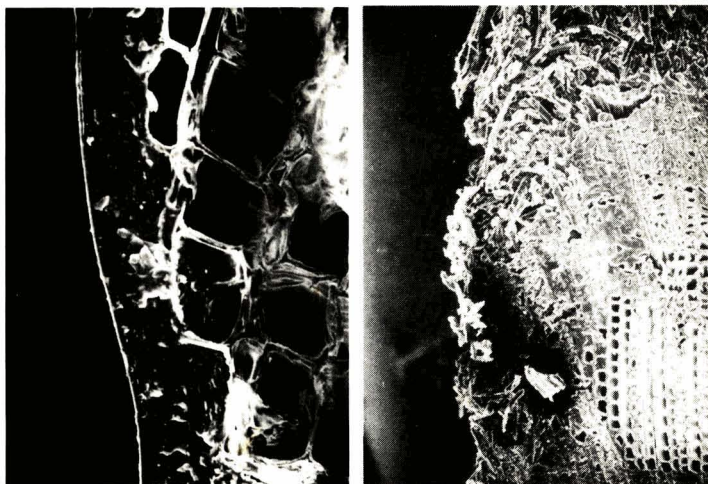


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Stain applied to unweathered (left) and weathered (right) spruce.

Wood protection – the interaction between substrate and product and the influence on durability

Quality control of coating application

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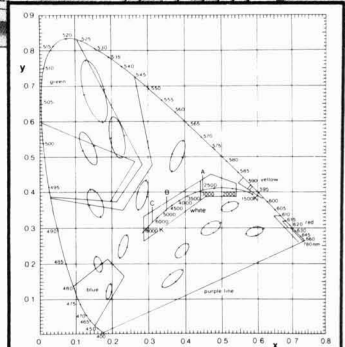
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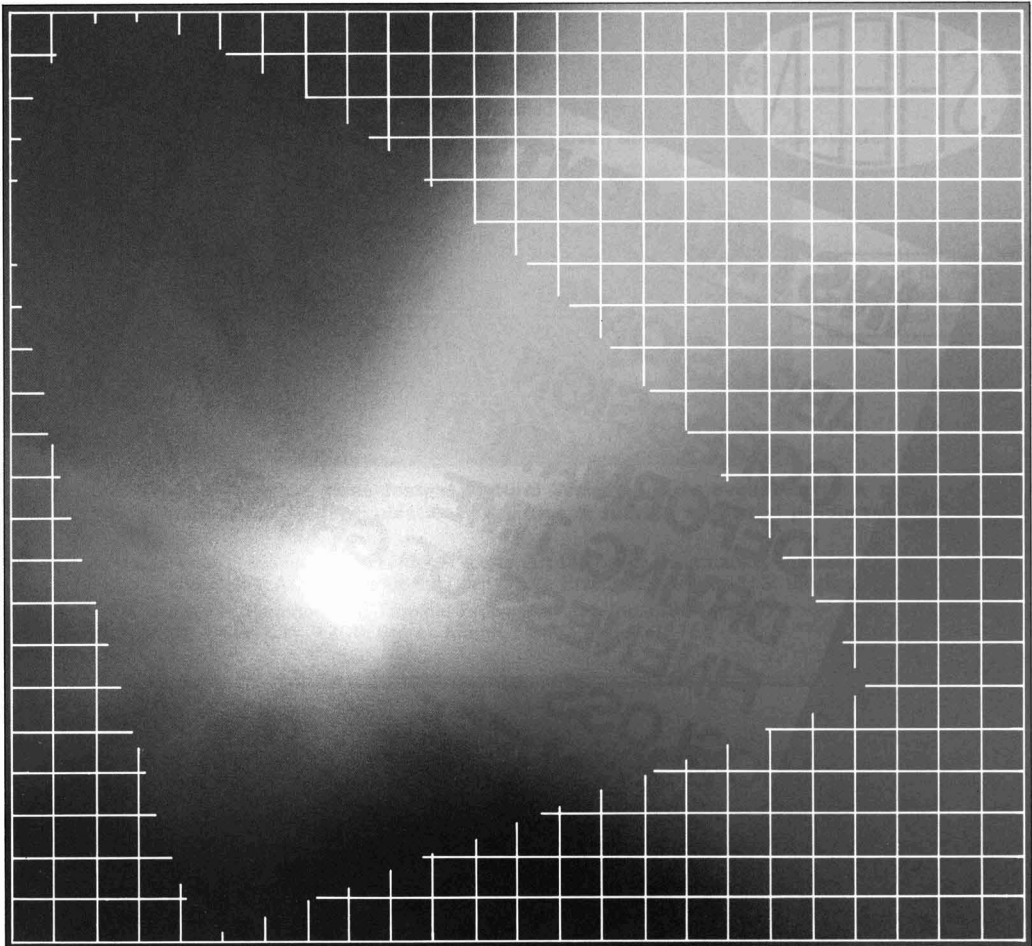
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Annual subscription to non-members:
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Single copies £5.00 (\$12), post free by
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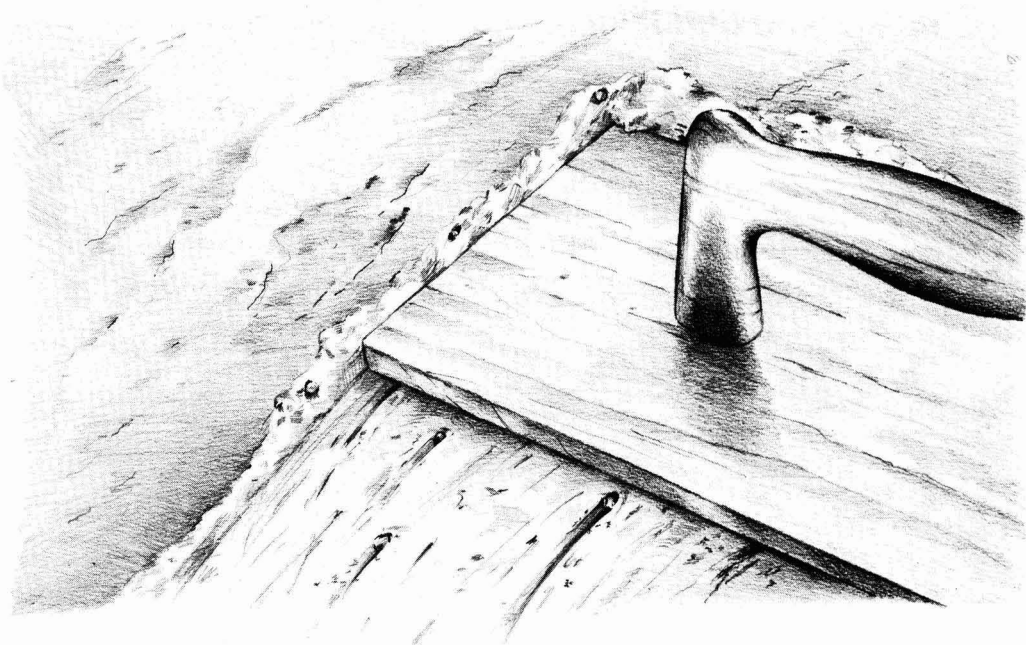
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Contents	Vol. 66 No. 11	November 1983
<i>Transactions and Communications</i>		
Quality control of coating application		327
	<i>D. A. Bayliss</i>	
Mechanistic model for corrosion protection via paint		329
	<i>F. L. Floyd, R. G. Groseclose and C. M. Frey</i>	
Acoustic emission – further unpublished results of the new technique for the study of paint performance during environmental exposure tests		341
	<i>T. A. Strivens and M. S. Bahr</i>	
Wood protection – the interaction between substrate and product and the influence on durability		345
	<i>Å. Underhaug, T. J. Lund and K. Kleive</i>	
Assessment of paints for the exterior bodysides of railway rolling stock (short communication)		351
	<i>D. M. Bishop and D. Bottomley</i>	
Conference discussion		352
<i>Next month's issue</i>		355
<i>Letters</i>		355
<i>OCCA meetings</i>		356
<i>News</i>		357
<i>Exhibition news</i>		360

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Priory House, 967 Harrow Road, Wembley, Middlesex, HA0 2SF England

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Quality control of coating application*

D. A. Bayliss

Steel Protection Advice Bureau, ITI House, 177 Hagden Lane, Watford, United Kingdom

Summary

Independent inspection is now widely used on important coating projects for structural steelwork and helps to avoid a considerable amount of abuse and corner cutting that can occur during coating application. Nevertheless failures can still occur and in this paper the following major points are considered.

1. How far do the duties of a painting inspector need to extend beyond mere quality control measurements?
2. What training and experience is needed for a painting inspector?
3. Are the methods of measurement and assessment used sufficiently accurate for the purpose?
4. Does the paint industry give the painting inspector adequate help and information?

Introduction

The paint industry of today can now make protective coatings to meet almost any requirement. Over the last 20 years in particular the advances in polymer technology have been revolutionary, but in some aspects the inspection and quality control of coating applications has not necessarily kept pace. This is important because although failures of protective coating systems on structural steelwork, for example, are only a small proportion of the vast areas covered, individually such failures can have a considerable adverse economic and nuisance value.

Causes of coating failures

There are many reasons why coatings fail prematurely or do not attain the level of performance anticipated. Some of the more common causes are discussed below.

Failures arising from surface preparation

Problems can arise in using steel with excessive surface defects such as laminations and shelling. Unfortunately these faults are generally not revealed until the surface has been blast cleaned. At this stage the painter is anxious to get the surface covered and is not interested in, or has not been paid for dealing with such defects.

As in the case of laminations and shelling, heavily pitted steel is also generally a sign that there is excessive contamination with soluble iron corrosion products. Under subsequent wet exposure conditions these could possibly cause premature breakdown of the paint system. Some countries in Europe, but not the UK, forbid the use of steel to Swedish Standard SIS 51900 rust grade D or worse.

Problems also arise by the contractor not employing the specified method of cleaning or using an adequate alternative. If the specification states that the surface preparation shall be to Sa 2½, this implies abrasive blast cleaning and that particular visual standard cannot be achieved by

other methods. Similarly, if abrasive cleaning is used then the abrasive particles must be neither too large nor too small for the purpose, since this will result in an incorrect blast profile. The blast profile might be, for example, too low for a very thick system or too high for a very thin system such as a blast primer.

The blast cleaning process in particular produces a great deal of dust and dirt. This is blown into the atmosphere and inevitably will collect onto the surfaces to be painted. Subsequent paint failures can occur because the paint is applied to layers of dirt, or sometimes even large accumulations of abrasive etc. There will always be some dust on the surface but there is no reliable standard field test of measuring the quantity. In any case the tolerable quantity will vary depending upon the type of paint to be applied, the method of application and the size and composition of the "dust".

Paint systems frequently fail first at areas of welds. This is due to some extent to contamination from weld fluxes etc., but mostly to the fact that the weld surface is too rough and too sharply angled to be adequately covered by the paint coating. In a majority of cases there is no adequate method of preparation other than blast cleaning. Since this is likely to be the most expensive method it will not be used unless specified in detail. Even if blast cleaning is used on welds there is also the danger of damaging surrounding paint systems which can go undetected until subsequent localised failure.

Too often steel structures used in construction are carefully coated with relatively expensive coating materials and then stored on site so inadequately that the life of the coating is seriously reduced, or alternatively such coatings are damaged by incorrect handling techniques.

Problems arising from the use of the paint materials

Paints with heavy pigments or those with two or three components will not reach their full potential unless mixed carefully. This is particularly important for modern industrial painting because of the very wide use of zinc silicate primers and two-pack epoxy top coats; materials that very definitely come into this category.

Obviously defects can also occur in applied paint films due to the excessive use of solvent or the use of the wrong solvent.

Some coating materials now widely used for industrial painting have a very limited shelf life. Such a life can be seriously affected by storage of the paint in, for example, high temperatures or wet conditions. Similarly, transport of paint materials by sea for long periods, as when they are exported from the UK to the Far East, can result in paints arriving at their destination in an inferior condition.

Two-pack materials such as epoxies and polyurethanes

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

have a pot life which is heavily dependent on temperature. Too often this is not taken into account by manufacturers' data sheets so that there is insufficient guidance to the user of the differences for example between temperate and tropical climates.

Application of paint by airless spray apparatus is at least eight times faster than brush application and requires greater skill and experience from the operator. The considerable advantages of solvent-less coatings has meant that the increased use of hot airless spray, with the need for heating and monitoring the two components and the rapid cure of the coating system, has added further complication to the application process. Skilled operators can produce an excellent, glass-like finish with such apparatus, unskilled operators can create havoc over large areas.

Paint inspection/instrumentation

All the above causes of failure can be detected and avoided without the use of instrumentation by the vigilance of a trained and experienced painting inspector. But even where instruments exist to assist in quality control it is necessary to exercise considerable care in the use of such instruments and in the interpretation of results. For example, wet film thickness measurements are useful for on the spot control of application methods, but only with materials that do not dry very rapidly or soften any preceeding coats, e.g. chlorinated rubber or vinyl paints, which are now being increasingly used for industrial applications.

If dry film thickness gauges are initially calibrated on flat steel and then used to measure paint coatings applied to blast cleaned steel, the measured film thickness will generally over estimate to the extent of 25-50 microns, which is that amount merely contributed by the roughness of the surface. Authorities and the instrument manufacturers disagree as to the best method of calibration. Some say that the instrument should be calibrated by the use of standard thickness shims on a flat steel surface, and then measurements taken from the blast cleaned surface to obtain an average factor which is then removed from subsequent results. Others say that the shims should be placed on a representative part of the blast cleaned surface and the instrument calibrated to read the shim measurement. The American Steel Structures Painting Council (SSPC) state that the first method should be used for pull-off type gauges and the second for electronic type instruments with probes. The two methods do not necessarily give identical results but actually there is a greater error introduced from the considerable variation in roughness across any blast cleaned surface. Dry film measurements must therefore be interpreted with a full understanding of their limitations, and not taken too literally.

Other sources of error with which an inexperienced painting inspector can cause considerable problems to the contractor occur with the use of film thickness gauges of the magnetic type.

For example, when measuring soft or tacky paint films; use of a magnetic probe contaminated with iron or steel detritus; measurement close to edges etc., causing variation in magnetic flux; or simply by overshooting of the reading on the dial gauge type of instrument.

Some modern paint systems are sensitive to high humidities during their application and curing period, and/or cannot be applied satisfactorily over surfaces with dew point condensation on them. In these cases it is

important to measure the relative humidity and surface and air temperatures. But these measurements must be made as close as possible to the surface to be painted since localised micro-climates can exist, particularly for example under such structures as bridges.

In order to avoid painting on top of moisture or contaminating newly applied paint films with condensation, it is generally accepted that the surface temperature should be at least 3°C greater than the dew point temperature of the surrounding air. The inspector should recognise that this is a safety factor rather than a rule to be applied rigidly since it is far more important to take into consideration the type of paint being used and also to note whether the trend is for rising or falling humidity. Measurement of surface temperature can also raise difficulties since the too rapid reading of thermometers before they are stabilised can introduce considerable error. Stick-on magnetic type dial gauges are cheap, foolproof and simple to use. However, they take so long to stabilise that they tend to be left on the surface and then are lost or painted over. The electronic digital type appears to give a more rapid and accurate reading but large errors can be introduced by faulty mechanism or incorrect adjustment; such apparatus also may not be acceptable for intrinsic safety areas. For the most effective and efficient use of painting time, weather trends and forecasts should be taken into consideration by the intelligent painting inspector so that the weather/ambient conditions can be anticipated.

One form of instrumentation, namely holiday or pinhole detection by the use of high voltage detectors, can actually, if incorrectly used, cause damage to the coating. It is essential therefore that the correct voltage related to the type of coating and thickness is used. Surface contamination or dampness can also give an apparent indication with such apparatus and questionable areas should always be re-tested.

Requirements for the painting inspector

The points mentioned above are just some of those which can occur during coating application. Inspection work can cover a number of different materials such as conventional paints, metal coatings, powder coatings and hot applied solvent-less epoxies. It is obvious that the inspector must be trained in the characteristics of all such materials. These can differ widely from one type to another. Unfortunately, for obvious reasons, the paint industry does not like to publicise any sensitivity or intolerance of their materials. This means that they are not always applied under optimum conditions. Very often the application and inspection criteria are inherited from drying oil type materials. Ideally paint manufacturers should issue inspector and quality control data sheets just as they generally issue application sheets for the painting contractor.

To carry out his job to advantage the inspector must also possess certain personal qualities. Communication is an essential part of his work, this particularly applies to communicating with the men at the work face. At the same time he must also communicate with the site engineer, express himself clearly when speaking and have the ability to write in straightforward and correct English for the essential production of records and reports.

Coating inspection is also very much more effective if the inspector himself is capable of using the coating or blast cleaning apparatus, and this should be included in his training.

Training and certification of painting inspectors

An untrained, inexperienced painting inspector can easily do more harm than good. It has been realised in recent years that a training and accreditation scheme for coating inspectors would be a valuable addition to the coating industry.

Over the last five years British Gas has operated a certification scheme for painting inspectors, but this has been mainly for British Gas work. The Institution of Corrosion Science & Technology operated an assessment scheme for one year and is currently operating a revised version of this. The National Association of Corrosion Engineers (NACE) of the USA have now started a combined training and certification programme over three separate one-week sessions. Session one covers a comprehensive basic understanding of the processes of

industrial coating. Session two focuses on common shop coating processes for steel and the required inspection techniques. Session three is for advanced coating inspectors and participants who have successfully completed sessions one and two and finally who should be knowledgeable regarding the inspection of virtually any shop or field coating project.

Conclusion

Science is rapidly encroaching on the coating application art in the form of technically advanced paint materials and more sophisticated application methods. Coating inspection techniques and procedures must also become more professional, and comprehensive training and certification schemes must be part of this progress.

[Received 14 January 1983]

Mechanistic model for corrosion protection via paint*

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Summary

A variety of theories have been advanced in the literature to explain the failure mechanism of organic coatings applied to steel substrates. These theories have typically sought to explain performance based on *single* film properties and have been relatively unsuccessful.

This paper presents a progress report on our attempt to predict the corrosion protection behaviour of coatings, based on the *combined* relationships among several film properties and salt spray results. The film properties studied were permeability to water and ions, stress-strain behaviour, wet and dry adhesion, and electrochemical behaviour of the steel substrate in the presence of the liquid paint and the dried film. Using multiple correlation techniques, a model was developed which produced a correlation of 0.95, which was significant at the 99 per cent level.

While the present work resulted in a model wherein barrier properties predominate, it is speculated that a more general model should contain electrochemical factors as well.

Introduction

The theories on the mechanism of corrosion control by coatings, as discussed in the literature, consist of the coating acting as a physical barrier, chemical inhibitor or electrical resistor. To be effective, allegedly a system must stop diffusion of oxygen, water or ions through the film to the metal/coating interface or else provide passivation of the metal at the interface.

Most of the literature on coatings concentrates on the permeation of oxygen, water and ions. Several different theories have emerged as to which of these processes is the controlling factor in corrosion. Early studies by Mayne^{1,5}, Bacon⁶ and Cherry⁷ concluded that while water and oxygen were essential to the corrosion process, they were not rate-determining as they could not be prevented from reaching the metal surface sufficiently well by an organic

coating. Rather, protection was due to the high electrical resistance of the coating which resulted from low permeability to ions. Guruviah⁸ and Bauman⁹ challenged Mayne's conclusions in their work on oxygen permeability. They found that while water permeability was always much higher than Mayne's calculated limit for corrosion, oxygen permeability was below this limit for several of their films. Further studies by Kresse¹⁰ disregarded oxygen and ion permeability and concluded that water diffusion was really the controlling factor. In an additional series of papers, Haagen and Funke^{11,12} concluded that contrary to Kresse, and in agreement with Guruviah and Bauman, oxygen permeability was the controlling factor. Water permeability was seen as the rate determining factor for the loss of adhesion, but not corrosion.

There are almost as many theories about the role of adhesion failure in corrosion as there are for the role of permeants. Although there is general agreement in the literature that adhesion is important, the degree of adhesion which a paint system must have to be effective is highly debated¹³. Gerhart and Parker¹⁴ found adhesion to be very important to corrosion performance, and Haagen and Funke¹² found that even if a paint was highly water permeable, it still gave good protection if its wet-state adhesion was good.

A recent paper by Funke¹⁵ reviewed the current state of corrosion testing and came up with a model to predict corrosion performance based on water permeability, oxygen permeability and adhesion on exposure to high humidity. Using this model he then made a rank order of the properties of seven different electrocoating systems versus salt spray ratings. No further work was carried out to cast the information into a mathematical form.

In earlier work¹⁶, the present authors carried out a multiple correlation study of latex maintenance paints. An

*Paper presented on behalf of FSCT at the Association's York Conference, 15-18 June 1983. An edited transcript of the discussion that followed this paper can be found on page 353.

equation was generated that correlated salt spray performance to several film properties:

$$\text{Salt spray} = 6.3 - 1.2 (\text{wet adhesion}) + 3.14 (\text{water vapour transmission}) - 0.01 (\text{work-at-break}).$$

The equation had a correlation coefficient of 0.993 and an F value of 80.6 (confidence greater than 99.9 per cent). In addition, a logarithmic correlation was found between work-at-break and ion conductivity. Work-at-break can be thought of as the energy required to fracture a material. As such, it is related to flaws and imperfections in the film, as is the ability of a film to pass water-borne ions. It is thus reasonable to expect the two properties to be somewhat correlated.

However, the model generated was of an unexpected form. It predicted that for latex paints containing an inhibitive pigment, corrosion performance improved as barrier-related properties declined. It was speculated that since "reactive" pigments function via their water-soluble components, they require a permeable system to generate their active species and allow their migration to the steel substrate.

The work in this paper represents an extension of this earlier multi-parameter model approach to water-borne and solvent-based primers and to the introduction of electrochemical measurements.

Materials

Twenty different paints were tested. Their properties are shown in Table 1. Fourteen of the sixteen latex paints contained the same latex. The all-acrylic (BA/MMA/MAA), modified acrylic (contains acrylonitrile) and styrene-acrylic (BA/S/MAA) are all commercially available lattices designed for maintenance coatings. Paint systems number 10, 19 and 20 are commercially available as maintenance coatings. The balance are experimental systems from other maintenance related research programmes in the authors' laboratories. Paints 6-10 were incorporated from the authors' earlier model study¹⁶ in order to assess the reproducibility of our results. The water-reducible paints consisted of a commercial resin (polyester A) and an in-house resin (polyester B). Two solvent-borne primers were also included. Primer number 19 is considered the "Cadillac" of the alkyd maintenance paints. Primer number 20 is a "Chevette".

Salt spray testing

All paints were tested on cold-rolled steel (CRS) panels. Four replicates were run for each paint. Exact details of panel preparation and salt spray rating calculations are given in the Appendix. Four latex paints were evaluated from the previous multiple correlation work¹⁶ to provide a measure of reproducibility versus replication.

The values obtained in the current work are similar to the values previously attained (Table 2). The differences can be reduced by normalizing the values using paint number 6 as a control in the following way:

$$(\text{rating} - \text{control}) + (\text{mean of control}) = \text{normalized value}$$

Only two of the latex paints had respectable salt spray performance: the acrylic latex with ZnO·ZnPO₃ + ZnPO₄, and with ZnO·ZnPO₃ + Zn molybdate. The Zn

Table 1
Composition of test paints

Paint No.	Resin type	Functional pigments
Latex paints		
1	acrylic	ZnO·ZnPO ₃ , mica
2	acrylic	ZnO·ZnPO ₃ , ZnPO ₄
4	acrylic	ZnO·ZnPO ₃ , Zn molybdate
5	acrylic	ZnO·ZnPO ₃ , ZnO
6	acrylic	ZnO·ZnPO ₃ , 20% PVC
7	acrylic	ZnO·ZnPO ₃ , 25% PVC
8	acrylic	ZnO·ZnPO ₃ , 30% PVC
9	acrylic	ZnO·ZnPO ₃ , 35% PVC
12	acrylic	Zinc phosphosilicate
13	acrylic	ZnO·ZnPO ₃ , organonitro salt
14	acrylic	ZnO·ZnPO ₃ , Zn molybdate
15	acrylic	ZnO·ZnPO ₃ , BaB ₂ O ₄
16	acrylic	ZnO·ZnPO ₃ , phosphate dispersant A
17	acrylic	ZnO·ZnPO ₃ , phosphate dispersant B
3	modified acrylic	ZnO·ZnPO ₃
10	styrene-acrylic	BaB ₂ O ₄ , mica
Water-borne paints		
11	polyester A	none
18	polyester B	BaB ₂ O ₄ , mica
Solvent-borne paints		
19	tall linseed alkyd	Zn molybdate
20	long oil alkyd	Zn molybdate, mica

Table 2
Summary of salt spray data

Paint No.	Salt spray rating		
	1 Week	2 Weeks*	3 Weeks*
Latex paints			
1	8.6	5.9	4.3
2	8.9	8.3	8.3
4	10.3	8.0	8.0
5	6.5	4.4	4.0
6	8.9	6.7 (6.3)	4.5 (5.4)
7	6.6	4.4 (8.4)	4.4 (4.4)
8	6.6	4.4 (4.3)	4.5 (5.4)
9	6.5	6.0 (5.7)	4.4 (3.1)
12	3.5	3.0	0.2
13	6.7	5.6	3.8
14	6.1	5.5	5.8
15	8.4	6.8	6.0
16	6.0	5.0	4.0
17	4.1	4.0	3.5
3	6.2	5.8	4.2
10	4.8	4.1 (2.2)	4.1 (1.6)
Water-borne paints			
11	11.0	8.9	8.9
18	10.7	8.5	8.0
Solvent-borne paints			
19	11.0	8.9	8.9
20	11.0	11.0	11.0

*Salt spray data in brackets are from previous work (reference 16).

Table 3
Summary of water vapour transmission

Paint No.	Permeance*		
	4 day dry	30 day dry	Change (%)
Latex paints			
1	3.11		
2	4.27		
4	4.37	3.24	26
5	4.08		
6	4.27 (4.44)		
7	3.82 (4.03)		
8	3.56 (3.75)		
9	3.20 (3.42)		
12	4.34		
13	3.95		
14	4.01		
15	4.21		
16	4.34		
17	4.21		
3	2.91	2.07	29
10	1.23 (1.14)	0.84	32
Water-borne paints			
11	0.84	0.65	23
18	0.71	0.71	0
Solvent-borne paints			
19	0.65	0.65	0
20	0.33	0.33	0

*Values in brackets are from previous work (reference 16). Numbers are grams per square meter per 24 hours normalized for the relative humidity gradient across the film.

phosphosilicate-pigmented acrylic latex system gave exceptionally poor salt spray performance.

The water-reducible formula containing polyester A had very good salt spray performance after three weeks, even though it contained no reactive pigment. Polyester B exhibited characteristically good salt spray performance as did the solvent-based coatings.

Moisture vapour transmission

The data on moisture vapour transmission are given in Table 3 (procedure is given in the Appendix). Data from the previous work¹⁶ are also included. The data obtained from moisture vapour transmission are usually quite reproducible, with less than 5 per cent standard deviation. As we can see from Table 3, the data obtained in this work are slightly lower than from the authors' earlier work¹⁶. All the paints made with all-acrylic latex have permeance values from ≈ 3 to 4.5, with the mica pigmentation yielding the lowest permeance. Paints made with the styrene-acrylic and modified acrylic lattices had lower permeance than any all-acrylic latex paint. The two water-reducibles had values comparable to the alkyd paints. The relationship for latex versus water-reducible versus solvent-borne can be seen more clearly in Figure 1.

Several paints were also run again after a 30 day dry time (Table 3), and the latex paints were found to have about a 30 per cent reduction in moisture vapour transmission. Polyester A also showed some improvement, but the solvent-based paints had the same moisture vapour transmission after 30 days dry that they had after 4 days dry.

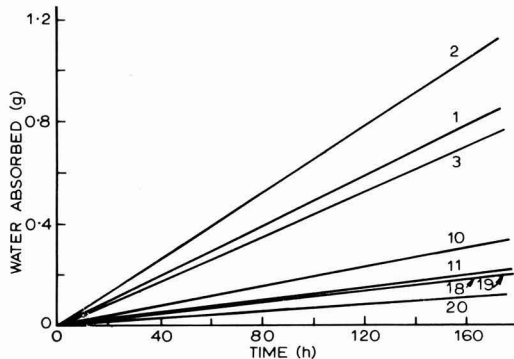


Figure 1. Comparison of moisture vapour transmission (all paints had 4 days dry)

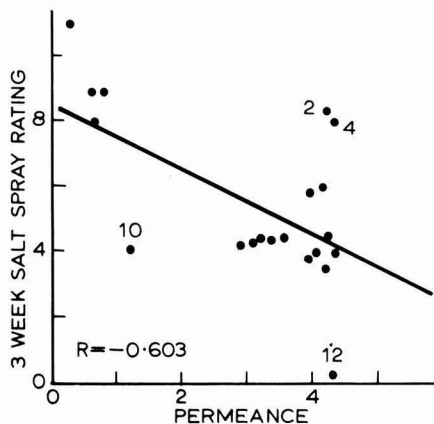


Figure 2. Salt spray rating versus permeance

A single-variable correlation was run between salt spray and permeance results to see if permeance could predict salt spray performance (Figure 2). The correlation coefficient was found to be -0.603 (99.6 per cent confidence level). Thus, the higher the moisture vapour transmission, the lower the salt spray performance. It can be seen that in a plot of salt spray rating versus permeance (Figure 2), a number of data points fall substantially away from the calculated line.

Wet and dry adhesion

The procedure for the 180° Instron peel test is given in the Appendix. The data seem to show no trend with vehicle type or pigmentation (Table 4). Plots of salt spray rating versus wet and dry adhesion are given in figures 3 and 4. Both plots look like scatter diagrams and have low correlation coefficients ($r = -0.01$ for dry adhesion, 0.376 for wet adhesion). Also, wet and dry adhesion are not correlated ($r = 0.103$), as has been consistently observed in the authors' laboratories over the years.

Ion conductivity

The data for the ion conductivity are expressed as the time, in minutes, it takes a coated panel to be penetrated by a 5 per cent NaCl solution (see the Appendix for details of method). Therefore, the greater the time to failure, the less permeable the coating is to ions. The data are found in Table 5. The paints employing the all-acrylic latex all failed in ≈ 150 to ≈ 220 minutes with the exception

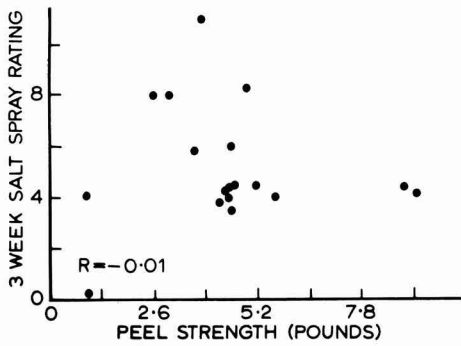


Figure 3. Salt spray rating versus dry adhesion (paint aged for 30 days)

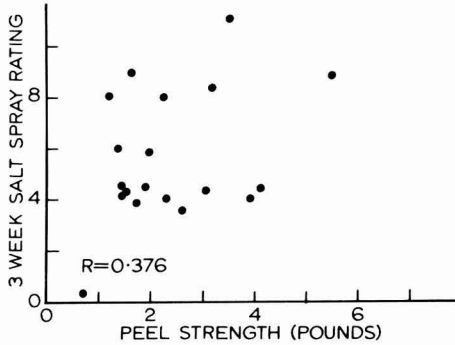


Figure 4. Salt spray rating versus wet adhesion (paints aged for 30 days)

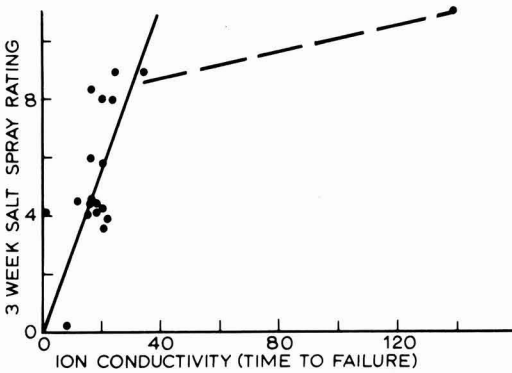


Figure 5. Salt spray rating versus ion conductivity

of a system pigmented with zinc phosphosilicate. The two water-reducible paints had failure times just slightly higher than the latex paints. The solvent-borne paints performed better than any of the water-borne coatings with paint number 20 nearly an order of magnitude better.

A plot of salt spray versus ion conductivity (Figure 5) suggests a non-linear relationship, although the data are skewed by the presence of paint number 20 at 1,400 minutes. A linear correlation of salt spray rating versus ion conductivity gave an r value of 0.612 (99.6 per cent confidence). A polynomial regression was run and it was found that the results are linear except for one point. By running the correlation without paint number 20 the r

Table 4
Summary of adhesion testing*
(paint aged one month)

Paint No.	Dry		Wet	
	Peel strength	Standard deviation	Peel strength	Standard deviation
Latex paints				
1	4.47	0.50	3.43	0.47
2	4.97	0.55	3.20	0.25
4	3.41	0.46	1.24	0.08
5	5.83	0.57	2.34	0.25
6	4.63	0.35	1.45	0.00
7	4.53	0.64	4.15	0.07
8	5.23	0.72	1.45	0.05
9	9.30	2.08	1.93	0.11
12	1.02	0.25	0.74	0.21
13	4.30	1.15	1.75	0.55
14	4.16	0.67	2.00	0.33
15	4.60	0.26	1.40	0.73
16	3.90	0.85	3.95	0.72
17	4.60	0.28	2.64	1.01
3	9.40	1.25	1.57	0.81
10	0.90	0.13	1.48	0.42
Water-borne paints				
11	brittle fracture		1.65	0.13
18	5.30	2.12	2.26	0.52
Solvent-borne paints				
19	brittle fracture		5.50	0.58
20	3.85	0.55	3.53	0.35

*Values are pounds for a one inch wide test area.

Table 5
Summary of ion conductivity

Paint No.	Time to failure (minutes)	Standard deviation (minutes)
Latex paints		
1	177.0	51.5
2	167.8	46.6
4	205.2	81.0
5	156.3	44.7
6	166.4	50.4
7	187.6	69.2
8	121.0	54.8
9	158.7	43.2
12	87.0	8.2
13	226.1	64.9
14	206.4	57.2
15	163.3	28.2
16	184.5	68.8
17	209.6	28.3
3	217.2	25.4
10	9.2	0.4
Water-borne paints		
11	245.5	24.6
18	238.0	37.4
Solvent-borne paints		
19	344.0	48.3
20	1388.5	449.3

Table 6
Summary of anodic polarization data of liquid paint

Paint No.	I_{corr}	E_{corr}	Current at $E_{corr} + 100$ mV
Latex paints			
1	96.5	-0.340	216
2	96.5	-0.313	197
4	248.1	-0.339	514
5	139.6	-0.325	338
6	274.1	-0.325	436
7	112.0	-0.330	326
8	155.1	-0.329	436
9	166.3	-0.306	360
12	365.4	-0.343	549
13	193.0	-0.328	406
14	140.5	-0.353	337
15	106.9	-0.355	360
16	250.8	-0.345	460
17	43.7	-0.358	406
Other lattices			
3	206.0	-0.308	474
10	255.1	-0.383	545
Water-borne paints			
11	156.8	-0.291	349
18	102.6	-0.356	321
Solvent-borne paints			
19	*	*	*
20	*	*	*

*Data could not be obtained from solvent paints because of low dielectric constant.

value dropped slightly to 0.59, indicating that the correlation is sound even with the one skewed point. This finding is consistent, then, with the barrier model of performance.

Electrochemical measurements – liquid paint¹⁷

In the authors' opinion, it was unrealistic to expect something as complex as salt spray resistance to be explained in terms of a single property or class of properties. The operating hypothesis of this work was that the electrochemical interaction between the paint and substrate should be important in any general model. This interaction could derive from the binder itself, added inhibitors or reactive pigments.

An assessment of this interaction was attempted using the P-350 Corrosion Meter of the Princeton Applied Research Company.

A single anodic polarization scan was run for each water-borne paint. The test substrate was polished CRS; further details are given in the Appendix. No scans could be run with solvent paints because the dielectric constant was too low preventing any current flow. All data are tabulated in Table 6. The most corrosive latex paint, based on current, was the zinc phosphosilicate system, which also looked the worst in salt spray testing. The paint containing potassium tripolyphosphate (KTPP) had the lowest I_{corr} but the current was similar to the rest of the paints after scanning at 100 mV. The water-reducible systems, which performed better in salt spray, had electrochemical data not very different from the latex paints.

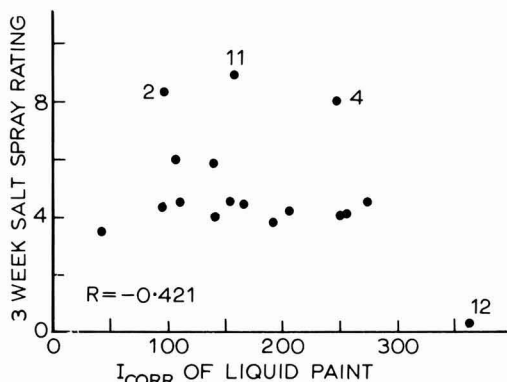


Figure 6. Salt spray rating versus I_{corr} (liquid paint)

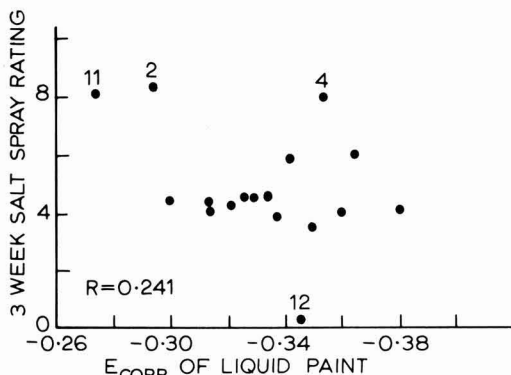


Figure 7. Salt spray rating versus E_{corr} (liquid paint)

Figures 6 and 7 contain plots of salt spray rating versus I_{corr} and E_{corr} . In neither case was there significant correlation between the salt spray rating and the electrochemical evaluation. A plot of salt spray rating versus current after scanning at +100 mV (Figure 8) also showed little correlation.

Variable	r value
I_{corr}	-0.421
E_{corr}	0.241
Current at $E_{corr} + 100$ mV	-0.446

The data for the linear polarization measurements are contained in Table 7 and Figure 9. The latex paints made with all-acrylic latex all had values from 0.03 to 0.04 mil (thousandth of an inch) per year (MPY) with the exception of zinc phosphosilicate at 0.074 MPY. The polyester A paint, containing no reactive pigment, had the highest MPY per year rating, suggesting the reactive pigment in the other paints is soluble enough to cause some passivation of the metal substrate. The correlation of MPY to salt spray rating was also low ($r = -0.088$, Figure 9).

Electrochemical measurements – coated panels

The resistance and E_{corr} values for coated panels of both water-borne and solvent paints are given in Table 8. Five

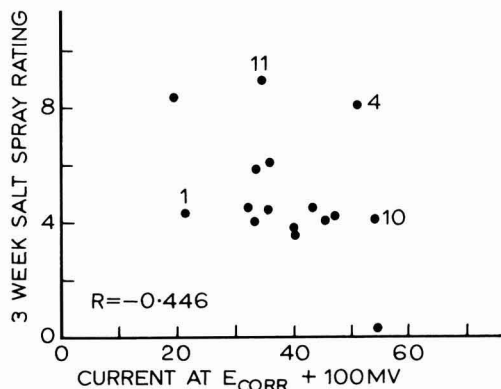


Figure 8. Salt spray rating versus current at $E_{corr} + 100$ mV (liquid paint)

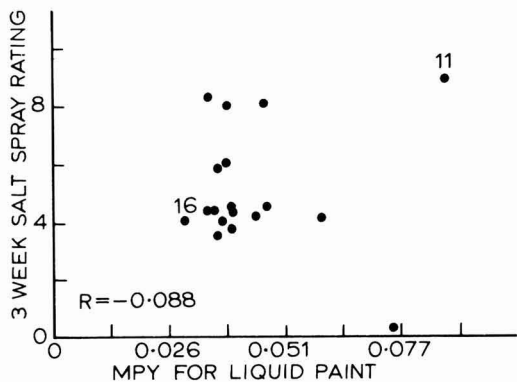


Figure 9. Salt spray rating versus mils (thousandths of an inch) per year (liquid paint)

measurements were made for each panel. Most of the latex paints had resistance values from 13 to 18 thousand ohms. The only two exceptions were the all-acrylic latex paint containing zinc phosphosilicate and the styrene-acrylic latex paint. Both had low resistance values as well as poor salt spray performance. The water-reducible paints had resistance values slightly lower than most of the latex systems. The solvent-borne paints had slightly higher resistance values than most of the other paints.

Most of the coated panels had E_{corr} s from 0.03 to ≈ 0.180 volt. Only four systems had negative E_{corr} s: both of the solvent-borne, a water-reducible and one of the poorly performing latex paints.

Plots of salt spray ratings versus E_{corr} and resistance measurements are given in figures 10 and 11 respectively. Neither variable alone appears to be a strong predictor of salt spray performance. For E_{corr} , $r = -0.092$, and for resistance, $r = 0.448$.

Multiple regression analysis

The BMDP, P9R multiple linear regression program¹⁸ was used to analyse the data. A regression program seeks a relationship between a dependent variable and one or more independent variables in the following format:

$$A = b + c(x) + d(y) + e(z)$$

Table 7
Summary of linear polarization data of liquid paint

Paint No.	Corrosion rate (mils per year)
Latex paints	
1	0.039
2	0.034
4	0.038
5	0.037
6	0.039
7	0.035
8	0.046
9	0.034
12	0.074
13	0.039
14	0.036
15	0.038
16	0.029
17	0.036
3	0.044
10	0.058
Water-borne paints	
11	0.085
18	0.029
Solvent-borne paints	
19	*
20	*

*Data could not be obtained from solvent paints because of low dielectric constant.

Table 8
Summary of coated panel data

Paint No.	Resistance (ohms)	E_{corr} (volts)
Latex paints		
1	15,780	0.138
2	15,537	0.149
4	13,215	0.062
5	15,902	0.143
6	18,787	0.138
7	16,952	0.154
8	16,782	0.166
9	15,332	0.159
12	2,233	-0.326
13	17,712	0.177
14	16,612	0.082
15	15,927	0.162
16	14,780	0.111
17	13,532	0.130
3	17,832	0.114
10	5.6	0.032
Water-borne paints		
11	13,042	0.264
18	13,026	-0.213
Solvent-borne paints		
19	18,466	-0.364
20	22,216	-0.053

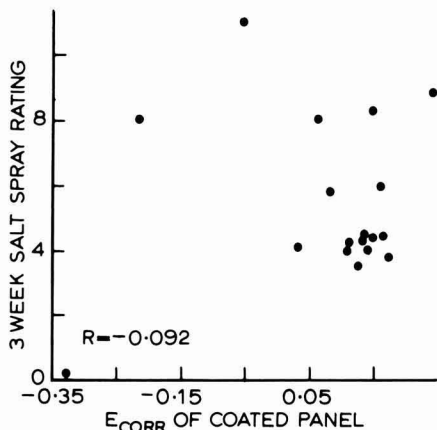


Figure 10. Salt spray rating versus E_{corr} (coated panel data)

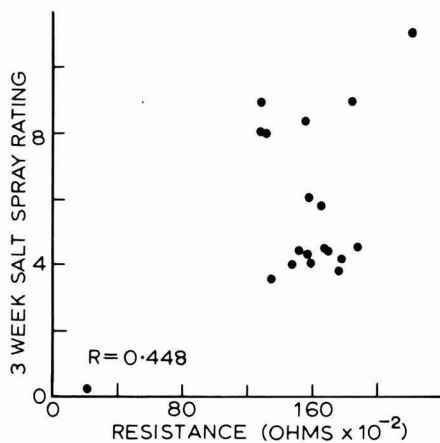


Figure 11. Salt spray rating versus resistance (coated panel data)

The program also prints out values for various statistical parameters. The three values of most interest to us are r (multiple correlation coefficient), F (an inverse measure of data scatter), and the degree of significance (probability that relationship is occurring by chance). In order to have a statistically significant fit, we would like r to exceed 0.60, F to be as large as possible, and degree of significance to be less than 5 per cent (or confidence to exceed 95 per cent).

While the values for R_p (resistance polarization) and $PRIC$ (I_{corr} from linear polarization) were used in the regression equation, they are not listed in the following tables because MPY is calculated from R_p and $PRIC$, so these variables are already considered.

Adhesion values were not obtained for two systems because the films were brittle and snapped before readings could be made. Liquid paint electrochemical measurements were not performed on the solvent-borne paints because of dielectric constant problems.

One variable

The single variable correlations are summarised in Table 9. A few variables provide significant, though incomplete,

correlations to salt spray ratings: ionic conductivity ($r = 0.612$, confidence: 99.6 per cent) and permeance ($r = -0.603$, confidence: 99.6 per cent). As mentioned earlier these results are consistent with a barrier model. This will be discussed more fully later.

A few of the variables also correlated to each other: 1. I_{corr} and current ($r = 0.779$), 2. E_{corr} and dry adhesion ($r = 0.718$), 3. film resistance and dry adhesion ($r = 0.664$). The first case is not surprising since both are measures of current flow under polarized conditions. The other two are not so obvious.

E_{corr} measures, among other things, the tendency of a metal to form an oxide layer in a given environment, which may or may not be protective (passive) in nature. Since dry adhesion is thought to involve polar as well as chemical forces, a higher E_{corr} is thought to provide a more compatible surface (oxide layer) for such forces. An alternate thought suggests that the functional groups on corrosion inhibitors and those used as adhesion promoters in polymer backbones function similarly on metal substrates, viz to attach to (and therefore passivate) the metal substrate. The authors prefer the former explanation since the latter should also apply to wet adhesion, which is clearly not the case here ($r = 0.1$). The correlation between film resistance and dry adhesion is also thought to be due to the same cause as described for case 2.

Two variables

The multiple correlation program was run to see if salt spray performance could be predicted by some combination of two variables. Of the 45 combinations tested, nine gave r values greater than 0.6. These are listed in Table 10. The best fits were:

+ ion conductivity, - permeance; $r = 0.706$ (99.7 per cent confidence)

- permeance, + resistance; $r = 0.757$ (99.9 per cent confidence)

Both relationships suggest the importance of barrier properties to good salt spray performance, whether it be suppression of water or ion migration.

Three variables

A correlation of salt spray performance with three variables was then run (Table 11). One hundred and twelve combinations resulted. Of these, 29 had r values greater than 0.6. However, these systems also had relatively low levels of significance. Those combinations with $r > 0.60$ are listed in Table 11. No three-variable parameter model had a better statistical fit than the models generated with two parameters. In looking further at the printouts, it was seen that in systems containing permeance and ion conductivity or resistance, the statistical fit with an additional parameter was poorer than with the corresponding two-parameter case.

Four or more variables

The computer was then allowed to generate the best fit to the data using four or more variables. Rather than listing all possible four-variable-or-more combinations, the ones with the most statistical relevance are listed in Table 12. Although the relationships listed have r values greater than 0.6, most of them are not statistically meaningful, and none of them improve upon the two-parameter model.

Table 9
Single variable correlations – all paints

	Salt spray rating	Ion conductivity	Wet adhesion	Dry adhesion	I _{corr}	Current at E _{corr} + 100mV	MPY (mils thousandths of an inch) per year)	E _{corr}	Coated panel resistance	E _{corr} coated	Water vapour permeance
Salt spray rating	1.000	0.612 (99.6)	0.376 (88.7)	-0.010 (28.6)	-0.421 (91.8)	-0.446 (93.6)	-0.088 (27.0)	0.241 (66.5)	0.448 (95.2)	-0.092 (30.0)	-0.603 (99.6)
Ion conductivity		1.000	0.345	0.495	0.443	-0.416	-0.267	0.432	0.485	-0.190	-0.493
Wet adhesion			1.000	0.103	-0.491	-0.576	-0.502	0.100	0.424	-0.239	-0.284
Dry adhesion				1.000	-0.383	-0.335	-0.509	0.718	0.664	0.429	-0.054
I _{corr}					1.000	0.779	0.424	-0.036	-0.486	-0.435	0.112
Current						1.000	0.349	-0.294	-0.521	-0.354	0.042
MPY (mils thousandths of an inch) per year)							1.000	0.204	-0.567	-0.150	-0.394
E _{corr}								1.000	0.502	0.445	0.011
Coated panel resistance									1.000	0.275	0.009
E _{corr} coated										1.000	0.396
Water vapour permeance											1.000

Values in brackets below correlation coefficients are confidence values (chance in per cent that value is *not* random accident) for given correlation.

Table 10
Multiple correlations, all paints.
Salt spray rating = dependent variable. Two variables

Ion conductivity	Dry adhesion	Wet adhesion	Water vapour permeance	I _{corr}	E _{corr}	Current at E _{corr} + 100mV	MPY	Coated panel resistance	E coated	r	Confidence
+X	+X									0.663	0.9987
+X		+X								0.635	0.9875
+X			-X							0.706	0.9971
+X								+X		0.636	0.9877
+X									+X	0.613	0.9817
	-X						-X			0.654	0.9802
		+X	-X							0.640	0.9886
			-X					+X		0.757	0.9993
			+X						+X	0.628	0.9860

Character X denotes pairings of variables. Sign in front of character denotes sign of coefficient in regression equation.

Optimisation

The best predictor of salt spray performance was a two-variable equation with water vapour and ion barrier properties. Further analysis was carried out to see if some of the 20 paints could be deleted as statistical outliers and thus generate a better fit. From the computer analysis (Cook's distances) it was suggested that the deletion of latex paints 2, 4, and 15 would give a much better fit with an r value of 0.952 and a confidence of >99.9 per cent. The results are given in Table 13. Figure 12 contains a plot of actual salt spray values versus predicted salt spray values. The predictive equation is:

$$\text{Salt spray rating} = 6.01 - 1.41 (\text{permeance}) + 2 \times 10^{-4} (\text{ohms})$$

This result suggests that the barrier properties of the paint film control salt spray performance.

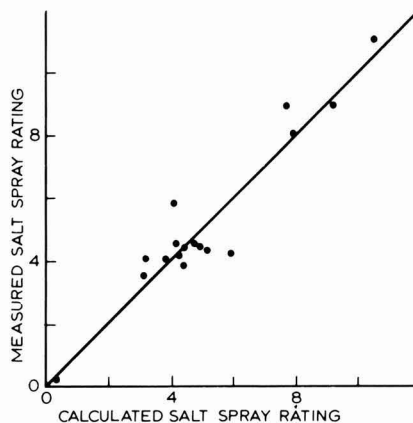


Figure 12. "Best fit" subset correlation

Table 11
Multiple correlation, all paints.
Salt spray rating = dependent variable. Three variables

Ion conductivity	Dry adhesion	Wet adhesion	Water vapour permeance	I _{corr}	E _{corr}	Current at E _{corr} + 100mV	MPY	Coated panel resistance	E _{corr} coated	r	Confidence
+X	+X	+X								0.666	0.9630
+X	+X		-X							0.679	0.9699
-X	-X						-X			0.656	0.9447
+X	-X							+X		0.681	0.9709
+X	+X								+X	0.671	0.9662
<hr/>											
+X		+X	-X							0.716	0.9982
+X		-X					-X			0.600	0.9090
+X		+X						+X		0.646	0.9697
+X		+X							+X	0.638	0.9647
<hr/>											
+X			+X	+X						0.642	0.9469
+X			-X		-X					0.615	0.9244
+X			-X				-X			0.664	0.9619
+X			-X					-X		0.625	0.9340
+X			-X					+X		0.768	0.9979
+X			-X						+X	0.724	0.9933
<hr/>											
	-X	-X						-X		0.734	0.9849
	-X		-X					-X		0.696	0.9697
	-X		-X					+X		0.736	0.9898
	-X				-X			-X		0.657	0.9456
	-X					-X		-X		0.655	0.9437
	-X						-X	-X		0.661	0.9481
	-X							-X	-X	0.670	0.9544
	-X							-X	-X	0.671	0.9551
<hr/>											
		-X	-X					-X		0.757	0.9971
		+X	+X						+X	0.668	0.9790
			-X	-X				+X		0.604	0.9135
			-X					+X		0.622	0.9307
			-X						+X	0.613	0.9222
			-X					+X	+X	0.757	0.9972

Character X denotes combination of variables. Sign in front of character denotes sign of coefficient in regression equation.

Unfortunately, while this is a statistically acceptable procedure, it deletes latex paints which perform much better than the model predicts. We therefore conclude that this model is not a general one, although it is highly informative. The results also suggest that we do not have an adequate measure of the electrochemical component, which may account for the outliers.

Comparison with earlier work

Since the results of this work are in direct conflict with our earlier results¹⁶, we re-examined the earlier data in order to reconcile this difference.

The model in reference 16 was limited to latex paints containing reactive pigments, since the others performed so poorly. The resulting equation,

$$\text{Salt spray rating} = 6.3 - 1.22 (\text{wet adhesion}) + 3.14 (\text{permeability}) - 0.001 (\text{work-at-break})$$

had a correlation coefficient of 0.993 (99.8 per cent confidence level) and suggested an inverse relationship between barrier properties and salt spray performance.

However, when all systems were included, ionic conductivity became the dominant factor in salt spray perfor-

mance, indicating barrier properties are indeed controlling. The resulting equation is:

$$\text{Salt spray rating} = 1.139 + 0.065 (\text{ionic conductivity})$$

Which yields a correlation coefficient of 0.815 (99.8 per cent confidence). In this case, additional parameters did not improve the correlation.

By combining the data from this work and reference 16 (via the normalization procedure described in the section "Salt spray testing"), ionic conductivity is again seen to be the controlling factor in salt spray performance:

$$\text{Salt spray rating} = 0.551 + 0.0295 (\text{ionic conductivity})$$

This yields a correlation coefficient of 0.898, with a confidence of >99.9 per cent. However, the best (paint number 20) and worst (paint number 12, reference 16) were omitted to achieve this fit. As in the previous case, additional variables did not contribute to the correlation.

To further test the validity of the multi-parameter approach, regression analysis was also applied to Funke's data from reference 15. Since the raw data were not available, the rank orderings for water and oxygen permeabilities, cross-over time (COT) (a measure of wet adhesion), and salt spray ratings were employed.

Table 12
Multiple correlation, all paints.
Salt spray rating = dependent variable. Four or more variables

Ion conductivity	Dry adhesion	Wet adhesion	Water vapour permeance	I _{corr}	E _{corr}	Current at E _{corr} +100mV	MPY	Coated panel resistance	E _{corr} coated	r
Correlation with 4 variables										
+X			-X					+X	+X	0.770
+X		+X	-X					+X		0.768
		+X	-X					-X	+X	0.758
+X		+X	-X						+X	0.738
+X		+X						+X	-X	0.647
+X		-X	-X			-X				0.685
+X			-X			-X			+X	0.684
+X			-X				+X		+X	0.671
+X			-X			-X	-X			0.666
+X			+X			+X		+X		0.665
+X			+X			+X				0.665
+X			+X	+X		+X				0.664
Correlation with 5 variables										
+X		+X	-X					+X	+X	0.770
+X		-X	-X			-X			+X	0.706
+X		-X	-X			-X	+X			0.698
		+X	+X			+X	+X		+X	0.697
+X		+X	+X			+X	+X			0.693
+X		+X	+X				+X		+X	0.691
Correlation with 6 variables										
+X		+X				+X	+X	+X	+X	0.739
+X		+X	+X			+X	+X		+X	0.732
+X		+X	+X			+X	+X		+X	0.718
+X		+X	+X			+X		+X	+X	0.716
Correlation with 7 variables										
+X		+X	+X			+X	+X	+X	+X	0.774
Correlation with 8 variables										
+X		+X	+X	+X		+X	+X	+X	+X	0.788
+X		+X	+X	+X	+X	+X	+X	+X	+X	0.777
Correlation with 9 variables										
+X		+X	+X	+X	+X	+X	+X	+X	+X	0.788
+X	+X	+X	+X	+X	+X	+X	+X	+X		0.773

Table 13
"Best fit" data

Statistics for "best" subset							
							0.90707
							0.95240
							0.89380
							0.711741
							0.843647
							68.33
							2.00
							14.00
							0.0000
Regression data for "best" subset							
Variable	Regression coefficient	Standard error	Std. coef.	T-stat.	2tail sig.	Tolerance	Contribution to r ²
Intercept	6.01427	0.714808	2.323	8.41	0.000		
Water vapour permeance	-1.40954	0.139882	-0.821	-10.08	0.000	0.999975	0.67396
Coated panel resistance	0.000225365	0.0000377085	0.487	5.98	0.000	0.999975	0.23708

Table 14
Single variable correlations for data
from reference 15

	Permeance		Ion conduc- tivity	Salt spray rating
	H ₂ O	O ₂		
H ₂ O	1.000			
O ₂	0.847	1.000		
COT	0.352	0.128	1.000	
Salt spray rating*	0.633 (87.3)	0.767 (95.6)	0.442 (67.9)	1.000

*Values in brackets are confidence limits for each correlation.

The single variable correlation coefficients are listed in Table 14. Oxygen and water permeabilities were highly correlated, a not surprising result. Salt spray performance is correlated to each. The "best fit" model is shown in Table 15, which yields a correlation coefficient of 0.951, with a 99 per cent confidence level.

$$\text{Salt spray rating} = -2.44 + 0.866 (\text{H}_2\text{O permeability}) + 0.745 (\text{COT})$$

This result implies: 1. that the multiple parameter approach to building descriptive models has merit, and 2. that barrier properties are the controlling parameters, which is consistent with the present work. The latter is not surprising if one recalls that Funke's data are from alkyd paints.

Proposed mechanism

To explain the apparently contradictory results in this and other work, the authors propose the following mechanism for the control of corrosion of steel substrates with coatings:

Paints deter corrosion of steel by either preventing the corrodants from reaching the substrate (barrier properties)

or by interfering with the corrosion reaction (electrochemical properties). Any given paint may function by either, or some combination of these mechanisms. To illustrate this, the following cases are offered:

Case 1. Impermeable films, reactive pigment or additives

Barrier properties dominate. Flaw sites are protected by electrochemical behaviour of reactive pigment or additive (any corrosion inhibitive species added to the paint). Examples: alkyds, epoxies.

Case 2. Impermeable films, no reactive pigments or additives

Barrier properties dominate. Corrosion proceeds from flaw sites, however. Examples: many chemical coatings (e.g. paint number 11).

Case 3. Permeable films, reactive pigments or additives

Electrochemical properties dominate. Barrier properties interfere with passivation reactions and hence detract from salt spray performance. Examples: latex paints in general.

Case 4. Permeable films, no reactive pigments or additives

Barrier properties again dominate, although absolute performance is extremely poor. Examples: paints 5-8 and 12 from reference 16. Few commercial examples due to poor performance.

General case

Two-parameter model containing appropriate measures of barrier and electrochemical behaviour of paint film. Highest performing system will be the one with high barrier properties plus electrochemical back-up for flaw-site protection.

The authors, therefore, suggest that the reason for disagreement among workers in this field may well be due to selecting different subsets to test their respective theories.

Table 15
Best fit for data from reference 15

Statistics for "best" subset							
		Squared multiple correlation		0.90480			
		Multiple correlation		0.95121			
		Adjusted squared mult. corr.		0.85719			
		Residual mean square		0.606928			
		Standard error of est.		0.779056			
		F-statistic		19.01			
		Numerator degrees of freedom		2.00			
		Denominator degrees of freedom		4.00			
		Significance (tail prob.)		0.0091			
Regression data for "best" subset							
Variable	Regression coefficient	Standard error	Std. coef.	T-stat.	2tail sig.	Tolerance	Contribution to R ²
Intercept	-2.44323	1.09405	-1.185	-2.23	0.089		
H ₂ O permeance	0.866288	0.158712	0.900	5.46	0.005	0.876158	0.70909
COT	0.744518	0.161679	0.759	4.60	0.010	0.876158	0.50471

The contribution to R² for each variable is the amount by which R² would be reduced if that variable were removed from the regression equation.

Conclusion

1. A multiple correlation program was used to generate an equation that predicted salt spray performance with a high degree of statistical significance:

$$\text{Salt spray} = 6.01 - 1.41 (\text{permeance}) + 2.20 \times 10^{-4} (\text{ohms});$$

$$r = 0.952, F = 68.33 (99+ \text{ per cent confidence})$$

2. All latex paints had relatively high moisture vapour transmission rates. The values for the water-reducible paints approached those of solvent coatings. The lowest permeability to water was displayed by premium alkyd primer.
3. The solvent paints had electrical resistance values only slightly higher than most of the latex systems. Most of the electrochemical measurements on liquid paint were fairly similar and did not predict salt spray performance.
4. The multiple correlation technique was successfully applied to earlier work, resulting in a barrier model for corrosion protection.
5. A two-parameter mechanism is proposed to describe the corrosion protection behaviour of coatings. Barrier properties are speculated to be the primary determinant, with electrochemical properties providing back-up protection in the case of highest performance.
6. No adequate characterisation of the electrochemical interaction between paint and substrate exists. This will be the subject of future work.

[Received 17 February 1983]

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Appendix 1, test methods

Sample preparation and conditioning

In all the testing listed below, the paints were drawdown over the appropriate substrate and allowed to dry at room temperature.

Salt spray testing

Duplicate drawdowns were made with a 6 mils (thousandths of an inch) Bird blade on 4" x 12" cold rolled steel panels that had been hand cleaned with MEK. Dry film thickness was 2.7-3.0 mils. After drying for 5 days, the backs and edges of the panels were primed with alkyd and an "x" was scribed on the front. Panels were placed in salt spray and rated after 2, 3, and 4 weeks. Blistering size and density was rated according to ASTM Method D-714-56. Rusting was rated on a scale from 10 to 0, where 10 = no rusting. The rust and blister ratings were combined to give an overall salt spray rating as follows:

Salt spray rating =

$$\frac{(\text{blister density} \times \text{rust rating}) + \text{blister size}}{10}$$

Blister density - ASTM rating: 10 = none, 0 = dense

Blister size - ASTM charts: The larger the number, the smaller the blister.

Typical error is ± 0.15 units for salt spray rating replication.

Ion conductivity

Six replicate paint panels were prepared in the same manner as for salt spray testing. They were then cut in half and the back and sides covered with electroplaters tape such that the same area of coated surface was exposed in each panel. Ion conductivity measurements involved putting a constant voltage (2V) across a coated panel immersed in 5 per cent NaCl solution and recording the current rise with time. A Heath Regulated LV Power Supply was used as the voltage source. The recorder was a Bausch and Lomb stripchart recorder set to read current (amps full scale). Data were reported as the amount of time it took for the current flow through the coated panels to rise to 25 mA.

Wet and dry adhesion testing

Cold-rolled steel (CRS) panels were cut to 3" x 9" and cleaned with MEK. A one inch strip was masked off over the length of the panel using masking tape. The test paint was poured between the masking tape strips, and a one and three quarter inch wide strip of cheesecloth (4 thicknesses) was pressed into the paint. The paint-cheesecloth composite was dried for 30 days and then tested by an 180° peel test on the Instron equipped with tension cell C. The crosshead speed was 0.5"/min. A force/deflection trace was obtained with the automatic pen recorder at a chart speed of 1"/min. Samples for wet adhesion were prepared in the same manner except for a four-hour soaking in deionized water prior to testing. All samples were run in triplicate. It was observed that samples which failed by a combination of adhesive and cohesive fracture exhibited the largest recorded force variances. Results were reported as pounds peel strength (1" wide sample).

Moisture vapour permeability

ASTM Test Method 96-66 was used. The test paint was applied to Champion AP-60# Lithol Paper and a three and a half inch circle cut out and placed in an Albert-Thwing cup containing dessicant. The paint film was sealed to the permeability cup with wax. The samples were kept at 23°C/50 per cent RH in an environmental chamber for seven days. Weight gain was measured every 24 hours. Weight gain in grams was plotted versus time in hours. The slope of the best fit straight line was

used to calculate water vapour transmission (WVT). Data were further converted to permeance.

$$\text{WVT} = \frac{(\text{slope}) (24)}{(\text{exposed area})} \text{ in } \frac{\text{g}}{\text{m}^2} \times 24 \text{ h}$$

$$\text{Permeance} = \frac{\text{WVT}}{S(R_1 - R_2)}$$

S = saturation v.p. (21.068 mm Hg)

R₁ = RH at source (0.5)

R₂ = RH at sink (0.00)

For the paint samples run in triplicate, the average deviation per paint was ± 0.15 for permeance.

Anodic polarization¹⁷

A 4" x 12" polished CRS panel was cut into five 2" test panels. A panel was boiled in xylene for five minutes, allowed to cool, placed in the electrochemical test cell with 100 ml of a 0.025 M sodium borate buffer solution and held at a potential -1.5 V below E_{corr} for 30 seconds. This electrochemical cleaning removes the oxide layer and yields a reproducible steel specimen.

The borate buffer was then discarded, the cell rinsed several times with deionized water, and 100 grams of the test solution added to the cell and an anodic polarization run. The steel sample was anodically polarized to 250 mV above E_{corr}. The scan rate was 0.1 mV/sec.

Linear polarization (mils per year)

The linear polarization mode on the corrosion meter allows the calculation of corrosion rate in mils per year (MPY) loss of metal substrate. This is the amount of corrosion one would get if a coupon (panel) of CRS were immersed in the sample for a year. In a linear polarization measurement, the current is measured ± 25 mV of the equilibrium potential (E_{corr}). Since we are making measurements on either side of E_{corr}, we are looking *both* at anodic and cathodic reactions. The corrosion rate is then calculated as follows:

$$\text{Corrosion rate (MPY)} = \frac{0.13 (I_{\text{corr}}) (\text{eq. wt.})}{d}$$

Where:

d = density of the corroding species in g/cm³ (7.9 for iron)

eq. wt = equivalent weight (27.92 for iron)

I_{corr} = corrosion current density

$$I_{\text{corr}} = \frac{\beta_a \beta_c}{2.3 (\beta_a + \beta_c)} / R_p$$

Where:

β_a = anodic Tafel constant

β_c = cathodic Tafel constant

both can be obtained from the anodic and cathodic curves. Tafel constants are typically 0.1 V/decade.

R_p (polarization resistance) = slope of the volt/current relationship ± 25 mV with respect to E_{corr}

For all systems in this report, we set anodic and cathodic Tafel slopes to 0.1 rather than carrying out lengthy evaluations to determine values for each system. Reproducibility was ± 10 per cent for corrosion rate.

Resistance measurements¹⁷

To obtain the resistance measurements, a coated panel is mounted in the corrosion cell. One hundred millilitres of 5 per cent sodium chloride is added and oxygenated for one hour. The Princeton 356 IR Compensation Module is then used to measure the uncompensated resistance of the film.

E_{corr} of coated panel¹⁷

The coated panel E_{corr} is obtained by mounting a coated panel in the corrosion cell. Five per cent sodium chloride is added to the cell and oxygenated for one hour. The PARS 350 is programmed to measure the specimen potential relative to a reference electrode. A specimen at E_{corr} has both anodic and cathodic currents present on its surface. However, these currents are exactly equal in magnitude so there is no net current to measure. Reproducibility was ± 21 per cent for I_{corr}, ± 8 per cent for E_{corr}, and ± 11 per cent for current.

Acoustic emission – further unpublished results of the new technique for the study of paint performance during environmental exposure tests*

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Introduction

Acoustic emission is a non-destructive technique, which has found considerable application in the past decade for detecting crack formation and propagation in the metal of engineering structures as diverse in nature as aircraft wings, high pressure vessels, North Sea oil rigs etc.

The principle of the technique is simple: any sudden

movement within a material results in the release of acoustic and thermal energy. The resultant acoustic waves propagate through the material in all directions from the source and may be detected by sensitive detectors on the material surface as mechanical oscillations. In certain cases, e.g. ice on a pond or wood of a stair tread creaking under a person's weight, they are in the right frequency and intensity (amplitude) range to be audible by the human ear. Such sudden movements and energy releases

*Paper presented at the Association's York Conference, 15-18 June 1983. An edited transcript of the discussion that followed this paper can be found on page 32.

may originate from crack initiation and propagation when the material is mechanically stressed, but they may also originate from phase separation or phase change¹.

For about six years, ICI (Paints Division) PLC, both by its own research work as well as sponsored work at Imperial College, London, has been pioneering the application of the technique to the study of paint performance during environmental exposure tests².

The techniques of acoustic emission

The equipment required for acoustic emission work can be very simple: a detector (usually based on some form of piezoelectric device), an amplifier and some form of signal analyser and recorder. In the case of paint samples, the paint on its substrate is placed in a tensile tester (after environmental exposure tests if required) and the detector is attached to the paint surface by a spring clip. Suitable acoustic coupling between the detector surface and the paint surface is provided by a thin layer of silicone grease. The specimen is then stretched at a constant low speed (usually 1.25 mm/min.) and the acoustic noise generated is analysed and recorded. In the case of paints such as car body paints, which are normally applied to sheet metal, the normal substrate is used, but, in the case of decorative paints, an artificial substrate of aluminium foil is used, as this material has low noise output and is more reproducible and less noisy than wood, plaster etc.

In principle, it is possible to analyse signal shape, frequency, amplitude and decay rate and, from this analysis, derive information about the acoustic source. In practice, the signal shape is modified by the propagation processes within the material (interfaces, inhomogeneities etc.) as well as the characteristics of the detector itself (most of these are narrow band resonant devices). Apart from this, many signals arise during the tensile test which originate from different sources or similar sources simultaneously or with small temporal separation. For these reasons the output signals from the detectors are very complex in form, and signal analysis involves some form of statistical analysis. In a paper of this length it is not possible to detail all the possible methods for doing this, but the review by Evans and Linzer¹ gives a detailed discussion of analysis methods as well as the physics of acoustic emission processes.

The simplest method of analysis is illustrated in Figure 1. If the amplified signal output from the detector arising from a single acoustic emission event is idealised as a decaying sinusoid as shown, then the simplest technique, known as ring-down counting, is to count the number of times the amplified voltage rises above a pre-set voltage threshold. Thus, in the example shown, a ring-down count of three would be registered. A variation of this, known as event counting, involves a pre-set delay time, chosen by the experimenter, between the registration of one count and the next one. This is most useful when there is a rapid

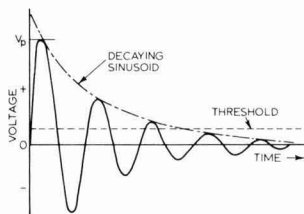


Figure 1.

sequence of events with a low percentage of significant signal overlap.

In the work at ICI, paint/substrate samples are stretched in a tensile tester and plots of cumulative ring-down or event counts against apparent total strain are recorded. Tests are done at room temperature (20°C) and the samples may be compared under "dry" or "wet" conditions (seven days either in a desiccator or exposed to 100 per cent humidity conditions respectively). Also, in the case of a multi-layer coating system, the individual layers, as well as the complete coating system, would be tested in order to help locate the source of acoustic emission in the system.

Most of the work has been concerned with the study of decorative coatings during accelerated weathering and the evaluation of the effects of formulation variables on performance. However, studies of painted metal in corrosive environments have also been initiated.

Results

All the results to be presented have been obtained using a type AC175L transducer (resonant frequency 150 kHz), a 40 dB preamplifier and a model AC 105 analyser (56 dB setting). All the equipment was supplied by Acoustic Consultants Ltd, St Ives, UK. Tests were normally run in triplicate.

Typical results

In Figure 2 a typical series of results are shown for an experimental alkyd-based decorative gloss top coat/undercoat system, tested initially and after 300 and 600 hours accelerated weathering exposure on the Atlas XWR accelerated weathering machine. Particularly noteworthy is the strong influence of the paint film water content on the results. These results were obtained with aluminium foil substrate. Figure 3 shows an electrodeposited primer paint (E) applied to zinc phosphate pretreated steel (S/P). The results show quite clearly the value of examining components as well as the whole paint system. By comparing the results obtained with those for steel alone, and the pretreated steel with the results for the whole system, it is easy to differentiate noise due to the steel (S), the pretreatment (P) and the primer paint (E).

New results

A programme of work to study the effect of chemical composition variations on the protective properties against

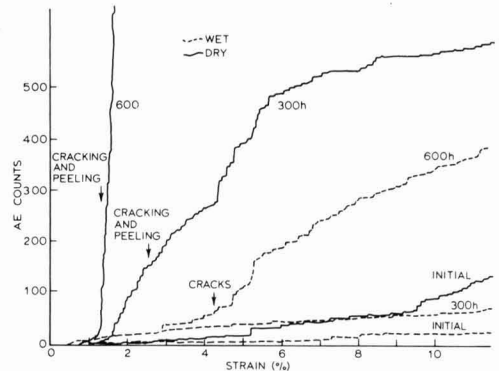


Figure 2.

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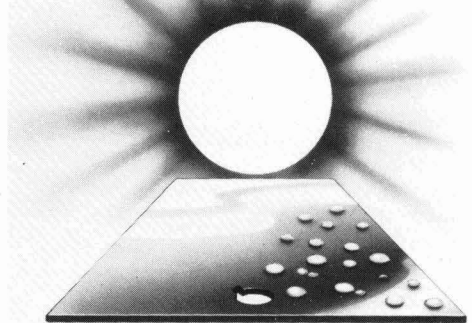
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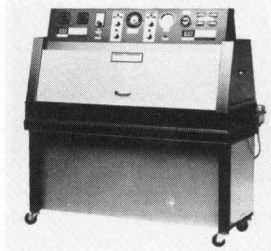
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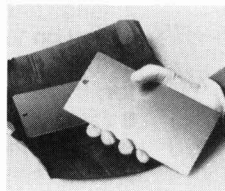
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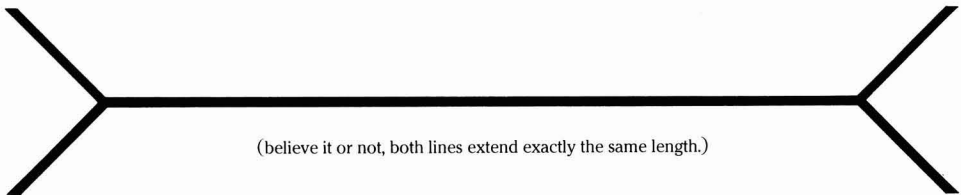
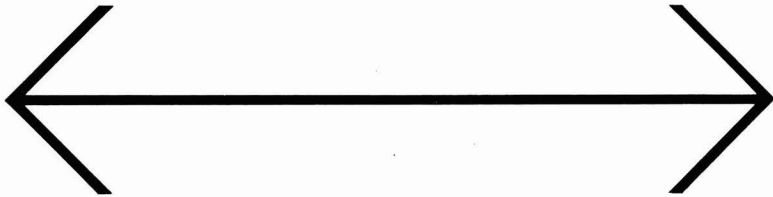
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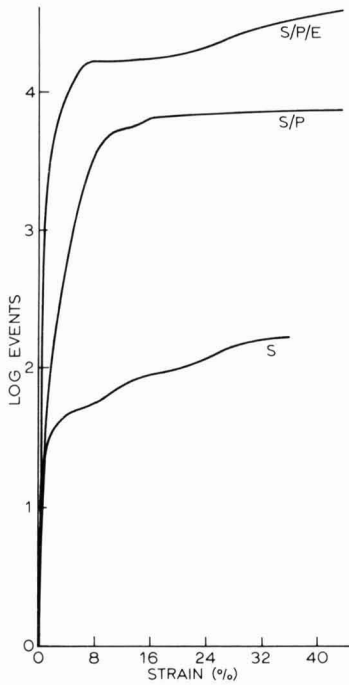


Figure 3.

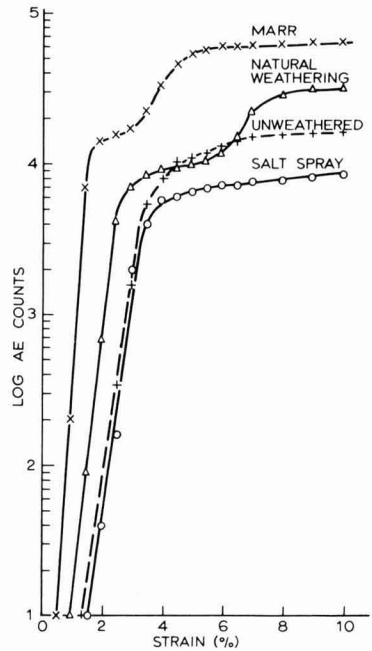


Figure 4.

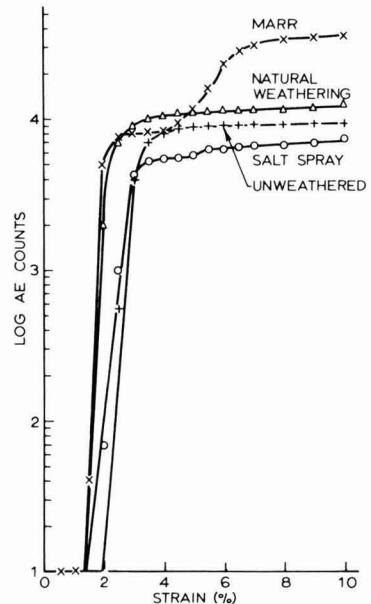


Figure 5.

corrosion of epoxy coatings on steel was initiated by Professor D. Williams-Wynn during a period of sabbatical leave from the University of Natal (Durban, S. Africa), which was spent with ICI (Paints Division).

The initial stage of the programme was aimed at the study of chemical variation on the protective properties of the unpigmented coatings. These coatings were applied to both bare steel and phosphate pretreated steel and their protective properties assessed by salt spray, humidity, and accelerated and natural weathering tests. Their behaviour during these tests were monitored by visual observation and various physical tests, such as mechanical properties, adhesion, electrical resistance (ac impedance etc.).

Amongst the physical tests applied were studies of acoustic emission during tensile testing. Whilst the results will be reported in more detail elsewhere³, a few illustrative examples of results obtained will be given to show how sensitive acoustic emission is to changes in film properties during environmental exposure.

System C1 was prepared by reacting stoichiometric amounts of tall oil fatty acid and Epikote 1004 (Shell) in methyl isobutyl ketone at 150°C (dimethylbenzylamine catalyst). The resulting resin solution was mixed in a ratio of 4:1 (resin weight ratio) with a urea/formaldehyde resin (manufactured by ICI (Paints Division) PLC). The resin mixture was applied to steel panels (finished mild steel, Gold Seal, and phosphate steel, Bondelite 134, supplied by Pyrene Chemical Services Ltd), allowed to dry for 30 minutes, and stoved at 170°C for 30 minutes. Average film thickness was 42 microns.

Figure 4 shows the acoustic emission results for this system applied to bare steel for the unweathered films, and the films after exposure for 21 weeks natural weathering at

Slough, 1,000 hours exposure in the Marr accelerated weathering machine, and 500 hours exposure to the ASTM B-117 salt spray test. Figure 5 shows a similar set of results for a set of films applied to phosphate pretreated steel.

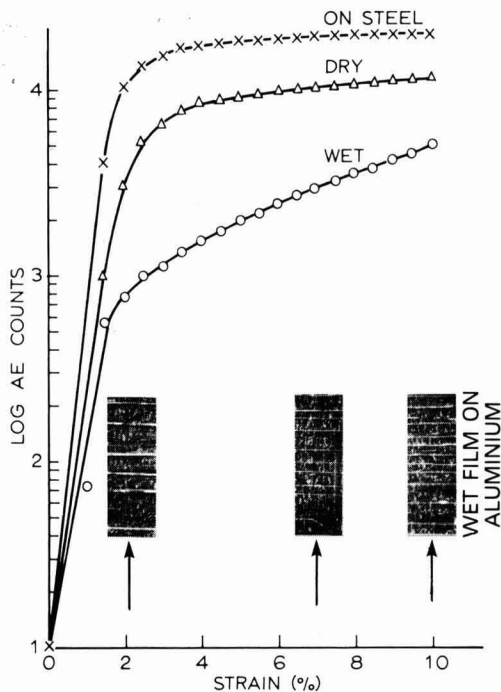
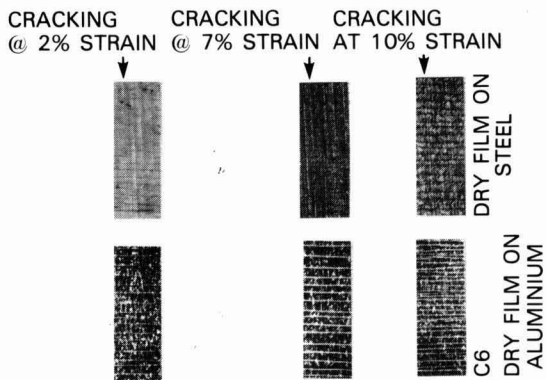


Figure 6.

Again, like the alkyd films, moisture content affected the acoustic emission results. Figure 6 shows initial results for films of another epoxy system, C6, applied to aluminium foil and tested in the dry and wet conditions, and applied to bare steel and tested in the dry condition only. C6 is the analogue of C1, using diethanolamine instead of tall oil fatty acid, and no catalyst. Also shown in the figure are photographs of parts of the tensile test specimens, showing the characteristic transverse cracks that appear at right angles to the direction of strain and comparing these at different strain values.

Discussion of results

The influence of moisture on the acoustic emission results is reflected in changes in other film properties. Thus the glass transition temperature, as measured by the ICI micro-indentation apparatus⁴, is 74°C for the dry C6 film

and 38°C for the wet film. This effect was quite general for all the epoxy variants studied (24 systems), although more pronounced with the harder films.

By contrast, adhesion tests showed a considerable difference between coatings on bare steel and phosphated steel, with only a small influence of moisture on the results. These results were obtained by a Hesiometer type instrument⁵ made at Paints Division, where a knife, loaded and inclined at a controlled small angle to the horizontal, is driven along the interface and the force exerted on the knife by the paint film is measured. Clearly, the greater the adhesion, the larger is the force measured. For untreated steel, values of 2.20 (dry) and 2.30 (wet) were obtained, whilst, for phosphated steel, the figures were, respectively, 0.79 and 0.80 kg force. The knife was 0.64 cm wide, inclined at 0.77° to the horizontal and weighted to 500 g total weight.

After exposure to environmental tests, the panels of C1 subjected to exterior weathering both showed a patina of rust under the film, with 2 mm rust creep from a scribe mark on bare steel and negligible creep on phosphated steel. After 500 hours in the salt spray, the coated bare steel panel was showing a lot of large blisters, many broken to reveal clean metal, and 16 mm creep back of rust from the scribe mark; whilst over phosphated steel, rust creep was 4 mm, with isolated blisters. After 1,000 hours in the Marr accelerated weathering machine, general blistering and underfilm blackspot corrosion was observable on the bare steel panel, whilst the phosphated panel showed general microblistering and underfilm corrosion.

In general, these visual assessments are in line with the acoustic emission results. These show less noise over phosphate pretreated steel than over bare steel for all the panels tested. Whilst the Marr test was run for a period which corresponds approximately to twice the natural weathering period, the acoustic emission results single it out as being the severest test for the system. What is also interesting in the acoustic emission data is the development of distinct "steps" in noise level corresponding to certain low strain values, which reflect the appearance of blisters in that particular environmental test.

Conclusions

Our experience with acoustic emission tests on a wide range of paint formulations during environmental testing, as well as the more systematic work on epoxy coatings, some of which have been selected for illustrative purposes here, suggests that the technique is a very sensitive indicator of changes in mechanical properties of paint film/substrate systems. As such it is a useful technique for picking up early signs of paint failure during environmental testing, as well as for more fundamental studies of paint failure.

[Received 10 May 1983]

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Wood protection – the interaction between substrate and product and the influence on durability*

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Introduction

This paper is not concerned with the coating of wood which is in a sound condition since this subject has been covered in a number of previous articles¹⁻³. However, when coating exterior woodwork, one has frequently to deal with wood that is not in perfect condition. This is natural when one considers that a mere week's exposure reduces the wood's paintability⁴. Longer exposure seriously reduces the life span of subsequent coatings^{5,6}. It is not always feasible to paint wood as soon as it is erected because the painter may have to wait for the carpenter to finish or because of unsuitable weather conditions. Therefore, in some countries, such as Norway, it has been a long-standing practice to give wood sidings temporary protection by applying a coat of semi-transparent stain. Lately the stain has even been applied by passing the boards through a staining machine before erection.

Unfortunately this does not always solve the problem. It has been shown that a semi-transparent stain does not fully protect the underlying wood against deterioration due to the influence of light^{5,7}. Hence, the painter is very often given the task of painting wood with a more or less degraded surface. We have tried to find the best way of accomplishing this.

Experimental methods

A simple test to assess the condition of a wood surface involves the use of adhesive tape. When pressed onto a new, unexposed spruce surface (*Picea abies*) the tape will adhere firmly, and when pulled off will tear away only traces of wood material – if any.

When progressively exposed spruce surfaces are tested in the same manner there is a progressive decrease in tape adhesion and an increase in the number of wood fibres which tear off and adhere to the tape.

This effect was termed "fibre chalking" and rated on a 0-10 scale as follows:

- 0 = no adhesion and thick layer of loose fibres on tape
- 10 = good adhesion and no loose fibres on tape

Figure 1 shows the results of the fibre chalking test on spruce and pine during 10 months of outside exposure in a vertical position facing south in Bergen, Norway.

It could be argued that the tape will only test the adherence of the very outermost layer of wood cells, while paint could penetrate between the loose cells and obtain a satisfactory adhesion. An indication of this effect is shown in Figure 2.

A weathered panel was painted with an alkyd house

paint on the left, and with a latex house paint on the right. The relatively large latex particles could not penetrate and the paint flaked off after a short time due to lack of adhesion, i.e. to adherence of wood fibres to the paint film.

The alkyd paint gave a better performance on this substrate. The Figure 2 photograph was taken after 2.5 years of vertical exposure.

However, a penetrating primer does not appear to solve the problem of painting weathered wood – as shown in the next experiment.

Planed spruce panels were given one coat of stain and exposed for five years. There were then only traces of stain left and the surface was silver-grey. These panels were painted and the adhesion of the paint systems were measured, using the pull-off method, with an Elcometer Adhesion Tester Mod. 106. The adhesion on the weathered wood is shown in Table 1. (On new wood the adhesion of an alkyd house paint is typically 50-70 kp/cm².)

The results confirm that the latex paint was far inferior to the alkyd paint on weathered wood, and the performance of the alkyd-based primers did not significantly vary with viscosity, i.e. with varying ability to penetrate.

These results prompted the following questions: 1. Did

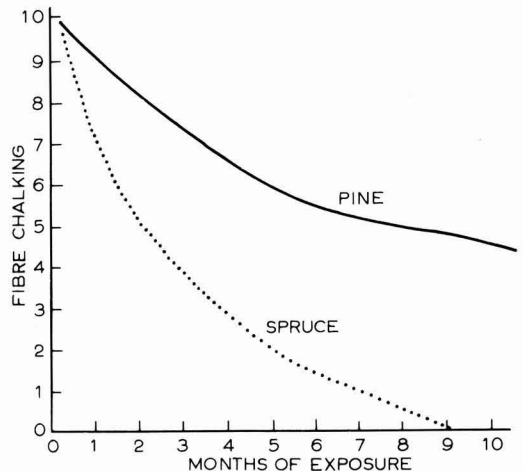


Figure 1. Fibre chalking of pine and spruce during ten months of outside exposure facing south in Bergen, Norway

*Paper presented on behalf of SLF at the Association's York Conference, 15-18 June 1983. An edited transcript of the discussion that followed this paper can be found on page 354.

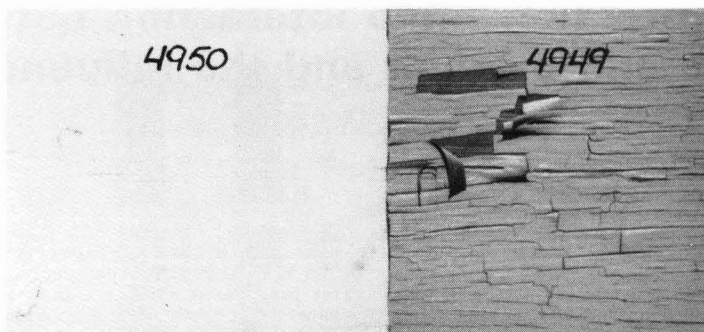


Figure 2. A weathered spruce panel was given two coats of alkyd paint on the left and two coats of latex paint on the right. The photo was taken after 2.5 years vertical exposure

Table 1
Adhesion to weathered wood

Primer	Viscosity (cp)	Adhesion (kp/cm ²)
Alkyd house paint undiluted	190	22
Alkyd house paint diluted with 10% white spirit	120	24
Alkyd house paint diluted with 30% white spirit	60	22
Alkyd house paint diluted with 10% linseed oil	160	20
Alkyd house paint diluted with 30% linseed oil	140	20
Alkyd-based wood stain	45	22
Latex house paint (acrylic)	100	10

the low viscosity primers not penetrate further? 2. Did the depth of penetration not influence the adhesion?

In an attempt to answer these questions we measured the uptake of primer by brushing it on to a weighed spruce panel. The surface was kept wet for 30 minutes by repeated application of more primer. The surplus was then rubbed off with dry tissue paper and the panel was immediately re-weighed. This was done on newly planed spruce and on panels which had been exposed vertically facing south for one year. The weathered wood was silver grey and the surface was full of micro-cracks.

Table 2 gives the results of these tests, which indicate that new wood, but particularly weathered wood, will absorb more of a primer with good penetration properties, but the adhesion is not significantly improved by good penetration.

The uptake of wet primer is higher in weathered wood because all the micro-cracks on the surface become filled, but this is not the whole story. SEM studies have shown that the cells near the surface also become filled when spruce is weathered. New spruce, on the other hand, is practically impermeable to primers such as these (figures 3 and 4).

Table 2
Primer penetration and adhesion to new and weathered wood

Surface	Primer	Viscosity (cp)	Uptake of wet primer (g/m ²)	Adhesion (kp/cm ²)
New wood	alkyd paint undiluted	190	11	40
New wood	alkyd paint diluted with 10% white spirit	120	9	45
New wood	alkyd-based wood stain	45	11	41
New wood	alkyd-based impregnating agent	≈5	18	48
New wood	boiled linseed oil	65	31	40
Weathered wood	alkyd paint undiluted	190	25	29
Weathered wood	alkyd paint diluted with 10% white spirit	120	58	24
Weathered wood	alkyd-based wood stain	45	71	33
Weathered wood	alkyd-based impregnating agent	≈5	119	29
Weathered wood	boiled linseed oil	65	136	25

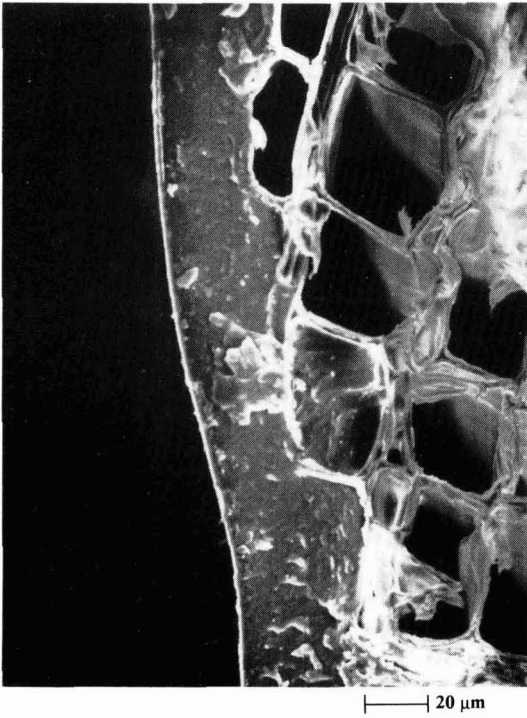


Figure 3. A new spruce panel was given one coat of alkyd-based stain. The SEM photo shows that all of it is deposited on the surface of the wood

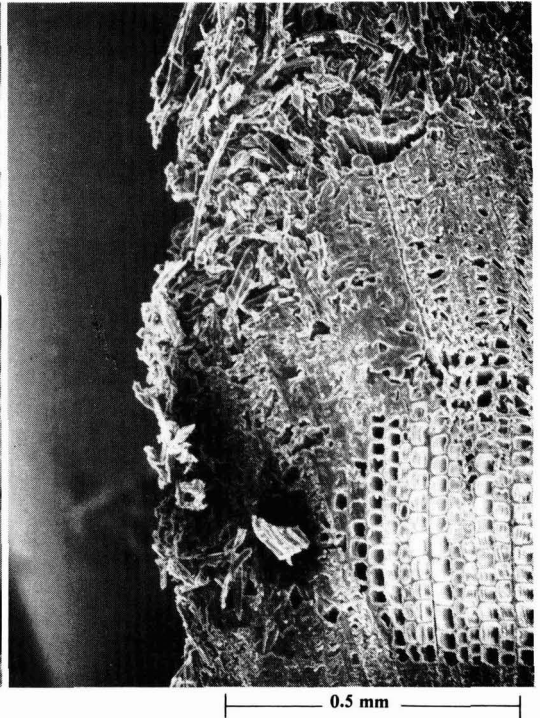


Figure 4. A weathered spruce panel was given one coat of alkyd-based stain. The SEM photo shows that much of the stain has penetrated the wood

Judging from the adhesion measurements there is not much difference between low and high viscosity primers – as long as we compare alkyd-based products. Exposure tests follow the same pattern.

Two different alkyd house paints were applied to new spruce using the primers shown in Table 2. They were all free from cracking and flaking after eight years of vertical exposure facing south.

The same systems applied to weathered spruce panels did not last that long. After five to six years they were found to be in need of repainting due to cracking and flaking, but again there was no difference between the different primers.

Our conclusion based on these and several other exposure tests is that an alkyd-based primer with good penetration does not help to solve the problem of painting weathered wood. If a primer based on a latex is used the life time of the coating will be very short indeed.

It was found that if weathered wood was vigorously rubbed with a steel brush, a lot of fluffy material was produced and brushing slightly improved the paint-holding properties of the wood.

In order to estimate how deeply the wood could be degraded the following experiment was carried out.

A panel of planed spruce was exposed vertically, facing south, for 15 months. It was then cut up into smaller panels. One of these was planed in a machine to a depth of

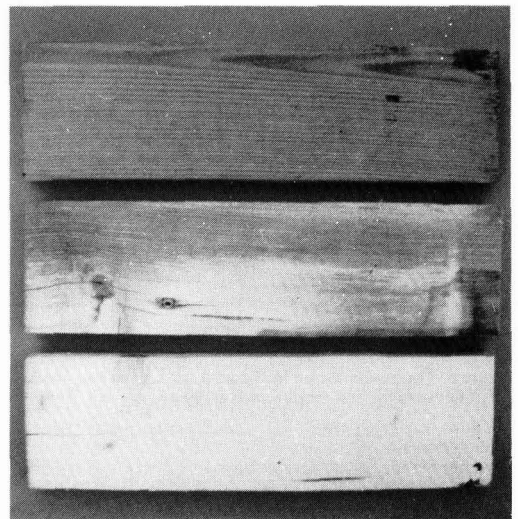


Figure 5. The upper spruce panel was weathered for 15 months. The middle panel has been planed to a depth of 1.0 mm and the lower one to 3.0 mm

1.0 mm, and another to 3.0 mm. These are shown in Figure 5 together with an unplanned panel. These and a panel of new spruce were given two coats of alkyd house

Table 3
Weather-O-Meter test results

Panel	Cracking		Flaking	Adhesion (kp/cm ²)	
	500 h	1000 h	1000 h	0 h	1000 h
New wood	10	10	10	63	60
Weathered wood	4	3	10	25	18
Weathered wood planed down 1 mm	9	8	10	42	45
Weathered wood planed down 3 mm	9.5	9	10	52	60

Scale: 0 = severe cracking/flaking, 10 = no cracking/flaking

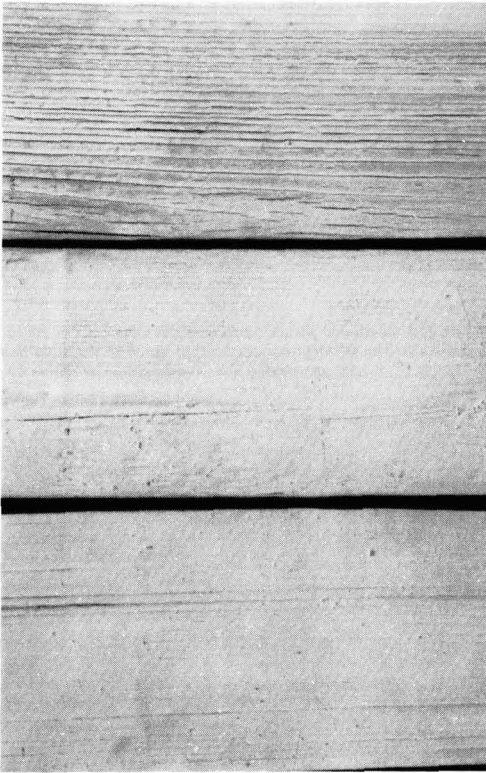


Figure 6. The panels shown in Figure 5 were given two coats of alkyd house paint and weathered for 1000 hours in a Weather-O-Meter

paint and were tested in an Atlas Xenon Weather-O-Meter. The results are shown in Table 3 and Figure 6.

Due to slight warping, the surface of the panel planed down 1.0 mm was not quite homogenous – as is apparent in Figure 5. This may have influenced the results in Table 3.

It therefore appears that at least 1 mm of the top surface of wood weathered for 15 months must be removed to expose a firm base for the paint.

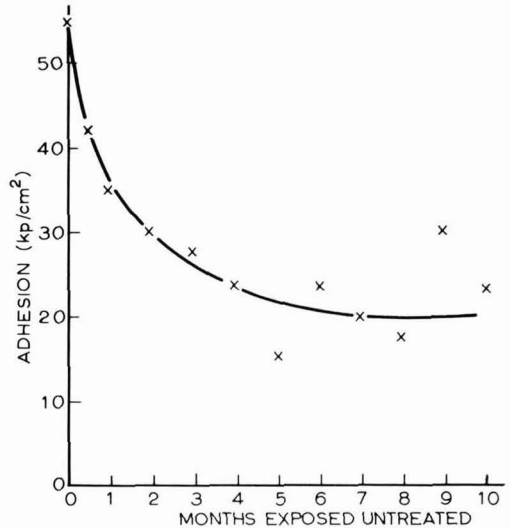


Figure 7. The average adhesion of two paint systems after various periods of weathering

To find out how fast and how seriously the surface of untreated wood is degraded by weathering, the following experiment was carried out.

On 11 spruce panels one-third of each surface was given one coat of wood stain. The panels were then exposed vertically, facing south commencing on 4 April. After 14 days the untreated part of panel 1 was checked for fibre chalking and then stained. After 1 month panel 2 was treated in the same manner and so on at one-monthly intervals. After a total of 2.5 years the stained panels were painted using two coats of alkyd house paint on two-thirds of each panel and an alkyd-latex-emulsion paint on the remaining one-third. The paints were then exposed for another five years. The general appearance of the paints was then rated, a value of 10 indicating no cracking, no flaking and no mildew. Loss of gloss was disregarded, and adhesion was tested using tape, a rating of 10 indicating that no paint was pulled off with the tape. The results are given in Table 4.

The adhesion was also measured with the Elcometer Adhesion Tester. The average adhesion of the two paint systems after various periods of weathering is shown in Figure 7.

Table 4
Results after progressive weathering

Panel No.	Months left untreated	Fibre chalking	Alkyd house paint		Emulsion paint		
			General appearance	Adhesion with tape	General appearance	Adhesion with tape	
1		9	10	10	10	10	
2	1	7	10	10	8	9	
3	2	4	10	10	7	7	
4	3	3	9	7	6	6	
5	4	3	7-8	7	6	6	
6	5	2	7-8	8	5-6	6	
7	6	2	7	7	5	5	
8	7	1	6	7	5	5	
9	8	1	6	7	4-5	4	
10	9	0	5	6	3	5	
11	10	0	4	7	2-3	4	
The one-third section of all panels stained before exposure		0	10	10	10		

It is clear from these results that after four weeks of exposure in Bergen, Norway, during April, which is a comparatively cold and dry month, the wood surface was damaged as regards being a substrate for paint, even though it was primed with a low viscosity primer. It is also apparent that measuring the "fibre chalking" with tape gave a good indication of the state of the wood surface, and that decreasing paint adhesion gave decreasing paint performance.

The panels hitherto tested had their surfaces degraded by weathering. It was found that under the given climatic conditions, the influence of micro-organisms on the degradation was negligible. Under different circumstances the degradation of wood may be partly or wholly due to the work of fungi or bacteria. In such cases the effect of a low viscosity primer was very beneficial indeed. This was demonstrated in the following test.

For the purpose of testing window paint systems, blocks of wood, 4.5 cm x 13 cm x 45 cm, were mounted as window casements in matching frames on the south wall of a test house. Each block represented the top or bottom of a casement. They were arranged this way in order to eliminate unpredictable leaks in corners and faulty glazing compounds.

However, to find the effect of such leaks on the various systems, a horizontal groove, 3 mm wide and 10 mm deep, was sawn through the outer panel along the whole length of the wood. In this way the "fault" was of the same magnitude in all the "windows" tested. Once a week the windows were weighed and the moisture content calculated.

Figure 8 shows the moisture content of pine wood window frames during the wettest time of the year. The insides of the windows were painted with three coats of alkyd paint and the outsides were painted with two coats of emulsion or alkyd paint, or alkyd stain. The wood used for these windows was in a sound condition.

Figure 9 gives the results for pine wood window frames where the sap wood part of the frames was attacked by blue stain fungi. These frames were also painted with three coats of alkyd paint on the inside.

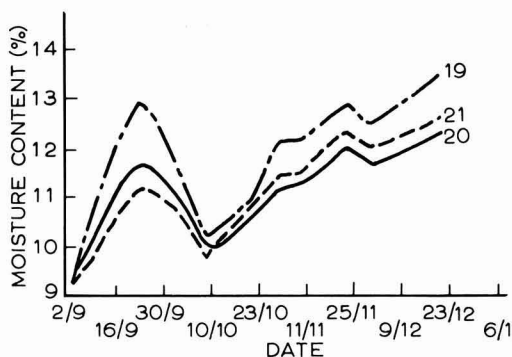


Figure 8. Moisture content in window casements of pine wood during the months September-December. No. 19 had two coats of emulsion paint on the outside. No. 20 had two coats of alkyd house paint with a groove sawn through the paint. No. 21 had one coat of alkyd stain and two coats of emulsion paint. All specimens had three coats of alkyd paint on the inside

Frame 22 had two coats of emulsion paint on the outside.

Frame 23 was treated with the alkyd-based impregnating agent (see Table 2). This was brushed on continuously until the surface stayed wet for a few minutes. The uptake on the blue-stained surface was calculated to be 140 times greater than that on a sound surface. It took a couple of months for the white spirit to evaporate completely (Figure 10). The frame was painted in the same manner as No. 22.

Frame 24 was given two coats of alkyd house paint on the outside. When dry, a groove was cut into the blue-stained part of the wood.

Frame 28 was primed with the alkyd-based wood stain (see Table 2) and then given two coats of emulsion paint.

It is apparent from figure 8 and 9 that a serious flaw, such as the one represented by the groove, has surprisingly

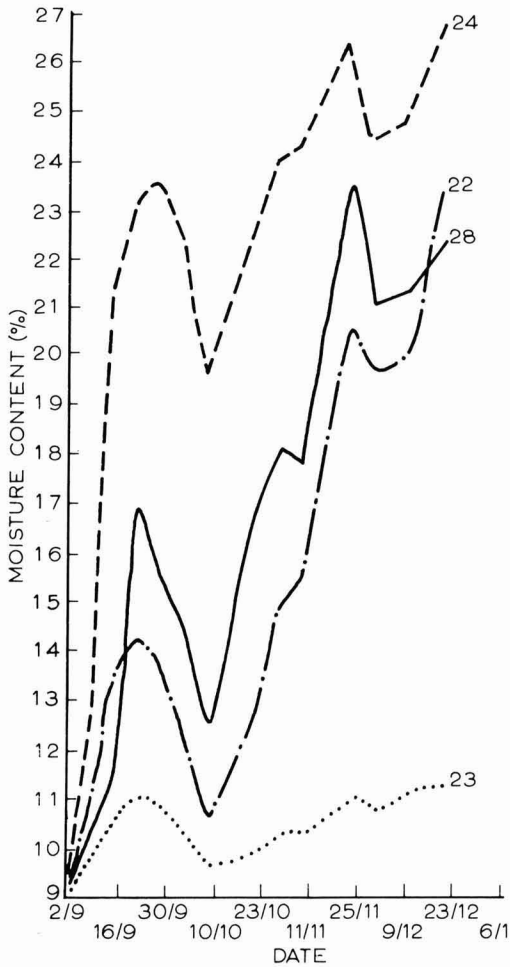


Figure 9. Moisture content in window casements of pine wood where the sapwood was attacked by blue stain fungus before painting. No. 22 has two coats of emulsion paint on the outside. No. 24 had two coats of alkyd house paint on the outside. No. 23 was saturated with alkyd solution before being painted as No. 22. No. 28 had one coat of alkyd stain and two coats of emulsion paint. All specimens had three coats of alkyd paint on the inside

little influence on the moisture content of a window frame as long as the underlying wood is sound. If the wood is made porous by micro-organisms, it may get soaked by rain in a very short time through faults in the joints etc; even without such faults the uptake of rainwater is very rapid.

The painter can improve the situation by saturating the porous wood with a very low viscosity impregnating agent before painting.

Conclusions

The surfaces of spruce and pine degrade rapidly when the untreated wood is exposed. After one month's outside exposure the paint holding properties are adversely affected and deteriorate throughout the next six to ten months.

On a weathered surface a latex paint is very short-lived. An alkyd house paint performs more satisfactorily, but far from the standard it achieves on new wood. Primers with good penetrating power do not improve the adhesion of the alkyd paint. To obtain a good performance on weathered wood the top layer should be planed down to a depth of at least 1 mm.

When the wood becomes porous due to the action of micro-organisms it is important to prime with a very low viscosity penetrating primer, thus ensuring that the wood becomes saturated.

(Received 7 February 1983)

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Figure 10. Blue stained pine sapwood, primed with an impregnating agent

Assessment of paints for the exterior bodysides of railway rolling stock

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This laboratory periodically assesses raw materials designed to improve the performance of paints for the exterior bodysides of railway rolling stock. Rapid evaluation of finishing paints in service conditions has always been a problem since the ultimate criterion must be whether the paint will withstand the various mechanical requirements, such as impact resistance, the scrubbing action of flails in automatic washing plants, etc., as well as having the required chemical resistance to cleaning agents, fuel oils, etc. Although complete or part vehicles can usually readily be painted for practical trials, this has several disadvantages and it became necessary to evolve a rapid method for paint evaluation in service conditions.

Field trials eventually led to the possibility of attaching Melinex sheets – which are clear polyester films used in the laboratory to measure paint opacities – to the vehicle bodysides in order to:

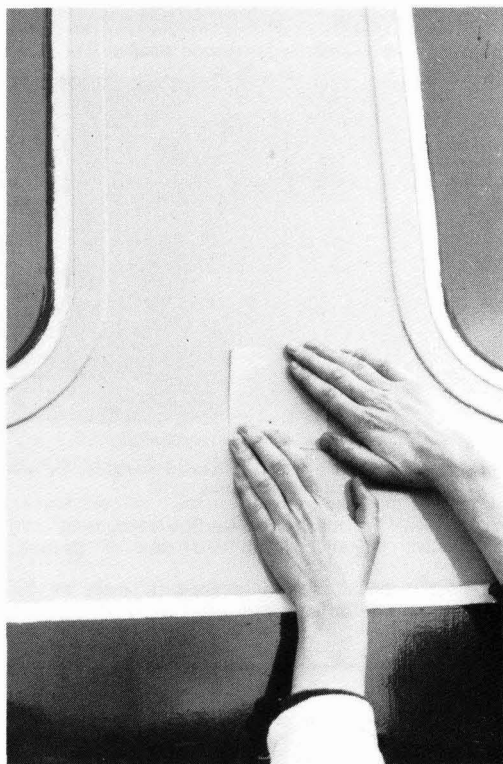
1. Determine the nature of the debris deposited.
2. Assess paint performances.

Melinex films (10 cm × 10 cm) both painted and unpainted were attached to vehicle bodysides with an industrial grade of double sided pressure sensitive tape in such a position as to be subjected to the regular mechanical cleaning of the vehicles, as shown in Figure 1. Adhesion failures between the Melinex and applied high stress coatings were overcome by using silica coated polyester draughtsman's quality paper, which has a textured surface. Films have been attached to high speed trains for up to five months with a very low incidence of detachment.

This technique greatly facilitated the assessment of the performance of various paints in service conditions as typically shown in Figure 2, where the silicone alkyd had acquired a permanent stain but which was not present on the urethane oil/alkyd finish. Scanning electron microscopy enabled the individual debris particles to be photographed and analysed for their inorganic elements (see Figure 3) and gave some indication of their frequency and source, i.e. rail head, brake pad, ballast, etc.; the detection of no inorganic elements indicated organic deposits from fuel oil, brake pads (which contain about 50 per cent w/w butyl rubber), lubricating oil, etc. X-ray fluorescence confirmed the inorganic elements and X-ray diffraction identified the crystalline phases present.

The film technique has proved very successful and preliminary results have shown:

1. Differences in the performances of various finishing paints are readily apparent, i.e. rate of soiling, ease of cleaning, gloss retention, etc.
2. The effect of the rheological properties of the under-

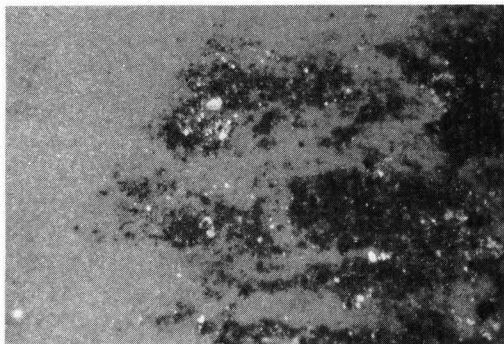


Attachment to upper bodysides

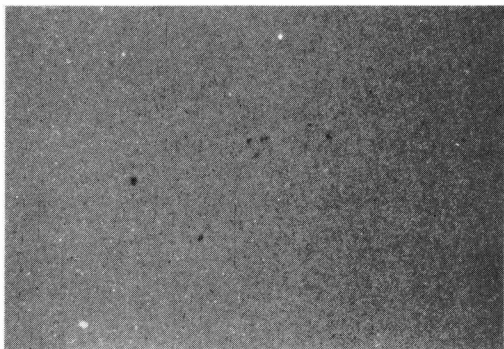


Painted sheets on lower bodysides

Figure 1. Attachment of sheets to vehicle bodysides



Silicone alkyd – permanent staining

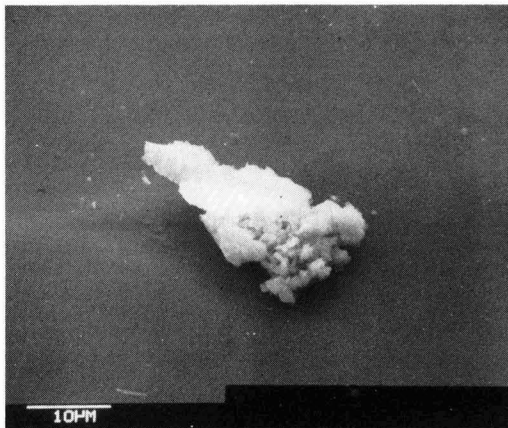


Urethane oil/alkyd – no staining

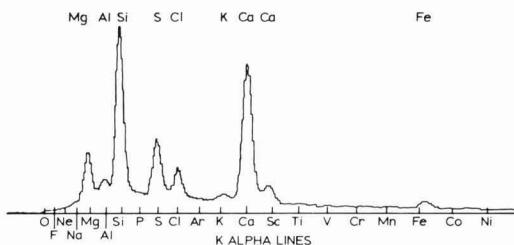
Figure 2. Performance of paints in service conditions for two months (magnification $\times 50$)

coats and finishes on the surface topography and its effect on dirt pickup and ease of cleaning.

3. Climatic conditions have a great influence on the rate/nature of the soiling.



Micrograph of deposited particle (magnification $\times 2,000$)



Energy dispersive X-ray analysis of above particle

Figure 3. Scanning electron micrograph analysis of deposited particles

This work is being extended and it is hoped it will be the subject of a later paper.

[Received 4 May 1983]

conference discussion

Discussion is encouraged at OCCA Conferences following the presentation of papers. Those who put questions were asked to fill in discussion slips with the details of their questions. The answers given by the lecturers/authors were recorded on tape. Edited versions of the discussions that followed the papers published in this issue appear below: questions in ordinary roman type, answers in italic. Only those questions for which discussion slips were received are published.

Acoustic emission – further unpublished results of the new technique for the study of paint performance during environmental exposure tests

T. A. Strivens and M. S. Bahra

R. L. J. MORRIS: Have you any data to indicate the repeatability of results obtained by this technique?

T. A. STRIVENS: *We normally carry out measurements in triplicate. On the whole, with the exception of an occasional aberration, we get very good repeatability. To put a figure on it I would say repeatability is perhaps typically within 5 per cent on the numerical values.*

One area of critical importance, as you will be able to imagine, is that of sample preparation. In particular, care must be taken to ensure that there are no edge defects due to the cutting process. Occasionally, however, this does occur, but these are obvious because the data from them are widely apart from the rest of the replicates.

A. A. KALWIG: Do you see the acoustic emission test

method as having relevance to the evaluation of coil coating materials?

T. A. STRIVENS: It's a little difficult to say. We've done a little coil coating testing and adhesion loss and failure within the paint itself can be identified by the acoustic emission test. I doubt whether you would be able to detect these failures as readily using the T-bend test.

I should perhaps emphasise that we have done all of our testing in the tensile mode, as much for convenience as anything else. Something we'd like to look at in the future is three point bending and other types of geometry because we feel comparisons between these and tensile testing may well give us different information from the acoustic technique. Also we work at low speed, this is to keep within the linear range of the paint behaviour for as long as possible; this avoids the introduction of errors due to the rate of testing.

T. GRAHAM: Have you managed to correlate results with practical weathering? And, following on from Dr Miller's earlier paper, have you been able to confirm that the

undercoat is the critical coat in systems for wood with regard to failure; is that where all the noise comes from?

T. A. STRIVENS: For certain systems we have been able to both correlate results and to confirm the critical role of the undercoat.

We have taken experimental systems with a very brittle undercoat covered with a highly ductile top coat. This has shown the modifying influence of the top coat – for as long as it retained its ductile properties – on the very noisy undercoat during exposure. We've done experiments looking at PVC and various other formulation variables and have been able, in some cases, to say that a system is not worth putting on weathering trials because it's so noisy. I would say that on the whole we get very good correlation with weathering and there is a strong hope that in the future we shall be able to predict from acoustic emission the life and time of service of coatings during weathering. At the moment we are coming to the end of a period of some years in which we have been testing a large number of systems and getting to know the sort of information the technique will provide.

Mechanistic model for corrosion protection via paint

F. L. FLOYD, R. G. GROSECLOSE and C. M. FREY

J. R. KELSEY: The ASTM salt spray test is much maligned for its poor correlation with results from natural weathering. Bearing this in mind, have you considered extending the technique to predict the results of natural weathering?

F. L. FLOYD: Yes indeed, but natural weathering takes time. We have initiated exterior exposures and will perform the calculations as the data become available.

T. GRAHAM: Do you use regression analysis fairly frequently or is this an isolated use for these particular properties and for corrosion? For instance, do you use it for the ordinary analysis of the performance of decorative coatings?

F. L. FLOYD: Yes, we often use regression analysis for the more usual type of studies. We published a paper in January in the Journal of Coatings Technology looking at the problem of cracking of paints applied to wood substrates. We came up with a model which suggested that the two parameters controlling the cracking of paint are the permeability of the paint film, because of the resulting swelling and contraction of the wood, and the fracture energy of the paint film, which is the ability of a material to resist the propagation of a crack through it. This two-parameter model seemed to account nicely for the results obtained.

T. GRAHAM: Are you able to use the conclusions you arrive at to correct shortcomings in products you look at?

F. L. FLOYD: We are able and have done this. However, the marketing department puts forward a package of performance properties they wish to market, and that's the ultimate criterion.

D. S. NEWTON: Have you examined the use of the AC impedance technique as a method of test for latex paints?

F. L. FLOYD: We haven't had very much luck in looking at AC impedance testing, although to be fair we haven't spent a great deal of time on it. We use a DC method which we feel is more capable of giving us the results that we need.

Regarding latex paints, yes we have been looking at them rather extensively, as you might infer from the preponderance of latex paints in our data.

D. S. NEWTON: There is a lot of discussion as to which technique reveals the most meaningful results. One school favours DC and another considers AC gives more meaningful results, especially in solvent-based materials. Do you have any comments?

F. L. FLOYD: I should firstly state my own interest in that I belong to the DC school.

I think it makes good sense to look at what actually takes place on a corroding substrate. One line of reasoning describes cathodic induced delamination from a flaw site as being the method by which the paint film is lifted, followed by the onset of any substantial corrosion. This is a typical DC phenomenon and we tend to think, perhaps rather simplistically, along these lines.

I think the AC school are more concerned with the detection of the flaw sites per se rather than the progression of the corrosion reaction. I don't know whether I've represented the AC school of thought adequately, but that's my impression of it.

A. BARKER: Have you carried out work on pigments other than predominantly zinc molybdate types as discussed in your paper?

F. L. FLOYD: Yes we have. In the United States we tend to concentrate on the non-environmentally hazardous materials due to our environment protection laws.

However, we have also looked at chromates in some of the areas where their use in the United States is permitted. They all fit the predictions pretty well. The chromates, of course, are very much better at corrosion protection and also show up very much better in some of the component tests.

D. A. KALWIG: Following that line of thinking, have you included the additional variables of metal pretreatment in your prediction analyses?

F. L. FLOYD: Yes, that was the earliest work we did with this particular corrosion meter. It is very useful for studying the substrate itself without paint, i.e. the variability of cold rolled steel, hot rolled steel, and also of the phosphate pretreatment that goes on to the steel. The results were presented last fall at the annual FSCT meeting and have been accepted for publication in JCT. It's a very sensitive test and it correlates very well with what is actually seen in terms of variability once the steel is coated with paint. In fact that technique is probably a more effective use of the P-350 than the one discussed in the present paper.

H. FOSTER: In Figure 2 of your paper you obtained a correlation coefficient of -0.603 between salt spray rating and permeance. Could you comment on the accuracy of this figure in view of the typical error of ± 0.15 units which

you quote in Appendix 1 for salt spray rating replication?

F. L. FLOYD: In order to detect differences in a single factor the data would have to lie outside the error bars of adjacent components. We calculate the correlation coefficients by building replication into the technique. The number of replicates for each of the tests is of the order 3-8, depending on the tests and its variability. If you are running non-replicated samples, which is highly ill-advised but sometimes occurs, and if the individual tests have a high degree of variability, your chances of getting accidental correlations or lack of them become enormous. These tests have a high degree of variability and the only way to get any sort of reliable answers is to use a high degree of replication. Problems in replication show up in the confidence interval. By requiring a confidence value higher than 95 per cent, we ensure that data variability (i.e. chance) is not a factor in the correlations.

H. FOSTER: In the above experiment of salt spray versus permeance, were all the films applied to give the same dry film thickness?

F. L. FLOYD: Yes, film thickness was kept constant in these tests. Permeability is, above a certain threshold, independent of film thickness, but below that point it is highly dependent due to the flaws in the film.

Wood protection – the interaction between substrate and product and the influence on durability

A. Underhaug, T. J. Lund and K. Kleive

D. A. KALWIG: With reference to alkyd penetrating primer (i.e. WRP), Australian recommended practice is to treat all joinery before delivery to building sites. This allows the choice of application of stain finishes, conventional alkyd 3-coat systems or acrylic systems. Your paper appears to offer this same type of treatment after weathering has occurred. Why not recommend pre-delivery WRP treatment of all timber joinery?

K. KLEIVE: In Norway over the last years there has been a tremendous change with respect to treating wood before it is delivered to a site. At present all window frames have to have been at least dip coated with a primer before delivery. This helps but only for a short period. The problem is that window frames can often be left for up to six months without treatment. This is too long for a clear primer coat to prevent degradation of the wood's surface, as is shown in my paper.

D. A. KALWIG: We have a recommendation in Australia that primed wood should be further treated after 4-6 weeks.

K. KLEIVE: Such recommendations should be specific for individual primers. If a clear primer is used, further treatment should take place within 6-8 weeks.

T. GRAHAM: Presumably the problems associated with the degradation suffered by bare wood surfaces also applies to what starts off as a sound coating but which is allowed to deteriorate too far.

K. KLEIVE: Yes that is the case. It leads to difficulties

particularly in maintenance work. I know in the UK, council maintenance periods are often of 5 years duration. A situation has arisen where after 5 years the existing system has been seen to be in perfect condition and the council has said why don't we wait 1 or 2 more years? We insisted that they keep to the 5 year period, arguing that the surface was now in a good condition and could be successfully repainted to last another 5 years, whereas to wait a sixth year could necessitate burning the old paint off.

A. CLARKE BOYCE: How long should wood pressure treated with preservatives be left before painting?

K. KLEIVE: If wood is pretreated in some way it will last longer. But if a clear coating is used, for example an alkyd type vacuum pretreatment, photodegradation of the wood surface will take place. Under these circumstances I would recommend a maximum of two months before further treatment.

If the wood is impregnated with salts this period may be extended. This is, we believe, because there is a reaction between the salts and the wood itself. Chromates, for example, give a very stable wood surface.

K. BORER: Does photodegradation occur equally on grain and inter-grain wood?

K. KLEIVE: We haven't done work on this but it seems from tape tests that it is the middle lamella layer – the lignin – that breaks down and this progresses at a great rate.

conference discussion

K. BORER: How can one improve photodegraded wood *in situ*? Does scrubbing or burning off help?

K. KLEIVE: *We have tried vigorous wire brushing which helps but doesn't bring the surface back to the original condition. There are different types of wire brushes – some with bristles that have rounded ends, some with sharp chisel like ends. The latter are more effective since they cut degraded wood away.*

We are about to start tests looking at the effects of burning off old paint. If the burning goes too far it will blacken the wood, which will be easily penetrated by the paint and the adhesion will be poor. It is recommended that the surface be sandpapered and immediately coated with paint. This gives the best results.

There are other interesting questions which are so far unanswered, such as what is the effect of using alkali or acid paint removers. These tests take a long time, as you can see our results are based on a ten year period because we have to use natural weathering. We are, though, about to begin a series of different tests on other treated materials.

E. R. MILLER: Work at Princes Risborough also shows that wood which is vacuum pressure treated with

chromium containing preservatives possesses improved resistance to weathering, and that after weathering it holds paint better than weathered untreated wood. Like Mr Kleive we have examined various methods of restoring degraded wood surfaces and have failed so far to identify any means of raising paint holding properties to their original level. There is great scope here for new types of pretreatment.

In the UK, primed window frames are marketed in the main. (It is a cause of some concern that just as we raise the standards of wood primers there are separate trends towards the use of semi-transparent finishes on these frames, the latter being a somewhat retrograde step.) The question I would like to ask is, to what extent is pre-finishing used for cladding in Scandinavia?

K. KLEIVE: *Primed cladding is available from specialist stores and it is also possible to buy vacuum treated and salt impregnated cladding.*

Recently there was a meeting in Finland amongst Scandinavian wood technologists. It was decided there that much more effort should be put into the study of the surface of wood, how it should be treated and the way in which it deteriorates. So a lot of work will be done in this field in the future.

next month's issue

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

The use of modern application equipment and its efficiency* by M. G. Eaton

Paint finishing in the car industry* by H. L. Quick

Fire retardant paints* by D. M. Bishop, D. Bottomley and F. G. R. Zobel

*Paper presented at the OCCA Conference, York, 15-18 June 1983.

letters

“The fall of OCCA; depression ends 1994”

Dear Sir – *Yes The Fall of OCCA.*

Once again a headline can give the wrong impression, and it is fortunate that in this November issue of the *Journal* we can explain that “The Fall” is in fact autumn following the September report of a March Newcastle meeting.

The Association must follow the industries which provide the members and it is fair to say that the UK paint industry is in the middle of winter, with the major industrial advances being of non-UK origin and the subject of licences, with the decorative side lacking in advances or profit.

Whether this is due to poor performance by the chemists of the industry or a lack of commercial foresight is of little importance now, the climate has had its effect on UK membership.

Many things happen as a matter of course in “The Fall” and Council have ploughed through past performance and sown the seeds of biennial Exhibition and Conference and the initial germination looks good. Some pruning is also necessary and – whilst Council have taken steps to ensure continuity after the eventual retirement of the Director & Secretary – the acts of the sections are most obvious, where changed format, programmes and venues have set a pattern that can only give growth of numbers at meetings.

No autumn is complete without its Indian summer, which can easily be equated with the overseas membership increase as we welcome all including sub-continental, east, west and red. (There is no truth in the rumour that Clarke and Marjorie Boyce (FSCT) tried to scalp the Druids at Stonehenge – only the Hippies on the other side of the road.)

For the UK the ground looks good with larger, merged, rationalised companies and others beginning to look for men to develop the products needed for the future. There

letters

is also a certain number of smaller specialist companies emerging to provide potential numbers and interest.

At such a time it is possible to judge the condition of a tree by its fruits and the Association has the best crop of "NUTS" for years.

For the rest of the headline we must hope that 1994 does not see the start of another era similar to one we can all remember – when without much effort vast quantities of any old rubbish were sold – resulting in a further period

of no development with subsequent recession somewhere just past 2000.

This Association is no different to anything else in life and you only get out what you put in, so attend more in '84 and be alive in '85.

14 Wells Road
Chippenham
Wiltshire SN14 0QD

Yours faithfully
G. W. Fowkes
29 September 1983

occa meetings

Ontario Section

Pitfalls of pigment selection

The opening technical meeting of the Ontario Section's 1983-84 session was well attended with 35 members and friends turning out to listen to Mr R. W. "Bill" Bartsch, senior technical service manager of Ciba-Geigy, Ardsley, New York.

Mr Bartsch presented a stimulating and highly entertaining lecture on the "Pitfalls of pigment selection". The evaluation of the strength and shade of a pigment incorporated in a paint, ink or plastic is not always as easy as it might seem, and is fraught with many pitfalls for both supplier and user.

For example, two yellow pigments compared for tint strength (at various levels) as yellows, as greens and as oranges ranged from 5 per cent strong to 30 per cent weak! Such results mean that it is very important to evaluate the pigment in a system that is as close as possible to that of the end use.

Other problems occur when various methods are used for dispersion (e.g. Hoover muller, sand mill or two roll chipping), and when various vehicles are employed. Differences observed under these conditions can be quite large.

Numerous other pitfalls were discussed, including: changing the standard, use of a liquid standard which is subject to evaporation, and the use of the preceding delivery of pigment as the standard.

Mr Bartsch concluded by presenting a check list for pitfalls:

1. Appropriate test method selection.
2. Proper preparation of samples.
3. If using spectrophotometer, ensure complete hiding to prevent substrate interference.
4. Use correct evaluation technique.
5. Standard illuminant.
6. If visual assessment, use trained personnel.

Following a question and answer session, the vote of thanks was proposed by Mr Alan Gray.

P. Marr

Thames Valley Section

Pressure polymers

Held on Thursday 15 September at the Crest Motel, Beaconsfield, the above lecture was given by Dr J. Fairless of Vinyl Products.

Dr Fairless introduced the evening lecture by giving a short but comprehensive guide to the history of "Pressure polymers". The most common types were the copolymer of ethylene and vinyl acetate, and the terpolymer of ethylene, vinyl acetate and vinyl chloride.

The speaker then reviewed the currently available monomers both "soft" and "hard", their physical/chemical properties and cost comparisons.

Ethylene, as a modifying soft monomer, could be seen to be most cost effective in comparison to the more traditional monomers. This was well illustrated by a series of slides detailing such properties as minimum film formation, elongation and heat seal. Ethylene as a comonomer also played an important role along with vinyl chloride in achieving improved alkaline and water transmission rates when polymerised with vinyl acetate.

From the available information it was self-evident that to meet individual paint manufacturers requirements no one combination of the three monomers could provide a universally acceptable terpolymer. Ample evidence was provided in the form of 6-7 year weathered panels showing terpolymers to be superior products to the traditional copolymers, and comparable to the currently available styrene-acrylics and pure acrylics.

As for the future, Dr Fairless was confident that terpolymers will provide more technical advances. It was stated that in one area alone, that of fire retardant finishes, terpolymers were well ahead of the field.

The lecture ended with an informative discussion on CPVC and the important role played by the terpolymer particles and the many surface treatments to be found on rutile titanium dioxide.

A lively question time followed the talk and the meeting finally closed with a vote of thanks by Mr John Gant, endorsed by the audience in the usual manner.

J. Gant

JOCCA

UK paint contracting businesses sold

International Paint has sold the majority of its UK paint contracting businesses to their respective managements.

The marine paint contracting business (International Marine Contractors) and the industrial paint contracting business (International Structural Contractors) together with the scaffolding division was sold to DMB Contractors Ltd with effect from 1 October 1983.

The blasting and paint application equipment supply business (International Contracting Equipment) has been sold to Inmar Contracting Equipment Ltd which is controlled by the previous management of ICE headed by Mr J. Hughes.

The London branch of International Structural Contractors (which used to trade as T H Kenyon & Sons) and the insulation business (which trades as THK Insulations) are retained by International Paint.

Reader Enquiry Service No. 31

Swale Chemicals move

The continued expansion of both the UK and overseas business of Swale Chemicals Ltd, the manufacturer of coatings and inks for converters, has necessitated a restructuring of its research and sales functions.

Two major improvements scheduled to take place at the end of this year have been announced by Swale. Firstly, the sales office and development laboratories will move from Thornton Heath to new purpose-built premises at the main production plant at Darlington. Secondly, the sales force for the southern area will be strengthened by a new technical service laboratory at Iver, in Buckinghamshire.

Reader Enquiry Service No. 32

Colour and special chemicals

The Colour & Special Chemicals Division of Durham Chemicals Distributors Ltd is now offering its services as an independent supplier of pigments, dyestuffs and auxiliaries following the termination of its distributor agreement with ICI in this product sector.

The Division's product range includes azo, lead chrome, phthalic blue and green pigments, oil- and solvent-soluble colours, acid, basic and direct dyestuffs, chrome and iron oxides, and pigments dispersed in aqueous, solvent and alkyd resin media.

Henceforth, marketing will be heavily

concentrated on long-established own-brand names as has traditionally been the case with its Keegan group of dyestuffs, pigments and auxiliaries for the textile and leather trades. Colour & Special Chemicals Division's national distribution and technical back-up services continue from Gomersal in West Yorkshire and Peckham, London.

Reader Enquiry Service No. 33

Bayer UK move

Bayer UK Ltd has moved its headquarters from Richmond, Surrey, to new offices in Newbury, Berkshire.

The move involves the company's head office staff and six sales divisions as well as the Pharmaceuticals Division from Haywards Heath, Sussex.

Continued growth of the company, which has increased its turnover four-fold to £200m in the last ten years, has put increasing pressure on office space at the two locations, says managing director John Webb.

"The reasons for our choosing Newbury included the good communications to all parts of the country, the pleasant environment for us to work and live in, and the fact that the building was tailor-made for us and has room for future expansion."

As well as the corporate divisions, the Organic, Inorganic, Rubber, Plastics & Surface Coatings, Polyurethanes, Pharmaceuticals and Consumer Products divisions will have their headquarters in Newbury.

Reader Enquiry Service No. 34

Ex B + T director forms Simlak Ltd

In May of this year Colin Hampson left Briggs & Townsend (B + T Polymers), where he held the position of director - operations, following many successful years as director of sales and marketing. He has since established Simlak Ltd, which will operate from Kent Works, Thomas Street, Congleton, Cheshire, and which will be active in speciality chemicals, high performance polymers and polymer additives and polyurethanes.

His technical and international marketing experience will ensure that Simlak provides motivated and technically strong product representation and distribution, and management and marketing services. In addition, Simlak will arrange and coordinate local manufacturing facilities.

Although the company will initially concentrate on the UK market, a number of agreements are already established under which Simlak will source and purchase a wide variety of raw materials

and equipment for overseas-based manufacturers. Current discussions include 1984 contracts totalling almost £1m for dibasic acids, glycols, isocyanates and laboratory equipment.

Reader Enquiry Service No. 35

Berger group reorganisation and investment programme

A reorganisation and investment programme for the UK Region of the Berger Group (Berger Jenson & Nicholson) has now been completed under the group chief executive, Mr T. B. Collins.

The Berger Group, part of Hoechst, manufactures and distributes paints, resins, wood preservatives, industrial sealants, household chemicals and wall-coverings in 32 countries throughout the world. Total sales for the Group's 43 companies exceeded £278m in 1982. The Group, which has its headquarters at Berger House, Berkeley Square, London, is run in three main geographical trading areas: the UK Region, the Pacific Region and the Overseas Region.

The £108m (sales) UK Region of the Berger Group has been reorganised over the past two years to form eight specialist companies, each with its own management and operating from separate production sites.

A new management team has been appointed based at the regional office in Bristol. It is led by Mr W. M. Collins who is the supervising director for the UK Region and chairman of the eight companies; he was formerly chairman and chief executive of Cuprinol Ltd, a company within the Berger Group. Mr G. M. Weightman has been appointed commercial director for the UK Region from financial director of Cuprinol Ltd. And Mr P. J. Medcalf has been appointed marketing and planning director for the UK Region from marketing manager of the Berger Group.

Formerly, there were five companies in the UK, Berger Paints, Berger Traffic Markings, Cuprinol, PGW Holdings, and Arthur Johnson. The new structure has been completed by the separation of Berger Paints into four separate specialist operations. They are: Berger Elastomers, Resinous Chemicals Ltd, Berger Decorative Paints, and Berger Industrial Coatings.

With the backing of Hoechst the Berger Group is in the middle of investing a total of £5m in the UK to help equip individual companies for growth in their specialist areas. And it has been announced that a further £3.25m is to be invested in the development of Berger Decorative Paints and Berger Industrial Coatings.

Reader Enquiry Service No. 36

products

Colour and appearance measurement instrument

HunterLab has announced the introduction of a new colour and appearance measurement instrument, the LabScan II™ Spectrocolorimeter. With LabScan II, users will be able to select the most applicable of HunterLab's two optical sensors – 0°/45° or sphere – and combine them with a fully interactive DEC Rainbow™ Personal Computer.

Reader Enquiry Service No. 37



The LabScan II Spectrocolorimeter with 0°/45° and integrating sphere optical sensors

New coating thickness gauges

A new range of Mikrotest coating thickness gauges from Electro-Physik measure coating thicknesses up to 10 mm on steel. There are three different scales available: Type S3, 200 microns to 3 mm; Type S5, 500 microns to 5 mm; and Type S10, 2.5 to 10 mm.

These gauges are suitable for measuring heavy duty coatings and can also be used to measure the thickness of plastic and GRP, provided that a steel plate can be held on the opposite side to the gauge.

Reader Enquiry Service No. 38

Wettability tester

Now available from George Meller Ltd is the L & W Surface Wettability Tester. It is designed to determine the wettability of paper, board, plastic, textiles, metal surfaces, paint films and other materials by means of contact angle.

The tester consists of a sample holder, light source, microsyringe, microscope and a projection screen with graduated scale. It may be used with water, oil, wetting agents, size for corrugated fibreboard or other liquids.

To carry out a test a measured drop of liquid is dispensed from the microsyringe onto a surface. The magnified image of the drop is focussed on the matt glass screen and the height and the base dimensions of the drop are measured. With these figures the contact angle is obtained from a nomogram supplied with the unit.

Reader Enquiry Service No. 39

Tannic acid rust conversion

Increasing interest is being shown in tannic acid for rust treatments.

Tannins have for many years been known to convert rust to stable iron tannates. Hydrolysable tannins (e.g. gallotannins or tannic acids) are preferred because, when compared to condensed tannins, they produce a stronger bond to the iron.

Stetley Chemicals Ltd has been working for several years with Silva of Italy who produces a comprehensive range of tannic acids including several grades suitable for rust converter applications. Other applications for tannic acid include after-treatment of dyed nylon, printing inks, and clarification of some foodstuffs and beverages.

Further information and samples are available by completing the Reader Enquiry Service form at the back of the Journal.

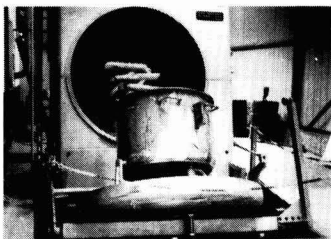
Reader Enquiry Service No. 40

Jenag distributor for Rio Beer cleaning machinery

Jenag Equipment Ltd has concluded an agreement with Rio Beer Maschinenfabrik AG of Niederwil, Switzerland to market its complete range of industrial washing plant exclusively throughout the UK.

The Swiss company is said to be the originator of automatic washing systems for drums and mixing vessels and is a major worldwide supplier of cleaning plant. The new product range, known by its brand name Beer, is capable of cleaning all types of vessels and associated process equipment automatically and comprises numerous models in a variety of specifications to cater for all capacities and potential cleaning applications.

Jenag itself has long been involved in the development of equipment for the separation and removal of foreign matter from all types of industrial substances and sees the move as a logical step



Safety and efficiency are described as being the main features of a new range of Swiss made, automatic drum and mixing vessel cleaners from Jenag Equipment

forward in an effort to offer its UK customers the latest in-plant cleaning technology.

Reader Enquiry Service No. 41



The new Graco Contractor Spray Gun, designed with long service life in mind

New long-life spray gun from Graco

Graco UK Ltd has announced the introduction of a new airless spray gun which it is claimed gives up to 30 times longer life than its nearest competitor.

Designed specially for arduous, high volume applications, the new Graco contractor gun has a specially designed leak-free needle-seal and an easy dismantling procedure for cleaning (no tools are required for this operation).

Light in weight (590 g), the new gun comes with a 2-finger trigger as standard, but can be specified with a 4-finger trigger. A stainless steel guard is fitted to prevent accidental triggering, which unclips speedily to allow removal of the filter. The fluid tube is manufactured from chemically resistant stainless steel, and the hose attachment at the base of the gun is fitted on a swivel to allow easy wrist movement in operation. A safety guard is fitted as standard to keep the operators' fingers well clear of the spray fan. The defuser is manufactured from carbide, and there is the usual Graco hook at the top of the gun for easy and convenient storage.

With a working pressure of 252 bar (3,600 psi), the gun has been tested to a burst pressure of 1,260 bar (18,000 psi).

The Graco contractor gun accepts all conventional airless spray tips, together with Graco's Reverse-a-Quick and Reverse-a-Clean patented tips.

Reader Enquiry Service No. 42

New polymer and resin remover

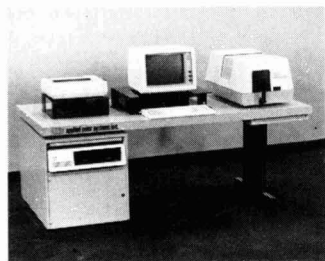
Drew Ameroid UK Ltd has introduced a new liquid non-silicate alkaline cleaner, Drewclean 32.

This non-flammable product is designed to remove polymer and resin deposits from reactors, storage tanks, pipework, pumps, filters, road and rail tankers, and other production and transportation equipment. It may also be used for cleaning small components by soaking.

Drewclean 32 is claimed to be cost efficient in that it is effective for up to six treatments. It is also claimed to reduce cleaning times by as much as 80 per cent through its rapid action, with a resultant decrease in costly plant closure times and the periods for which tankers are off the road.

It has high penetrating power which means that only low volumes need to be used and therefore disposal problems are kept to a minimum.

The cleaner is ideal for use with steel or stainless steel equipment, but it should never be used in contact with aluminium. *Reader Enquiry Service No. 43*



New compact and economical colour control systems from ACS feature IBM personal computer and Color-Calc software for colour quality control, colour formulation and batch correction

New colour control systems

Applied Color Systems Inc., a subsidiary of Armstrong World Industries, has announced the introduction of a new series of computerised colour control systems to complement its line of Digital-Equipment-Corporation-based systems. All of the new systems include the IBM personal computer, feature colour graphics display and utilise Color-Calc software, a program package recently developed by ACS.

According to ACS marketing manager, James DeGroff, the new systems were designed to meet a growing market demand from smaller companies in the textile, paint, plastics and printing industries.

Reader Enquiry Service No. 44

literature

Custom chemical synthesis

A second, revised and updated edition of this unique guide to companies offering custom chemical manufacturing facilities in the UK has just been published by Industrial Aids Ltd at £95.

The guide is intended to assist companies contemplating the use of custom chemical synthesis services or seeking technical or commercial links with other concerns (e.g. through licensing or joint venture agreements).

This second edition of the UK guide brings together details of 61 companies or manufacturing sites providing custom chemical synthesis services on behalf of outside organisations.

Reader Enquiry Service No. 45

Paint faults and remedies

Specialist paint manufacturer H. Marcel Guest Ltd has published a new and totally revised edition of its guide to "Paint faults and remedies".

A useful guide to the cause and correction of faults in paint and paint application, the A4-size leaflet opens out to an attractive and easy to use A2 wall chart.

The guide also includes hints on successful application of spray paints, guidelines on spraying metallic colours and tips on how to get the best results from paint.

Copies of the guide can be obtained free of charge from H. Marcel Guest Ltd by completing the Reader Enquiry Service form at the back of the *Journal*. *Reader Enquiry Service No. 46*

Product guide and reference data

MikroPul Ducon Ltd, manufacturer of air pollution control equipment and pulverisers, has published a product guide combined with a useful set of reference data. The brochure covers the company's range of products from simple filters through specialist equipment to complete air pollution control systems, gas scrubbers and pulverisers. Seven of the 16 pages are devoted to reference data relevant to the design of dust control systems. Tables of conversion factors together with charts for use in determining friction losses within ducting are provided.

"Product guide with reference data and tables" is available by completing the Reader Enquiry Service form at the back of the *Journal*.

Reader Enquiry Service No. 47

Philips analytical catalogue

A full review of the combined Pye Unicam and Philips analytical instrumentation capability is now available for the first time.

This 44-page catalogue reveals the strides in automation that have been made in the company's products during the past year – in UV/VIS, IR and AA spectrophotometry, chromatography, and X-ray, emission and electrochemical analyses alike.

The catalogue is available by completing this month's Reader Enquiry Service form.

Reader Enquiry Service No. 48

Free periodic table

Beckman has recently produced a periodic table of the elements in the form of a large colourful wall chart. Illustrated with colour photographs of the Beckman SpectraSpan IV, V and VI plasma emission spectrometers, the chart tabulates direct current (DCP) and inductively coupled (ICP) plasma detection limits in mg/l⁻¹ for the 70 elements which are determinable by plasma emission.

This wall chart is available free of charge by completing the Reader Enquiry Service form at the back of the *Journal*. *Reader Enquiry Service No. 49*

people

S. C. Johnson and Son Ltd has appointed **John F. Ambury** to the Canadian Specialty Chemicals Group as product specialist. He will contribute marketing and technical sales support for Johnson Wax polymer products used by the ink and coatings industries.

Mr Ambury has been associated with these industries for 20 years and maintains active membership of the Toronto Society for Coatings Technology as well as of OCCA. He will be based in the new Innochem Mississauga office.



BASF United Kingdom Ltd has announced that **Bryan Rigby**, presently deputy director general of the Confederation of British Industry, will join the company on 1 January 1984.

Bryan Rigby (50) is a Fellow of the Institution of Chemical Engineers and has been with the CBI for the last five years. Prior to that he was commercial director of Laporte Industries (Holdings) Ltd.

After a familiarisation period with the

parent company in Germany, he will take over as managing director from **Walter Maack** who will be retiring in the course of 1984 after more than 20 years service with BASF United Kingdom Ltd. In this function Mr Rigby will also be responsible for coordinating the activities of the BASF Group in the UK.



Dr K. G. Sansom has been appointed managing director of the Laporte Australia Group, the biggest overseas manufacturing and trading subsidiary of Laporte Industries.



Laporte Industries (Holding) PLC has announced that Sir John Hedley Greenborough, KBE has joined its board as a non-executive director with effect from 6 October.

exhibition news



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

THE INTERNATIONAL FORUM FOR THE SURFACE COATINGS INDUSTRIES

Official Guide

The *Official Guide* to OCCA-35 will be published in the April 1984 preview issue of *JOCCA*. Exhibitors, as part of the package deal, will be offered a 50 per cent reduction on space bookings in this issue (colours extra at normal rates). The *Journal* has a worldwide circulation and an estimated average readership per issue of over 22,000 (see its Audit Bureau of Circulation's Media Data Form for which *JOCCA* won the Reed International Award in November 1980) and advertisements in this prestigious publication reach readers in over 80 countries. Copies of the Media Data Form are available on request.

Exhibition Hall

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

Audited attendance

The Association completes the *Exhibition Data Form* of the Audit Bureau of Circulation and copies are obtainable on request. Not all exhibitions complete these important forms but wherever they do exhibitors are urged to compare them with this Association's, as it will be seen

that a very wide spectrum of those in the industries from 30 countries are attracted to the Exhibition and the cost of contacting such numbers by other means would be far greater than showing their products and services at OCCA-35.

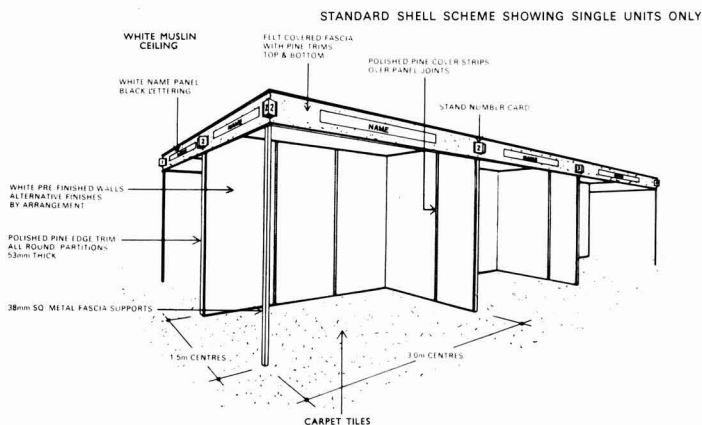
Competitions

The Association welcomes competitions on stands and points out that small "give aways" are often of considerable value in reminding visitors of information supplied from the stands concerned.

Lecture series

Following the successful introduction of lectures by exhibitors in 1982, this facility will be repeated at OCCA-35.

Any company wishing to receive copies of the ABC's *Exhibition Data Form* or copies of the *Invitation to Exhibit* should contact the Director & Secretary of the Association at Priory House, 967 Harrow Road, Wembley, Middlesex HA0 2SF, England (telex 922670, telephone (01) 908 1086).



Note: In addition to the shell scheme shown above, a few complete rooms for exhibitors and "stand space only" in the Drake Suite (all without shell scheme) are available on the mezzanine, where the Lecture Hall is situated

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additive for latex decorative masonry finishes. It prolongs the "open time" and prevents cracking.

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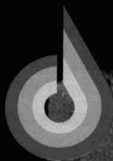
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This position has arisen due to a number of factors. They include promotion of the present Manager, expansion of production facilities to meet increasing business, recent acquisitions and the need to implement a modernisation programme.

Reporting to the Operations Manager, you would control and motivate around 90 hourly paid shift workers, plus a team of five Production Supervisors. Essentially you will need to be a good planner, making sure production schedules are adhered to, co-ordinating the priorities of customers, warehouse and sales. If you're around 30 with a strong technical background in production — ideally in surface coatings — and good man-management skills, our client would like to hear from you. A good negotiable salary is offered and benefits

include relocation expenses where appropriate.

Controller Warehousing and Distribution

Reporting to the Operations Manager, this is a position which both controls the warehousing function and plays an important role in planning and co-ordination. You would be responsible for controlling the function in terms of manpower, looking at working methods with a view to improving techniques, liaising with sales and marketing and taking an in-depth view of overall planning to meet the needs of future developments.

A sound background in warehousing and distribution is obviously of prime importance, ideally with relevant qualifications. In view of our clients products, knowledge of inflammable materials and storage would be an added advantage. Preferred age is 35+. A competitive negotiable salary is offered together with benefits which include relocation expenses where appropriate.

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appointments, please write with full c.v. to

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MISCELLANEOUS

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Bound copies of papers (86 pages) presented to the Silver Jubilee Convention in Melbourne are available at Aust.\$25.00 per copy (post free by surface mail). Please forward your request for copies together with your cheque (Aust.\$25.00 per copy) to:

**OCCA Australia,
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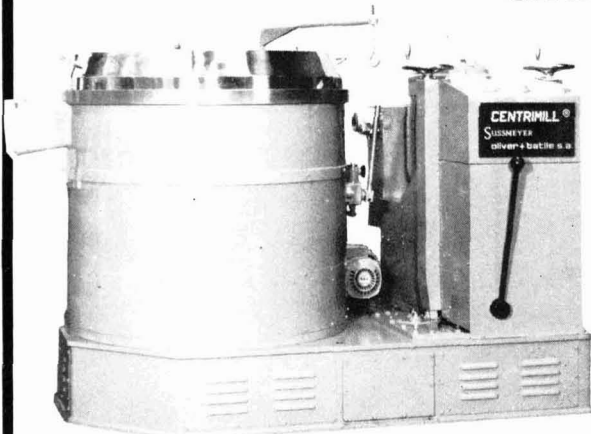
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B		
Bentham Instruments	(267)	Cover
C		
Chemische Werke Huls AG	(259)	v
H		
Henkel KGaA	(266)	ix
N		
NL Chemicals	(277)	viii
O		
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OSCA-35 Exhibition	(501)	Cover
P		
Pye Unicam	(260)	ii
Q		
Q-Panel Co	(275)	vi
R		
Riedel-de Haën	(274)	iv
S		
Sachtleben Chemie GmbH	(276)	vii
Sanyo-Kokusaku Pulp Co. Ltd	(112)	vi
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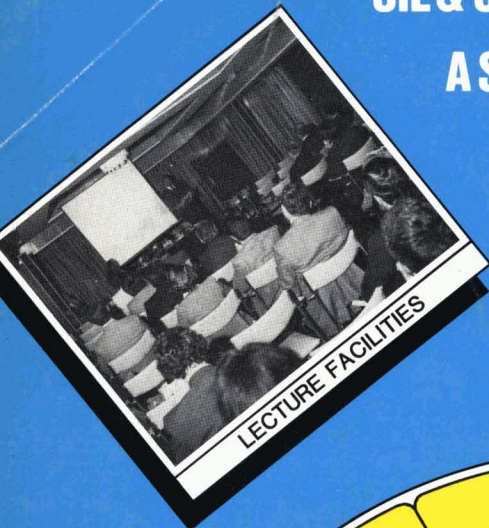
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(OCCA G)

Photocopy or cut out form and send to above address.

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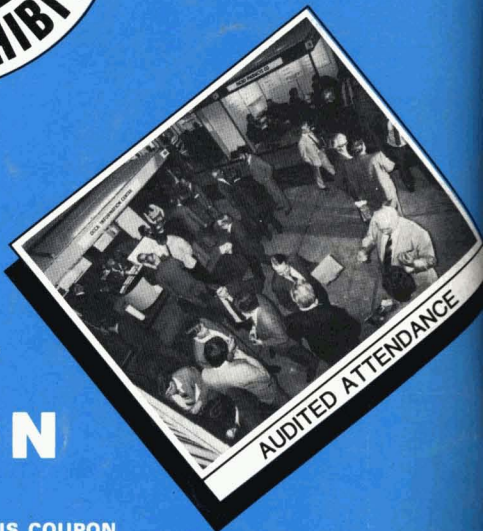
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We are interested in exhibiting at OCCA-35 (1-3 May 1984, Cunard International Hotel, London). Please send us a copy of the Invitation to Exhibit

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