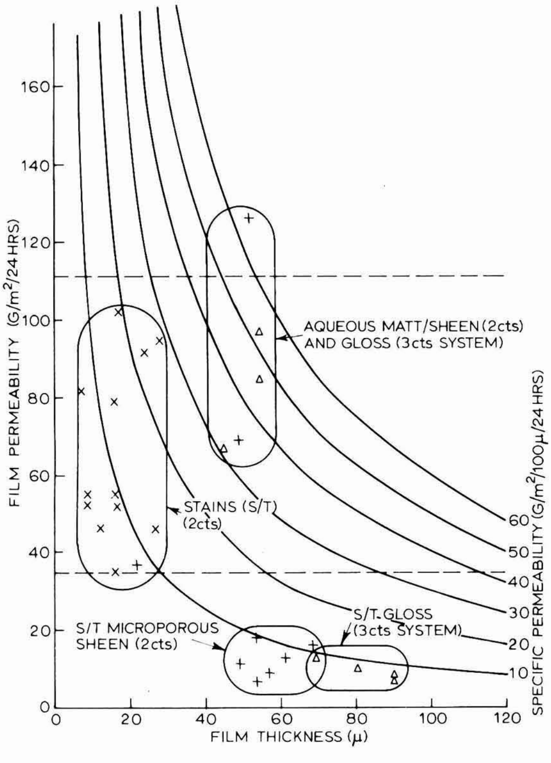

Figure 5. Permeability—Relation to film thickness

permeability of systems should be less than $50g/m^2/24$ hrs., whilst Burgers[10], in 1978, suggested that this figure should be varied for different timbers, quoting $60g/m^2/24$ hrs. for European Redwood and $35g/m^2/24$ hrs. for Meranti.

High permeability may be acceptable where the substrate is tolerant to free movement, such as on fencing or sawn cladding, where a degree of wood cracking may be acceptable. However, on joinery, where dimensional stability is required, systems of medium permeability must be specified.

In selecting a finishing system with the optimum level of permeability, it is important to recognise the distinction between specific permeability and film permeability. Specific permeability is controlled by the composition of the film and is quoted at unit film thickness, whilst film permeability is influenced by the actual film thickness achieved at normal spreading rates. Under normal circumstances, for a given coating system, permeability is inversely proportional to film thickness.

Results of permeability measurements on many commercially available products are summaried in Figure 5. All products tested to date gave results within the areas shown.

This highlights that the higher film permeability of wood stains is achieved at the expense of film build. The figure also demonstrates the relatively low permeability of the "so called" microporous solvent thinned sheen products which are normally used in a two coat system, using the same product as primer. Their reduced tendency to fail by cracking and flaking is likely to be due as much to their better balance between cohesion and adhesion as to their slightly higher film permeability than conventional three coat gloss systems.

All tests were carried out using a modifed Payne Cup technique, as described by PATRA[11], placed in an atmosphere of 25°C and 75 per cent RH, with a dry atmosphere of calcium chloride inside the cup. Whilst alternative conditions will change the scale of results, relative positions are likely to be unchanged. In practice, permeability is also influenced by temperature and the humidity gradient across the film. Air movement can also influence the rate at which the surface dries.

Studies on coated timber with total immersion in water have shown increases in moisture content of the wood ranging from 0.09 per cent to 1.21 per cent over a 24 hour period. Since it would require a 9 per cent increase to raise the equilibrium moisture content from 11 to 20 per cent, it can be seen that all specialised coatings systems for timber can adequately protect timber, providing there is not a break in the film, or exposed end grain.

This aspect was studied by Wagner[12], using pairs of electrodes embedded in the test specimen at different depths. In outdoor exposure studies over one year he found wood moisture contents varying from 10 to 25 per cent providing all faces were coated with a thick film varnish. As might be expected, maximum wood moisture content, of 58 per cent, was found when end grain was unsealed.

7. Conclusions

Providing adequate attention is paid to prevention of ingress of liquid water in the design of joinery, building construction and glazing methods, traditional coating systems can give long life. However, with modern practice, water does all too often get into the wood. In such cases alternative breathable systems are essential.

Substantial evidence exists to show that the use of aqueous acrylic primers and undercoats under conventional alkyd gloss paints can increase significantly the potential life of such finishes by reducing the incidence of stress cracking on ageing, coupled with some increase in film permeability.

Similarly the use of all aqueous gloss finishing systems can give long life in practice, in excess of ten years. Such systems, having greater flexibility, can resist the opening of joints, hence preventing an obvious source of moisture ingress, whilst their much higher permeability allows drying out, without failure, if moisture arises from other sources.

Medium build alkyd based sheen finishes can also give good protection, whilst having an adequate level of film permeability to cope with normal levels of moisture release.

Where stain type finishes are preferred, a medium-high build system is recommended for use on timber requiring dimensional stability, such as windows/doors. Whilst lower build stains can be used, they must be refinished at least every two-three years to maintain their level of protection.

On timber not requiring dimensional stability, and in situations where it is not practical to seal all faces, e.g. fences, cladding, etc., it is important to use systems with high film permeability. Low build stains or aqueous acrylic matt/sheen finishes are ideal. Again, the higher build of the aqueous systems can give longer life, with less frequent need for maintenance painting.

There is no single coating which can solve all the problems experienced in the refinishing of timber. But, alternative systems are now available which can meet all requirements — the important decision is to select the right system for each need.

[Received 29 March 1985

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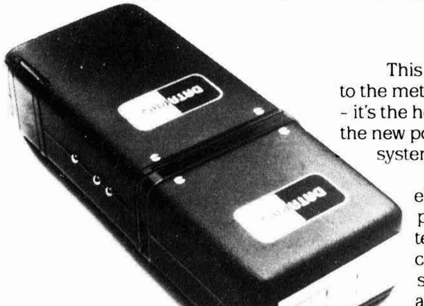

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The role of adhesion in corrosion protection by organic coatings

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Summary

For organic coatings in general and for corrosion protection of metal surfaces especially, adhesion in presence of water ("wet adhesion"), is the most important and decisive property. Adhesion theories provide considerable theoretical background for understanding the basic mechanisms involved, however, they are still of little help in improving adhesion of organic coatings and explaining practical defects. Moreover, statements like "polar groups are good for adhesion" or "there is no paint film impermeable to water" are so common and much repeated in literature, that too little notice has been paid to some incongruencies existing in the interpretation of practical facts.

Defects of organic coatings related to metal corrosion, like blistering, are always preceded by a significant reduction of adhesion as a consequence of water penetrating to the coating/metal interface. Accordingly, it is very important to know wet adhesion and to use organic coating systems which resist the interfacial action of water.

As a testing method the adhesive tape tear-off test is recommended, and for improving wet adhesion enhancing the barrier properties of the film and optimizing the co-operative action of adhesion bonds at the coating/support interface are suggested.

Introduction

Amongst all the technological properties of organic coatings adhesion is the most important one; and there are good reasons and enough experimental results to indicate that this statement is especially true for corrosion protection. Therefore, it is not surprising that much experimental and theoretical work has been dedicated to understanding the mechanisms involved (Table 1). And it is very difficult to give a proper selection of literature from the large number of publications in this field. Essentially, the following mechanisms may be cited[1],

Adsorption theories: describe adhesion by van der Waals forces between electrically neutral solid surfaces.

Diffusion theories: consider interdiffusion and entanglements of polymers as essential elements of interfacial interaction and are mostly applied in explaining autohesion and self-tack.

Electrostatic theories: are based on a charge transfer at interfaces with formation of an electrical double layer.

Chemical bond theories: assume covalant bonds crossing the interface between solid surfaces.

Mechanical bond theories: explain adhesion by mechanical anchoring of two surfaces with special morphological structures.

Table 1

Mechanisms of adhesion

Mechanisms of adhesion	Representative authors
Adsorption	Grimley, Lifshitz
Diffusion	Voyutskii
Electrostatics	Deryaguin, Weaver, Fowkes
Chemical bonding	Various authors
Mechanical bonding	Bikerman, Wake A.O.

Different mechanisms of adhesion may co-operate, and some mechanisms become operative only under special conditions, which certainly contributes to the difficulty in applying these theories to practical problems. As far as corrosion protection is concerned, it is helpful to consider the locations of molecular attraction as represented by polar, electrostatic and hydrogen bonds (Figure 1A).

Mechanical properties of coatings and internal stresses, which may influence adhesion, will be neglected in this discussion. Most metal surfaces are covered with oxide layers which are usually polar and hydrophilic. It may be expected therefore, that the polar groups of the binder macromolecules promote adhesion of organic coatings. Adhesion by polar groups resp. by polar interactions has become an axiom in paint technology, especially as there is also experimental evidence for the validity of this statement[2,3,4].

In discussing the significance of adhesion for corrosion protection by organic coatings it is important to realize, that for atmospheric corrosion, sufficient water must be present to provide the electrolyte for the electrochemical reactions involved. Consequently one may expect that adhesion data obtained with dry coating systems are irrelevant to their corrosion protective quality. As a matter of fact it could be shown[5,6,7] that, similar to adhesives, adhesion often drops dramatically on exposure of organic coating systems to high humidity or water over variable testing times. This decrease of adhesion is only observed above certain limits of humidity and may be accelerated by increasing the exposure temperature. Obviously water molecules are able to interfere with the molecular interaction and bonds responsible for adhesion and may accumulate at the film/metal interface, forming clusters and eventually causing complete delamination of the coating (Figure 1B).

Wet adhesion – The basic protective property of organic coatings

For understanding the mechanism of paint film failures like blistering, it is important to know how their appearance is related to adhesion. It was shown, with various types of coating systems[8], that blistering is always preceded by a substantial reduction of adhesion over the whole area of the

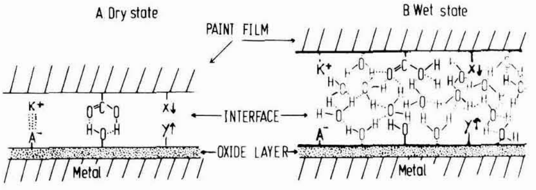

Figure 1. Interaction of water at polar interfaces

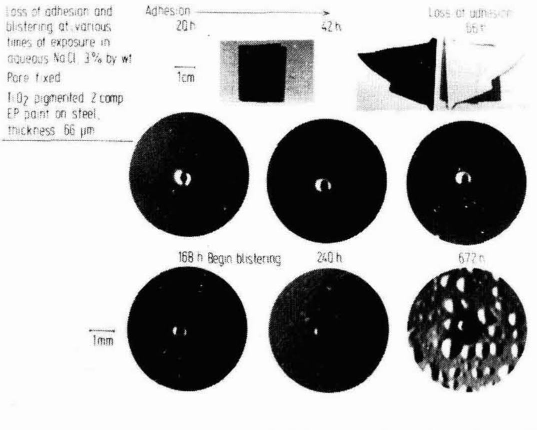

Figure 2. Loss of adhesion and blistering at various times of exposure in acqueous NaCl. 3% by wt, pore fixed, TiO_2 pigmented, 2 components EP paint on steel thickness 66 μm

exposed samples (Figure 2). At this stage obviously underfilm corrosion has not yet started, because the pH at the interfacial area is still neutral, the metal surface has its normal bright appearance and soluble iron compounds are not yet traceable[9]. However, the residual adhesion is still sufficiently high to keep the coating to the support in the neighbourhood of the locations where blisters are formed.

This simple result, which could be confirmed with coatings composed of different vehicles, has some interesting implications.

Obviously reduction of adhesion of defect-free organic coatings on exposure to high humidity or liquid water does not proceed immediately and continuously to complete delamination. There are intermediate stages of reduced adhesion, at which a partial recovery is possible when the coating system is allowed to dry. This recovery of adhesion has been frequently mentioned in the literature and has become a practical experience in paint technology[5,6].

Considering the dimensional changes of the film involved in delamination and the redistribution of ubiquitous traces of impurities or low molecular weight materials in the interfacial area, it appears impossible to fit together locations of interactions or bonds again, even to a small degree, once they have been separated completely. Therefore, after delamination the recovery of adhesion to any practically significant extent appears to be impossible. However, recovery of adhesion is feasible at a stage of reduced adhesion, which is effected by water at the interface.

The dissolution of the natural oxide layers at metal surfaces[10], cathodical formation of hydroxyl anions and the saponification of the coating adjacent to the metallic support[11,12] have been considered to play an essential role in paint film failures related to metal corrosion. However, keeping in mind the previous arguments, these processes seem to be secondary rather than the initiating ones, even if in the latter instance the vehicle is really susceptible to a hydrolytic attack.

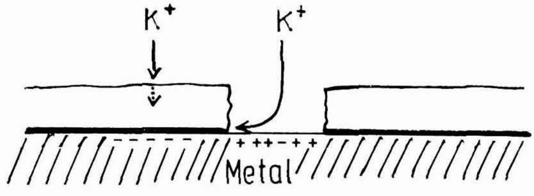

Figure 3. Diffusion pathways of cations required for charge balance at cathodic areas

Another question concerning the condition at the film/support interface on exposure to a corrosive environment is the diffusion of cations to cathodic areas, which is necessary for balancing the negatively charged hydroxyl anions formed by the cathodic corrosion reaction. Diffusion of cations, like Na^+ through paint films is a rather slow process[13,14]. Some experimental evidence exists[15], that cations may also diffuse to the cathodic areas in the coating/metal interface laterally from a defect (Figure 3). As this diffusion way is much longer than that through the film and obstructed by adhesional forces, a reduced adhesion observed on exposure to water would make interfacial cation diffusion more plausible.

Electrochemical corrosion of metal surfaces, which are covered by organic coatings, is only possible if the local cathodes and anodes are connected by an electrolyte. It is hard to understand how such electrolytic connections are possible without diminished adhesion. Once this stage of coating failure is attained, delamination may eventually take place by both electrochemical (cathodic) and physicochemical mechanisms. In presence of paint film defects, like pores or scribes, and in presence of ions, like those of NaCl, cathodic delamination accompanied by blistering in the neighbourhood of the defect is usually faster at the beginning. In case of poor wet adhesion, sooner or later complete failure by extended physico-chemical delamination may be expected, depending on the permeability of the coating system.

Testing of wet adhesion

The nature of failure in testing adhesion of organic coatings is important for interpreting the failure mechanism (Figure 4).

In the dry state cohesive failures are more frequent than adhesive failures, even when the former one is not so easily observed by microscopic or electron microscopic techniques. It has been argued that cohesive failures occur in a "weak" boundary layer adjoining the interface, which is deficient in polar groups due to adsorption at the metal surface. This would imply, however, that polar groups in the vehicle are generally responsible for the cohesive strength of organic coatings, which has not yet been substantiated experimentally. It is more reasonable to assume that the weak boundary layer is due to the molecular

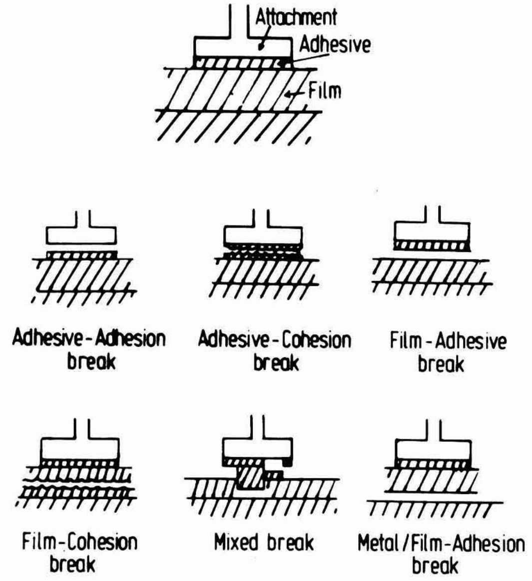

Figure 4. Types of breaks in measuring adhesion by the vertical pull-off test

arrangement and chain conformations in the vicinity of the interface[18]. Contrary to dry adhesion failure wet adhesion failure is usually an adhesive one, as water interacts with the polar forces in the coating/metal interface.

In testing adhesion of organic coatings for corrosion protective purposes too much emphasis was laid on dry state adhesion. However, adhesion in the wet state on exposure to water is much more important for corrosion protection and usually doesn't show much relation to dry adhesion[16].

The problem is that common testing methods for measuring adhesion of organic coatings to metal surfaces, like the vertical pull-off test, are not applicable to coatings in the wet state. Adhesion data in literature regarding the influence of water are mostly ambiguous as it is not clear, whether the respective measurements have been actually performed in the wet state[4,5].

Accumulation of water at the coating/metal interface can be detected by comparing water absorption of free and supported films (Figure 5). Apart from some limitations concerning comparable states of film formation, the cross-over of these absorption curves indicate the presence of substantial amounts of water in the interface[17]. Then adhesion has already significantly decreased. Despite accurate and practical test methods for wet adhesion are still lacking, the adhesive tape test proved to be quite satisfactory for practical purposes. The scribe is applied to the samples after exposing to water or high humidity for different times and wiping off adhering water. The exposure time, after which the coating may be torn off with the tape, serves for the classification. This simple test gives rather reliable and reproducible results and allows the determination of wet adhesion loss sufficiently accurate for practical purposes.

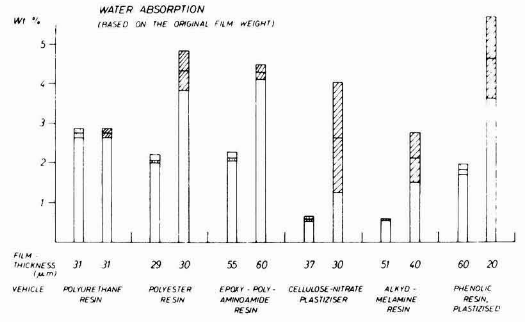

Figure 5. Water absorption of paint films (left columns = free films, right columns = on substrate, hatched sections = variation of single values)

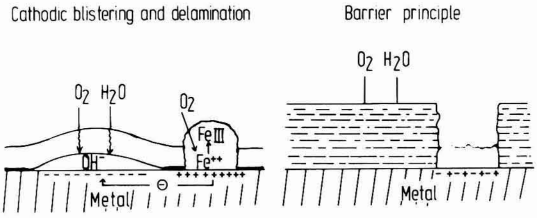

Figure 6. Prevention of blistering and cathodic delamination of coating defects by the barrier principle

Improvement of wet adhesion

There is enough experimental and theoretical evidence, that polar forces are important for bonding organic coatings firmly to the polar and hydrophilic oxide layers at metal surfaces. On the other hand it has been amply shown that the same molecular interactions are also especially sensitive and attractive to water molecules. After all, the same is true for interactions between oxidic inorganic pigments and the vehicle matrix, and even in case of organic pigments of low polarity, surface pretreatment and paint additives are needed to support the dispersion in paint media of appreciable polarity.

Therefore, polar molecular attractions may be considered as a characteristic feature of organic coatings before and after film formation. In view of this situation and regarding the relatively high permeability of most organic coatings to water, at a first glance the demand for good wet adhesion appears to be almost unrealizable. By increasing the film thickness, use of barrier pigments and choice of hydrophobic vehicles the permeability for water can be significantly decreased. In this way polar interactions at coating/metal interfaces may be protected against water even over longer times of exposure. This principle has been largely applied in thick-film systems for protecting metal constructions against strongly corrosive environments, like marine constructions, underground pipelines and when coatings are used together with cathodic protection (Figure 6).

In choosing such coating systems a direct improvement of wet adhesion is usually not involved and some inherent weakness in protection remains. Moreover, in many practical cases thick-film systems cannot be used by other reasons.

It is possible to improve wet adhesion by pretreating steel surfaces, e.g. by phosphatizing. As such layers are also hydrophilic the improved wet adhesion, which is often observed with these systems, is probably achieved by mechanical anchoring of the base coat to the crystalline structure of the phosphate layer. All these possibilities belong to the well known repertoire of corrosion protection by organic coatings.

Another way to improve wet adhesion is to enforce the co-operative action of polar bonds between the coating and its metallic support[17]. Normally interfacial bonding may be visualized by a dynamic process of bonding and disbonding at many sites of the interface, especially if the glass transition temperature of the vehicle is within the range of practical performance. Under this condition water molecules always have a chance to interfere permanently with the bonds due to their high affinity to polar groups. However, if after film formation the polymer backbone, to which the polar groups are attached, has become rigid, disruption of a single bond by water requires the simultaneous disruption of many bonds in the neighbourhood. Therefore, water molecules have no chance to interfere unless the chain segments become mobile. This is possible at elevated temperatures, and it is well known that the delamination of organic coating by water may be strongly accelerated by raising the exposure temperature above the glass transition temperature. On behalf of mechanical properties required it is sometimes unreasonable to increase the glass transition temperature of the whole film, e.g. by choosing special vehicles or increasing the cross-link density. Therefore, immobility of the polymer backbone should be achieved at least in a thin layer adjacent to the interface. The significantly better adhesion of very thin coatings (1-10 µm) as compared with coatings of the same composition but normal film thickness (e.g. 40-80 µm) is probably not only due to different internal stress. Likewise, primers or base coats are comparatively rigid films and thereby co-operation in interfacial bonds may be enhanced.

Improvement of wet adhesion can be promoted by increase in the adhesive bonds at the metal interface.

The purposes of some excellent commercial anticorrosive coating systems which do not have low permeabilities can only be explained by good wet adhesion properties.

Improvements in the barrier properties may enhance the corrosion resistance of the system but for an adequate safety margin, good wet adhesion should also be attained.

Acknowledgements

The support of this work by the Arbeitsgemeinschaft fuer Industrielle Forschung is gratefully acknowledged.

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next month's issue

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

Performance of a novel corrosion inhibiting pigment of low toxicity, in ferrous metal primers, applied to marginally prepared surfaces *by P. A. Draper*
Colouration of radiation curing system *by V. Kaden and P. Eckert*
Acrylic and polyurethane dispersions in industrial coatings for plastics *by R. Arnoldus*

Discussions arising from some of the papers given at the Edinburgh Conference together with comments by the lecturer(s) will be appearing in this and subsequent issues.

New developments in selfpolishing antifoulings

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Abstract

Since their introduction in the early seventies, selfpolishing antifouling paints have steadily increased their share of the market at the expense of the old, long-life antifoulings.

The many extra advantages associated with selfpolishing paints did not persuade some shipowners to change to these systems because a higher investment was required from the start, both in material costs and extra surface preparation.

The appearance of "high build" or "high solids" selfpolishings helped to increase their share over the traditional paints, due to lower application costs and reduced drydocking time, but higher initial investments were still necessary.

The recent release of a "third generation" of selfpolishing paints, with a raw material cost structure similar to that of long-life antifoulings and minimum surface preparation required, is expected to lead to further increase in the market share of selfpolishing antifoulings.

This paper analyses the latest developments in the interesting and competitive field of antifouling paints.

Fouling and Roughness

These are the two main problems associated with high bunkers consumption. They lead to an increase in the average hull roughness (AHR) and therefore, increased frictional resistance.

Hull design is important in determining the initial frictional resistance. This resistance will inevitably increase, unless the correct anticorrosive and antifouling systems are used.

Fouling is a kind of roughness, a temporary one, as it can be corrected, by removal. Corrosion, flaking, peeling, bad workmanship in paint application and mechanical damage are other causes of temporary roughness, which can be redressed by abrasive blasting followed by rebuilding of the anticorrosive and antifouling systems.

Sandwich Coatings

The continuous use of conventional and long-life antifoulings, necessitating sealer coats as well as new antifouling coats create "sandwich coatings".

Such accumulation of paint gives rise to peeling and flaking, thus increasing the roughness of the hull. Additionally, the biocides still present in the old antifouling are irrevocably lost, wasting valuable money.

The AHR tendency to increase as a result of many drydockings with conventional and long-life antifoulings, has been verified by various studies. Recently, Perry[1], in an "Owners view of underwater hull management", reported an increase of 35 microns/year in a study covering 12 vessels, over an eight-year period, a figure that confirms earlier studies.

Such AHR increase is bad news for owners. Early works, like Lackenby's[2] attempted to quantify the cost penalty attributable to rises in AHR. Basically, every 10 microns increase in AHR is expected to cause a 1 per cent rise in bunkers, although this penalty is halved for ships having an AHR higher than 200-250 microns.

Selfpolishing Antifoulings

The two major problems leading to an increase in bunkers consumption, fouling and roughness, can be solved efficiently by the use of selfpolishing antifoulings.

They are based on "organotin copolymers" which, unlike the conventional and long-life types, release the biocides in a controlled manner. The organotin biocides are chemically bound to the acrylic backbone and are released in contact with sea-water, by hydrolysis and/or ion exchange.

The remaining backbone then dissolves and/or is washed away, allowing a new, fresh surface to be exposed. Such a mechanism provides a much better, linear biocide release rate, both for the organotin biocide and the booster biocides incorporated as additives in normal selfpolishing antifoulings. It is this surface hydrolysis/ion exchange, which gives selfpolishing paints the edge over all other existing antifoulings.

An additional benefit is the "smoothing effect", which is due to differential polishing rates for peaks and valleys, because the turbulence created by the flow of water is higher on peaks. This means that for new ships (or indeed for fully blasted hulls, followed by rebuilding of the anticorrosive and antifouling systems) AHR can actually decrease in the interval between two drydockings.

Briefly the following advantages are associated with selfpolishing paints:

- Predictable performance
- Extended drydocking periods
- Control of roughness and smoothing
- No "sandwich coatings" problems
- Fouling control due to linear biocide release rate
- Lifetime directly proportional with dry film thickness (dft).

"Second generation" selfpolishing antifoulings

The original selfpolishing paints had solids in the region of 40 per cent, by volume, which allowed maxiumum dft's of about 100 microns per coat.

Developments in the organotin copolymer technology made possible the introduction of the "second generation" selfpolishing paints, the "high build" or "high solid" versions. Such paints have similar antifouling, polishing and smoothing properties to the low build versions, but higher solid content, of about 50 per cent, by volume, allowing maximum dft's of 150 microns per coat.

Consequently, high build selfpolishings offer the extra benefit of fewer coats for a given total dft. This leads to lower application costs, reduced drydocking time and longer drydocking intervals are possible.

"Third generation" selfpolishing antifoulings

Since their introduction in the early seventies, selfpolishing antifoulings have steadily increased their share of the market, at the expense of the old, long-life antifoulings.

Their main advantages, outlined above, were outweighed by the fact that they were more expensive and a higher investment was required from the start. The payback varied, although, generally is fairly short.

However, some owners did not, or were not, able to change to the new systems for various reasons, such as uncertainty in trading and up-front extra investments; reasons that are even more actual today.

The recent introduction[3] of a new high build selfpolishing paint, the first of a "third generation" of selfpolishing paints challenges this segment of the market. This paint has been developed to replace the old, long-life antifoulings at no extra investment.

To date, selfpolishing action of the paint could only be achieved if the content of the tributyltin (meth)acrylate monomer in the organotin copolymer was over 50 per cent by weight.

The new paint breaks this barrier, offering the capability of using organotin polymers with lower content of tributyltin (meth)acrylate.

The release rate of the organotin biocide is determined by the hydrolysis rate. However, polishing is greatly controlled by the number of free acid groups present on the backbone of the copolymer, after the organotin biocides have been released.

The more acid groups, the quicker the dissolution of the backbone in sea-water and therefore, the faster the polishing rate. The breakthrough was allowed by the use of a special monomer, which also hydrolyses, producing some of the extra acid groups required once the amount of tributyltin (meth)acrylate is lowered[4].

Such paints can be applied, in many circumstances, directly on conventional or long-life antifoulings, resulting in savings in drydocking time, application and material (sealer) cost savings.

Consequence of the new development

The appearance of the "third generation" selfpolishing antifoulings, with a raw material cost structure similar to long-life paints and minimal surface preparation required, indicates that the long-life antifoulings share of the market will diminish even further, given the extra advantages of the selfpolishing systems.

Conclusions

Selfpolishing paints are unique weapons in the constant fight against fouling and roughness. The key to further developments in the antifouling technology, as demonstrated so far and as in so many other fields, is innovation and the capability to implement it.

[Received 17 March 1985

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conference discussions

Discussion is encouraged at OCCA Conferences following the presentation of papers. Those who put the questions were asked to fill in discussion slips with the details of their questions. Edited versions of the discussions that followed the papers published in the **July 1985** issue appear below: questions in ordinary roman type, answers in italic. Only those questions for which discussion slips were received are published.

Keynote address

G. C. Fettis

G. W. FOWKES: Will the development of international groups lead to an increase or a reduction of UK technical input?

G. C. FETTIS: There may be some change but on the whole I believe UK technical input will remain on already established trends.

C. SCHOFF: Do you see a threat to the paint industry from non paint materials such as vinyl wall coverings, coloured plastics (rather than painted) etc?

G. C. FETTIS: Clearly there has been greater use of such materials in public buildings to reduce maintenance costs. I believe that paint can fight back with novel decorative effects.

R. J. WOODBRIDGE: Is not marketing innovation as important as technological development if the decorative paints sector is to compete with alternative finishing materials?

G. C. FETTIS: Both marketing and technical development are important, e.g. solid paint is presented in a new form of plastic package, the paint itself being a definite technical innovation.

D. S. NEWTON: Do you consider that the UK paint industry pays sufficient attention to "Targetting" in their long term strategy?

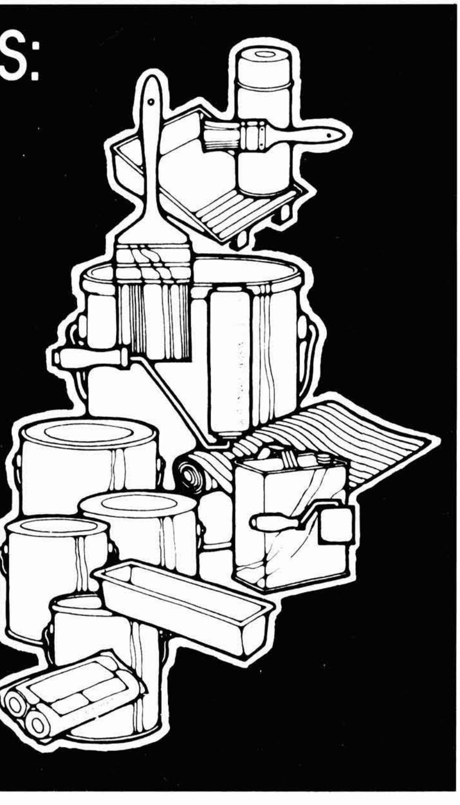
G. C. FETTIS: I believe there has been a lack of discipline in the past but targetting is becoming more the norm—witness the rationalisation currently taking place in UK paint companies.

Recent advances in vinylidene chloride copolymers for use in surface coatings

B. Elgood

D. SCANTLEBURY: In view of the obvious improvement in barrier properties of your system have you carried out any corrosion tests?

B. ELGOOD: Work at my company and others has indicated that fairly high VdC content copolymers can be formulated into good metal primers, presumably because of the good barrier properties of these copolymers. Corrosion tests show good resistance to flash rusting if properly formulated.



Metals and metal ions in pigmentary systems

W. E. Smith

P. J. MOLES: Can the resonance Raman technique be used to measure low levels of impurities/other materials on the surface or associated with pigments? What sort of levels are we talking about?

W. E. SMITH: Very small quantities can be detected at metal surfaces. It is claimed that signals from monolayers can be seen either directly or with a beam focussed through a microscope. These studies were on particularly suitable systems. The problem with pigments is self absorbtion of the incident and scattered light by the pigment and the absence of any known specific enhancement to supplement resonance. The work has not been done to answer your question directly but I would estimate that using our disc technique 5 per cent of a resonant material added to a pigment should be detected. With a colourless substrate levels down to ppm concentrations could be detected. With colloids, concentrations in solution of 10^{-10} *M have been seen.*

D. SCANTLEBURY: How do you know that the laser technique does not alter the corrosion mechanism that you are attempting to study?

W. E. SMITH: We do not know with any degree of certainty that the mechanism is unaffected. For insulators sample damage has always been a problem particularly with coloured materials. However, there are ways to aviod the problem. With electrodes coated with thin films of pigments such as copper phthalocyanine we have been unable to observes changes due to reasonable changes in incident beam or time of exposure but every system would require to be studied individually and it would be surprising if some systems were not affected.

occa meetings

Ontario Section

The composition of ink varnishes related to lithographic ink properties

The Ontario Section of the Oil and Colour Chemists' Association met on Wednesday, April 17 1985, at the Cambridge Motor Hotel, with approximately 45 members and guests in attendance. The Annual General Meeting with the election of officers for the forthcoming year was followed by the Technical Meeting.

Mr Kees van Esch of Synthese of Holland gave a highly detailed lecture entitled, "The composition of ink varnishes related to lithographic ink properties". In particular, extensive studies were described in which the effects of the viscosity of the alkyd resin and the solubility of the hard resin on properties such as tack, gloss, and waterbalance were studied.

Following a lively question and answer session, a vote of thanks was proposed by Mr Frans Grootveld, Vice Chairman.

Statistical Process Control

The Ontario Section of the Oil and Colour Chemists' Association met on Wednesday May 22 1985 at the Cambridge Motor Hotel, with a record turnout of 61 members and guests.

Mr Michael J. Slade, Technical Service Manager, Cabot Canada Ltd. (Sarnia) spoke on "Statistical Process Control (SPC)". He began by discussing quality, in its broadest sense, including not only SPC, but other aspects, such as vendors, statistical co-ordination, quality costs, training, customer demands and quality circles.

Mr Slade then went on to discuss, in some detail, the various SPC techniques, such as control charts, capability studies, designed experiments, task forces, system audits, parento analysis, and cause and effect study. SPC can be used for measurable processes, such as weights, dimensions, physical and chemical properties, calibration of test equipment, and values of control samples, etc.

Of the various elements required for a successful quality program, the speaker highlighted the commitment of top management, which is required to bear initial costs, such as training, and to ensure that short-term goals are compatible with long-term objectives. Other elements, as well as the many benefits to be obtained, were also described.

After a question and answer period, a vote of thanks was proposed by the new Chairman, Mr Robert Purnell.

P. Marr

Natal Section

Stress in industry

A meeting of the Natal Section was held at the Westville

Hotel on Tuesday, 14 May 1985. A lecture entitled "Stress in industry" was given by Dr J. Johnston of AECI Ltd.

The speaker outlined the provisions of the Machinery and Occupational Safety Act of the 5 October 1984 which replaced the Factory Machineries Act. This new act was promulgated as a result of the 1975/6 Erasmus Commission into occupational health which established that the provisions of the old act were totally inadequate in this regard.

Occupational hygiene is stated as being the recognition, evaluation and control of stress in the work place. The factors creating stress can be enviromental, e.g. exposure to excessive noise, vibration, temperature, radiation or specifically in the Paint and Chemical Industry the effects of inhalation of aerosol vapours, gases from volatile substances and skin absorption from certain raw materials.

As a result of a better understanding of the relationship between man and machinery, many stress problems caused by posture, boredom and repetitive movement can be overcome.

In one specific instance it has been found that the majority of respiratory equipment supplied in South Africa is designed to fit a Caucasian face and therefore is ill fitting and uncomfortable for the indigenous labour force.

Dr. Johnston detailed the various social causes of stress, unemployment being a major factor. Also psychological changes can occur e.g. depression, change in behaviour, heavier smoking or drinking and the onset of a physical affliction which will result in the reduction of worker performance.

Many employees suffer from multi stresses and these are more prevalent in the competitive and impatient Type A personality than the more serene Type B personality.

During a long and searching question time Dr Johnston emphasised that one should always adopt a pragmatic approach in these matters and many workers adapt to industrial enviroments without any visible physical or mental stress but at least the provisions of the MOS Act, with the stipulation of a safety representative for every 50 persons employed, will go a long way to improving the working enviroment in RSA.

A vote of thanks was given by Mr K. Engelbert who also thanked AECI Paints Natal (Pty) Limited for sponsoring the snacks.

R. H. Philbrick

letters

Mass or volume?

Sir – Paint, as is well known, is being marketed and sold by volume. Paint is also being applied by volume, by virtue of being spread over a specific surface area to a corresponding thickness (height).

It can therefore be expected that all basic paint formula parameters will also be expressed on a volume basis.

Unfortunately this is not the case. Most scientific papers and starting formulations of raw material suppliers abound with rather illogical and meaningless constants such as pigment/binder ratio, percentage pigment by mass and mass solids.

In our laboratories all paint development work has been successfully carried out on a volume basis for years and we therefore consider a paint formulation to have only the following three basic parameters:

PVC: total pigment volume concentration, which includes extender pigments.

PC: pigment concentration, i.e. the percentage pigment on solids by volume, excluding extender pigments.

Volume Solids: percentage solids by volume.

We suggest that these three formula parameters will far better define a paint formulation, than hitherto has been the case.

It is also our contention that many volume aspects of paint formulations have not, as yet, been fully explored such as pc and pvc levels in anti corrosive primers related to corrosion protection.

A final point is that substitutions and adjustments on a volume basis are not only easier but more effective.

General Chemical Corporation Ltd, *J Anneveldt*
P.O. Box 3389,
Johannesburg, 2000,
South Africa *2 July 1985*

news

BP Chemicals to close Cumene and Phenol plants

BP Chemicals is to close down its cumene and phenol plants at Grangemouth, Scotland. Production will cease in November and result in the loss of about 150 jobs.

In spite of capital investment to improve the efficiency of the production units, intensive sales efforts, and some improvement in market conditions, the small scale of the plant has prevented the business from becoming profitable. Losses of around £25m since 1980 make it imperative that these relatively old and inefficient units be closed to avoid the continuing serious drain on company resources.

The company is making long term arrangements to secure product for its customers.

Reader Enquiry Service No. 30

New UK agents for Sachtolen

Mercury Plastics Ltd. have been appointed as UK agents for Sachtolen^R special extender and reinforcing filler masterbatches. Sachtolen masterbatches, produced in West Germany, are the latest product development specifically for the plastics industry by Sachtleben Chemie GmbH who have over 100 years of experience in the manufacture of white pigments and extenders.

They are the result of the application of Sachtleben's experience to the latest processing techniques and though aimed principally at the polypropylene processor will also be of interest to users of engineering thermoplastics.

Amongst the benefits claimed for the extender masterbatches are: reduced processing temperatures through improved heat transfer; increased heat distortion temperatures; reduced cycle times for thick section mouldings; improved flow characteristics; less in-mould distortion; higher stiffness; easy to colour even in bright shades; excellent surface finish and radio-opacity.

Sachtolen reinforcing filler masterbatches are said to offer the user of conventional filled polypropylenes: Reduced storage costs; Increased product flexibility; Reduced material costs, especially at low filler loadings; and ideal filler dispersion.

As the Sachtolen products are compatible with Mercury's own range of Universal pigment masterbatches, together they are said to provide the polypropylene processor with a complete package.

Reader Enquiry Service No. 31

Handguns for India, but not for the army!

Ransburg UK Ltd. has recently shipped a total of thirty-five electrostatic paint spray handguns to its Indian agent, Thermax Private Ltd. of Puna, to meet outstanding orders throughout the sub-continent.

The guns—REH (airless) and REA-III (air assisted) models—will be used in a variety of applications including textile machinery, car bodies, and motor cycles.

The keynote of the REA-III is said to be its versatility. For use with both solvent or water-based paints, it permits above average transfer efficiency and provides notably superior wrap-round.

The REH combines the advantages of conventional airless spray with its high delivery at low velocity and the added efficiency of electrostatic. Designed to apply most kinds of coatings, lacquers, enamels, etc., the REH it is claimed will accommodate paints of higher viscosities giving a more uniform finish in a shorter space of time.

Both guns share Ransburg's customary technical excellence and robust construction.

Thermax is Ransburg's sole agent in

India, providing comprehensive sales and service facilities through a chain of regional offices and depots.

Reader Enquiry Service No. 32

Special finish based on Bayer resins for flats refurbishment

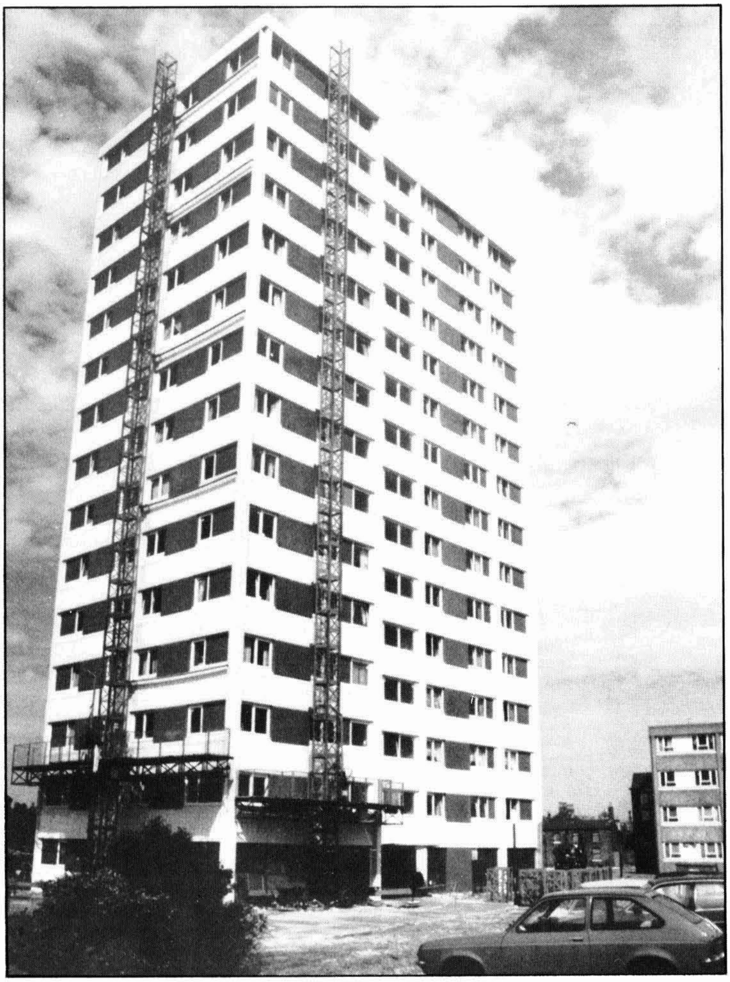
Close co-operation between materials supplier, specialist coating formulator and contractor has provided a bright new finish to seven blocks of high rise flats in Sefton on Merseyside.

At a cost of over £1.5 million, the flats have been extensively refurbished externally, with some internal work, by Fleet (Liverpool) Ltd., the main contractors for Sefton Borough Council.

The local authority specified aliphatic polyurethane finishes and sub-contracted the repair and refurbishment of external surfaces of the 15-storey blocks. Accrete Specialist Contracts Ltd. and its surface finish formulators Acorn Products Ltd., chose Bayer's Desmodur/Desmophen (DD) polyurethane resins as a basis for the coating.

Accrete managing director, John Winchcombe, forecasts that: "This two-pack aliphatic polyurethane coating will last up to ten years with minimum maintenance. It could well become the accepted standard for high rise block refurbishment over the next few years".

During their 20 or so year's life the precast reinforced sections of the flats had deteriorated visibly. Surface damage had occurred, believed caused by CO_2 penetration into the concrete causing carbonation. Accrete describes its remedial and finish work as "a combination of civil engineering and dentistry".



Flats in Sefton refurbished by Accrete using Bayer's Desmodur/Desmophen (DD) polyurethane resins as a basis for the coating.

Two coats of the two-tone mushroom/beaver coloured Bayer "DD" based coating were applied—in all over 35,000 sq.m.—to the seven blocks of flats at Sefton. This followed installation of replacement windows, cleaning, filling and finish by Accrete of all external concrete surfaces. To maximise the properties of the system, a third coat is recommended in most cases.

Conventional application techniques were used throughout for application of the two-pack coating. The first 'sealer' coat was applied by brush or roller: for the second coat, spray application was also used as needed.

Reader Enquiry Service No. 33

products

Stove enamelling temperature recorder

To produce good quality stove enamelling, it is necessary to ensure that the surface of objects being painted are at the correct temperature. The measurement of this temperature is of particular importance and should be taken as accurately as possible.

Specialists in this field, Grant Instruments Ltd, have for many years produced recording systems which pass through stoving ovens along with the objects for painting. The company has recently announced that it has developed a microprocessor based solid-state recording system for this purpose. Known as the Squirrel model 0Q2, this recorder fits conveniently inside the standard Grant vacuum container. It is claimed that it can store up to 2000 readings which allows recordings to be taken at five second intervals over a 40 minute run. Stored readings can be fed to any type of computer which accepts RS232C serial or

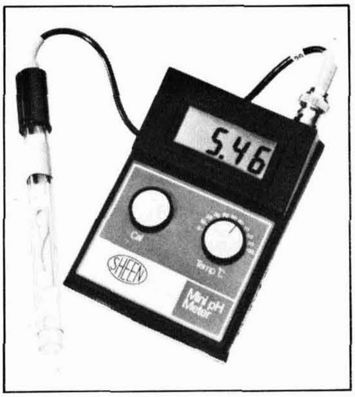
products

0Q2 Oven temperature recorder

8-bit parallel inputs. The 0Q2 is available for use with platinum resistance probes (PT100) or type K thermocouple probes. There are seven temperature ranges up to 300° (550°F) and up to four input channels, allowing air and surface temperatures to be taken at the same time.

In addition to recording, the Squirrel also has a digital display. This allows readings to be reviewed before transferring them to a computer for analysis; it can also be used as a hand-held digital thermometer.

Reader Enquiry Service No. 34



Mini pH meter

Mini portable pH meter

Now available from Sheen Instruments Ltd. is a light-weight (160 gms), battery operated, hand-held portable pH meter.

Known as the Mini pH meter, it displays results on a 13mm liquid crystal display, the figures being easy to read, even in direct sunlight. The low power consumption of the 3½ digit LCD is claimed to assure long life for the 9v PP3 type battery. A low battery warning light is fitted.

The mini pH meter covers the usual 0-14 pH range. Calibration accuracy is claimed to be +0.01 pH and temperature compensation is manual 0-90°C.

Accessories include a space combination electrode with removable protective end cap; a tough spear combination electrode; and a carrying case with foam inserts. Also provided are three 100ml bottles of buffer solution for pH 4, pH 7 and pH 10.

Reader Enquiry Service No. 35

Leyland looks to the future with Polycan

Looking to the future with its new Leyland 2000 acrylic paint system which protects exterior paintwork for up to 10 years, Leyland Paint is using Metal Box's all-plastics paint container "Polycan".

Metal Box is supplying 2.5 and 5 litre sizes for Leyland 2000, a two-paint system consisting of a special primer/undercoat followed by a microporous gloss top coat. The cans are dry off-set printed with a six colour design showing the four seasons through window panes.

Polycan is said to be suitable for all water-based paint and coating products. Leyland has also chosen the 2.5 and 5 litre versions for launching its new timber preservative "Fence Defence", which is harmless to plants and animals.

A single piece injection moulded container designed to run on existing high speed filling lines, it is made at the company's general packaging factory in Swindon, where a 1 litre size is to be added to the range shortly.

Moulded from co-polymer polypropylene, Polycan is claimed to offer a low-cost completely corrosion-free container in a sturdy dent-proof construction which incorporates an anti-static additive for protection against dust pick-up. The pack features a patented anti-slop device and a secure but easy to use snap-on lid. It provides a large surface area for promotional printing, using up to six colours dry off-set on the body and four on the lid.

A spokesman for Leyland said: "High technology products benefit from high technology packaging, and we believe that Polycan fits the bill in this respect.

Reader Enquiry Service No. 36

Leyland 2000 acrylic paint system in Metal Box's all plastic paints container Polycan.

meetings

The industrial application of surfactants

An International Symposium: The Industrial Applications of Surfactants", is to take place at the University of Salford; April 16-17, 1986. Organised by the Royal Society of Chemistry Industrial Division, the meeting hopes to promote an awareness of the many industrial uses of surface active agents outside the well known areas of household detergents and personal care products. These will include applications in agriculture, oil recovery and treatment, mineral processing, the paper and textile industries and in speciality industrial hygiene products. Details are available from: Dr D. R. Karsa, Lankro Chemicals Ltd., PO Box 1, Eccles, Manchester M30 0BH; Tel: 061-789-7300. Telex 667725 LANKRO G".

Pb86: Ninth international lead conference

The ninth international conference will be held in Goslar, West Germany, from 19-22 October 1986.

Pb86 will continue the successful series of triennial meetings which began in London in 1962. As on previous occasions there will be a comprehensive programme covering all aspects of lead—including technical developments and markets throughout the world.

To receive a detailed programme when issued, please contact the Lead Development Association, 34 Berkeley Square, London W1X 6AJ.

Process control viscometry seminar

Warren Spring Laboratory is to hold a one day seminar on Process Control Viscometry on 15 October 1985.

During the seminar a state of the art report will be introduced, "Process Control Viscometers: Current Applications and future needs". The objectives of the seminar are:

1. To inform users and potential users of the latest developments in these fields: commercial and home-made instruments, viscosity and viscoelasticity measurements, process control and microprocessor control, recommended procedures.
2. To exchange information between instrument manufacturers and users.
3. To discuss needs for future work.

Presentations will be made by representatives from existing and potential manufacturers of process control viscometers as well as users of commercial and home-made instruments.

For further information, please contact Miss P. Madhvi at Warren Spring Laboratory, Gunnels Wood Road, Stevenage, Herts SG1 2BX: Tel: Stevenage (0438) 313388, Ext. 335.

literature

New brochure and AV for chemicals industry from tanker company

Top tanker services company, Tankfreight, has introduced new full literature which introduces the company and its full range of services for the chemical industry.

A corporate folder incorporates special information leaflets which explain the company's range of bulk transportation services including contract hire and general haulage, and which introduce the ancillary services available from Tankfreight such as Tankfix (vehicle engineering and maintenance), Tankclean (tanker cleaning), Tankhire (vehicle hire) and Tankstore (product storage). Separate leaflets cover the key industrial sectors—chemicals, edibles, petroleum and gas.

The complete Tankfreight story is told in a new eleven-minute audio visual presentation which, like the literature, introduces the company, and its services to key industries.

Reader Enquiry Service No. 37

CSI's new catalogue

Custom Scientific Instruments, Inc. (US) have published a new catalogue covering their entire product line. This product line provides testing instrumentation to meet it is claimed all needs. For over 35 years CSI has been a manufacturer of standard and custom designed physical testing instruments. These instruments cover a broad range of materials durability testing such as abrasion, friction, stress, tensile, impact, flammability, and flow rate.

Reader Enquiry Service No. 38

people

The Leeds based operation of Diamond Shamrock UK will, in future, be headed-up **Mr Robert Moore,** who has recently been appointed Managing Director.

Mr Moore began his career as a Research Chemist at Vinyl Products Ltd (part of the Unilever Group). He was subsequently appointed Technical Service Manager promoting their emulsion polymers to the adhesives industry in the UK and Europe.

In 1977, Mr Moore joined Allied Colloids Ltd., in Bradford, as Technical Manager and subsequently became Divisional Manager with full responsibility for production and quality control.

He succeeds Mr R. Wolfenden, who was called back out of retirement by Diamond Shamrock Process Chemicals when they became independent of the parent company Diamond Shamrock UK Ltd., of Eccles, Manchester, in March 1984.

* * * * *

Dr David Montgomery, 42, has joined Berger Industrial Coatings as Operational Director. He has been with the Courtaulds Group for 13 years and was latterly Manufacturing Manager of the International Paints Plant at Silvertown in London. He has a Ph.D in research on synthetic fibres and a BSc in chemistry.

Dr Montgomery, reporting to Dr Ed Hough, Managing Director, will take over full responsibility for BIC operations including the new factory at Chadwell Heath.

* * * * *

BP Chemicals have appointed **Mr C. D. Prescott** business manager, Phenolic Foam and Speciality Coatings, Adhesives and Sealants (SCAS).

Mr Prescott, who was previously business manager, SCAS, has taken on the additional responsibility of phenolic foam as a result of the planned transfer of the Epok oil absorbing coatings and sealants business to Mebon, the speciality coatings manufacturer recently acquired by BP Chemicals. Mr Prescott will remain located at BP Chemicals' Barry Division in South Wales.

* * * * *

Robert v.d. Luft has been named to succeed W. Robert Clay as chairman of Du

news

people

Pont de Nemours International S.A. in Geneva, Switzerland, and as vice president—International Department for Europe, Middle East and Africa. Mr Clay will assume responsibility for Du Pont activities in Latin America and the Far East.

Mr Luft, 49, joined Du Pont in 1957 as a chemical engineer. After a number of research, production, marketing and finance assignments in various departments he was deputy chairman of Du Pont International and group director for Europe, Middle East and Africa from October 1978 to April 1982. He then returned to the parent company in the USA to become general manager, and later vice president, Information Systems Department.

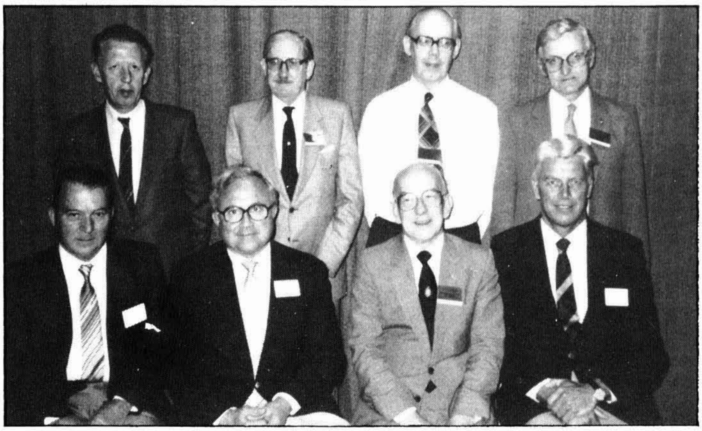
Mr Clay, 53, has been with Du Pont since 1954 and has held a number of research, manufacturing and marketing positions in the company's Textile Fibres Department in the United States and Europe, including a period in Geneva from early 1976 to December 1978. He returned to Du Pont International as chairman in January 1983.

people

Allied Colloids General Industries Division is expanding its sales force with the appointment of an additional Technical Sales Representative to cover the East Midlands and the North East of England. **Nigel Ambrose,** previously with Harlow Chemicals Marketing department has joined the company to take up this appointment. He is responsible to the Area Manager, Ray Sloan, operating out of Bradford.

occa news

International Liaison



Members of the International Coordinating Committee who held their annual meeting during the OCCA Conference in Edinburgh, Scotland, on June 27 1985. Standing (from left to right): Jacques Roire, Past-President of FATIPEC; Robert Hamblin, Director and Secretary of OCCA; Les Brooke, Hon. Secretary of OCCA; Frank Redman, President-Designate of OCCA. Seated: Amleto Poluzzi, Vice-President of FATIPEC; Joseph Bauer, President of FSCT; Cecil Finlay, President of OCCA; and Guttorm Abelsnes, President of SLF. ***The photograph was taken by Mr F Borrelle (Executive Vice President FSCT) who also attended the meeting.***

new members

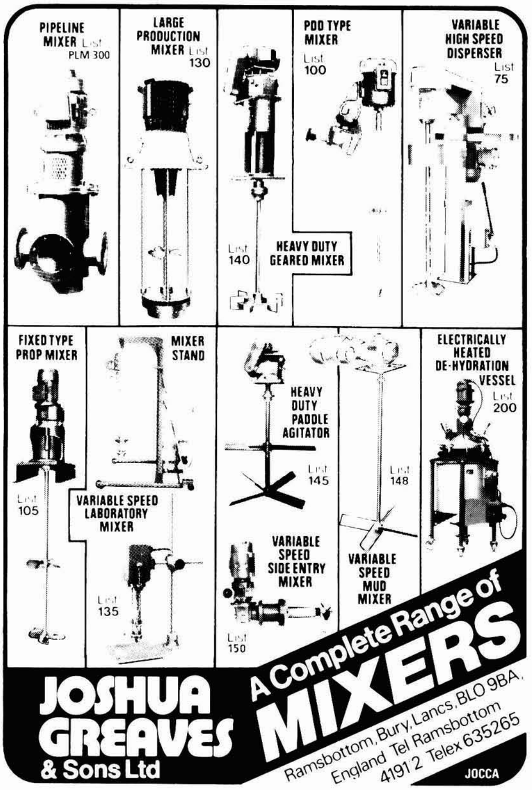
The sections to which new members are attached are shown in italics together with the country, where applicable.

Ordinary members

Anand, L. K., NZCS (Chem) *(Auckland)*.
Coxon, D. R., LRSC *(Newcastle)*.
Khatlawala, R. J., B.Sc. *(General Overseas—India)*.
Loye, B. A. *(London)*.
Moles, P. J., B.Sc., Ph.D., *(Manchester)*.
Styles, P. *(Cape)*.

Associate members

Bench, P. W. *(Auckland)*.
Grant, I. P. *(Cape)*.
Kavanagh, K. *(Cape)*.
Scott, I. M. *(Cape)*.



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CLASSIFIED ADVERTISEMENTS

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Foreign company wants experienced Chemist to advise on the manufacture of organic and inorganic pigments.
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