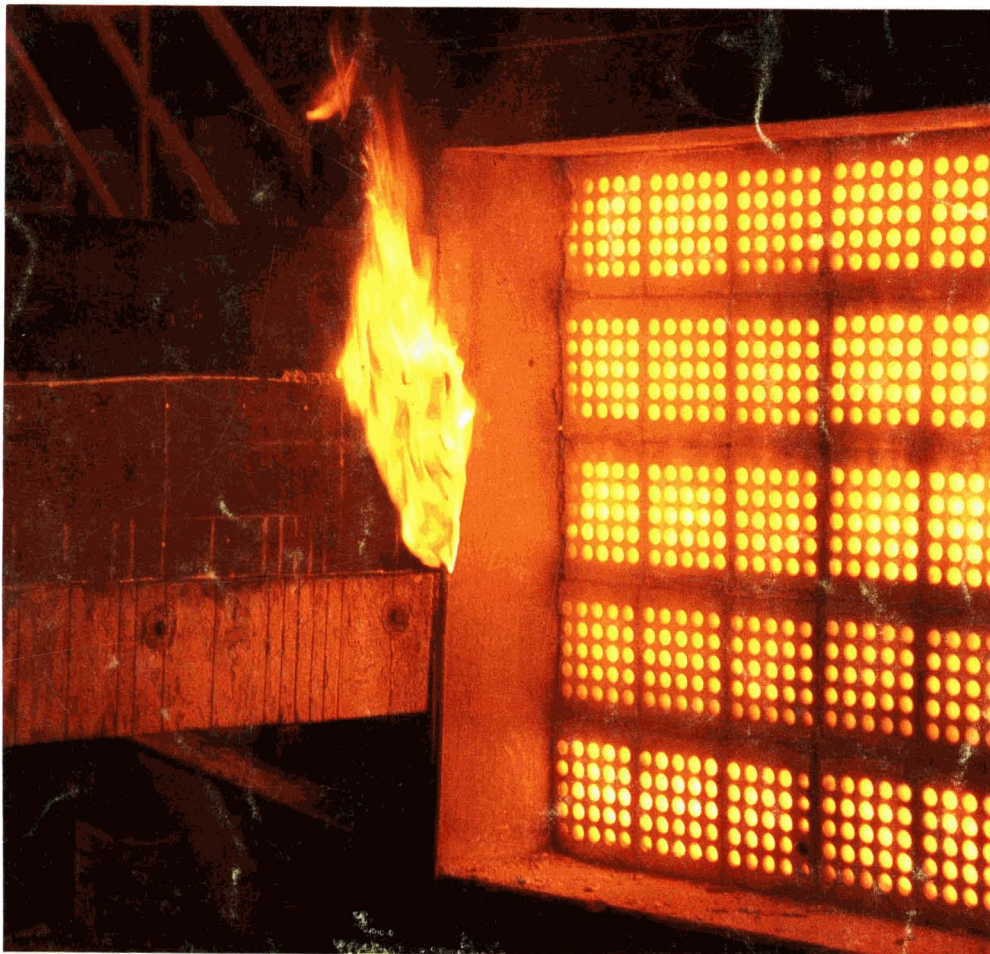


JOURNAL OF THE OIL AND COLOUR CHEMISTS' ASSOCIATION

JOCCA

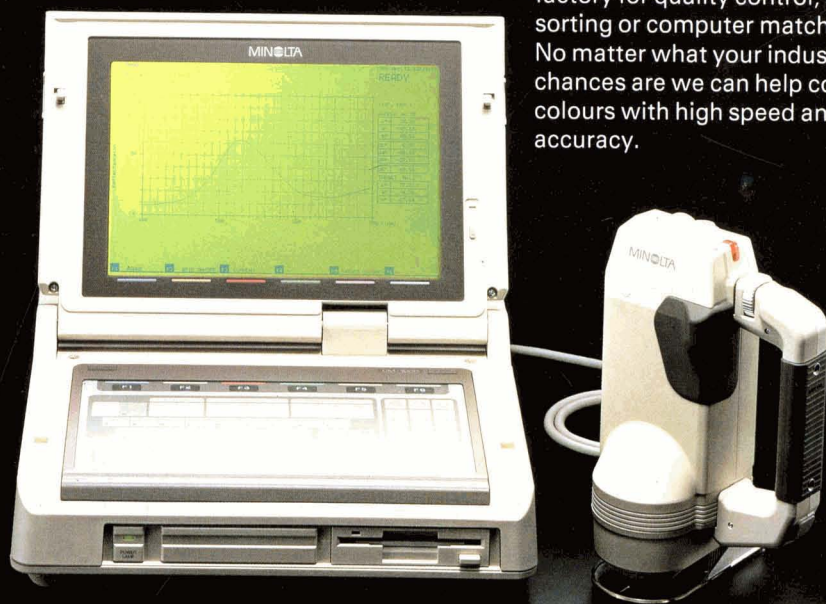


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Contents

Vol. 72 No. 5

MAY 1989

OCCA Conference 89	164
News.....	166
<i>Feature: Fire Retardant Coatings</i>	
Why protect structures and buildings	171
by C. Ian Smith	
The use of flame retardant coatings on walls and ceilings	177
by R. J. Shaw	
Intumescent coatings: protection of steel	181
by F. Allman	
The design and development of intumescent coatings for structural fire protection	185
by D. C. Aslin	
The role of insulating coatings in the fire protection of LPG vessels	192
by A. F. Roberts and K. Moodie	
<i>Transactions and Communications</i>	
Porosity measurement of aqueous coatings	196
by J. Anneveldt	
From the General Secretary	198
OCCA Meetings.....	199
OCCA News.....	201
Cover: BS 476 : Part 7 Surface spread of flame testing apparatus (Photo by courtesy of Ian Smith (Consultancy) Ltd).	

Forthcoming Features: June – Paint and the Environment, July – Printing Inks, August – Additives. Contributions are welcomed at least five weeks prior to publication date.

Oil and Colour Chemists' Association
Priory House, 967 Harrow Road, Wembley, Middlesex HA0 2SF England

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Chester Conference Column

At the time of writing we have not yet hit the 100 mark with registrations. I had hoped that we would have achieved this by the first week in April.

No doubt there are many who have already decided to come to Chester but simply have not got around to filling in the form on the back of the brochure. It would be appreciated if they would do so soon; apart from anything else their first choice of hotel may not be available much longer and the more attractive social events will have been fully booked.

In the case of the Lady Diana Evening River Trip, the number (for comfort) has been limited to 80 and this figure will be achieved very soon.

We do know that the Manchester and West Riding Sections are organising coach parties at a very much reduced rate for day-time attendance at the Conference. This price does not include Papers, Lunch and other full registration privileges. It is hoped that other Sections will follow suit and give an opportunity for delegates who are unable to attend the whole Conference to at least be there for part of it.

For those who have not as yet decided to register, we hope that they will give the matter serious thought. If anyone cannot attend this Conference, for one reason or another, there are two things that they can do:

1. Pass brochures (spares from Priory House) to contacts in industry who are not members,
2. Arrange for their company to take a complete table of 10 for themselves and business guests on the Friday night at the Dinner and Dance, for £135 (exclusive of wines etc.),

Do help us to make the Chester Conference a success so that I can set up the 1991 one at Cambridge with confidence knowing that I have your support.

Tony Jolly ■



Eastgate Street, Chester



Lady Diana Riverboat



River Dee, Chester

Social Programme

Wednesday evening (June 21)

The Ale Trail (a now famous series of tours around Chester's genuinely historic pubs with a very professional guide and with astounding surprises).

Thursday morning (June 22)

Tour of the City and its Roman Walls (an amazingly absorbing experience).

Thursday afternoon (June 22)

Coach Trip into the Welsh mountains with tea in Llangollen.

Thursday evening (June 22)

A few hours on board a riverboat through the Duke of Westminster's estate with good food and with a restrained jazz band.

Friday morning (June 23)

To Stapeley Water Gardens and The Palms Tropical Oasis (an experience unique to the UK—seeing is believing!).

Friday afternoon (June 23)

A visit to the Chester Heritage Centre (for as long as you like it the hairdressing appointment presses!).

Friday evening (June 23)

Reception, Dinner and Dance with the Lord Bishop of Chester and the Lord Mayor of Chester and their wives. Delegates and guests will be able to enjoy a good meal and dance to an excellent band.

The Town Crier of Chester will assist one of Her Majesty's Corps of Toastmasters in the more ceremonial occasions.

Chester is

1. on the UK motorwork complex
2. 35 minutes (by motorway M56) from Manchester airport.

Travelling times are approximately as follows:

“T” by Train, “R” by Road

London	3 hrs (T)	3½ hrs (R)
Leeds	2 hrs 10 mins (T)	1½ hrs (R)
Glasgow	4¼ hrs (T)*	2¾ hrs (R)
Bristol	3¾ hrs (T)*	2¼ hrs (R)

* includes changing trains



Town Crier of Chester

Oil & Colour Chemists' Association

International Conference on **Profitable Research and Development**

KEYNOTE SPEAKER

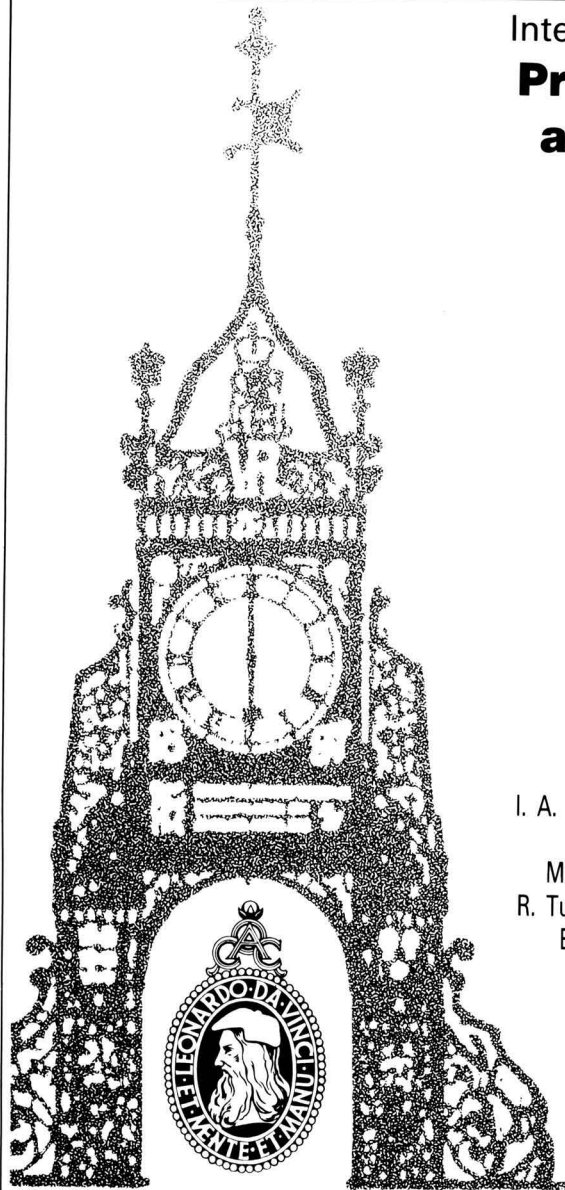
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21 - 24 June, 1989

**Chester
Grosvenor Hotel**



Contact OCCA on 01-908 1086 for Registration Form and
book a Company Table (10 places) at the Dinner Dance on Friday for £239.

Focus on France for ICI azo pigments business

ICI Colours and Fine Chemicals has sold its 40% interest in the Spanish pigment manufacturers, Intermedios Organicos SA (Intorsa), to Dainichiseika Colors and Chemicals Manufacturing Co Ltd, of Tokyo. The move is part of ICI's strategy to strengthen and develop its international pigments business concentrating in azo pigments particularly on the wholly owned ICI Francolor assets in France.

Boost to Baxenden's acrylic business

The speciality Chemicals Division of Baxenden Chemicals Ltd has acquired the Vinalak range of solution polymers from Vinamul Ltd, a subsidiary of Unilever. For the past five years Baxenden has co-operated closely with Vinamul in the manufacture and quality control of the products.

Baxenden's purchase is timed to coincide with a recent capacity increase for both acrylic and polyurethane production. The range, renamed Xenalak is used mainly in the manufacture of speciality coatings and surface treatments.

Wacker dispersions on course for growth

Wacker-Chemie is building a new production plant for vinyl acetate dispersions containing ethylene at its Cologne works. The project is due to be completed in 1990. Dr Karl-Heinz Michl, Director of Division Vinyl Acetate Polymers and Organics put the cost of investment in this new plant at over DM 20m. DM200m will be invested in the entire Division up to 1993, as Wacker's response to the increasing demand for dispersions and to consolidate the company's position in the market. Production of these dispersions began in 1964 by a process developed by Wacker, and today Burghausen has the world's largest annual production capacity at 100,000 tonnes. The new plant in Cologne will also operate by this process.

Manders Paints joins forces with Graco

Manders Paints and Graco have joined forces to offer a range of electric sprayers, powered rollers and accessories to users of decorative coatings. Manders will now be carrying the Graco coating equipment range for sale from branches in major centres across the UK.

Graco's Architectural Coating Range includes electric and petrol driven machines which will apply paints, coatings, sealants and grouting materials or any other architectural materials, single or plural component, by spraying, extruding or rolling.

The Graco range was launched to Manders Sales Force at a recent two-day course in Coventry, ensuring that efficient advice and assistance is available for Manders customers at the point of sale. This will be supported by Graco's own nationwide service network.



The Graco agreement launched at a recent Manders Conference. Seen inspecting the Graco PT2500 fitted with a powered roller are (left to right): Foreground: John Lawton, General Marketing Manager, Manders & Ken Dale, A.C.E. Manager, Graco UK Ltd. Background: Brian Ayres, Manders Paints, Mike Keep, Manders Paints & Robert Purshouse, Managing Director, Manders Paints.

BSI registered stockists scheme



The BSI Stockists Scheme has been designed to provide a quality system specification, including those elements essential for the effective management of the stock-holding function. A company assessed and registered against the BSI System is entitled to use the Registered Stockist Symbol as shown above (the stockist's registration number (RS No) must be used with the symbol).

The scheme is for manufacturers

who do not perform their own distribution functions. The BSI Scheme gives the distributor a quality assurance status, which demonstrates his competence in acquiring quality assured material, and the operation of a management system providing a degree of traceability.

The scheme is in two parts: under Part 1, all material stocked has lot traceability and any material sold in accordance with the stockist's registration will have been acquired from a quality assured source. Under Part 2, all material stocked retains the supplier identity and any material sold in accordance with the registration will have been acquired from a quality assured source.

For further information on the scheme contact Nigel Wickens on 0908 220908.

Further PA companies gain BS 5750



Recipients of the BS 5750 certificates with (centre left) Mr John E Ware, Director, Quality Assurance, BSI and the PA President, Mr W Junner.

Paintmakers who meet the British Standards Institute's criteria for quality management systems received recognition recently at the presentation of the BS 5750/ISO 9000 1987 scheme awards at the Paintmakers Association's offices in London.

Receiving certificates presented by John Ware, BSI's Director of Quality Assurance, were:

1. Becker Industrial Coatings
2. Carrs Paints Ltd
3. Coates Industrial Finishes
4. Crown Berger Europe Ltd
5. Crown Decorative Products
6. Desoto Titanine PLC
7. Freemans Chemicals Ltd
8. F T Morrell & Co
9. Holden Surface Coatings Ltd
10. H Marcel Guest
11. International Paint Felling
12. Kalon Group
13. Mebon Paints Ltd

Since 1985, the Paintmakers Association has been instrumental in promoting the scheme throughout the industry.

"The British Standard is widely recognised as the leading international standard," said Paintmakers Association Director, Michael Leveté. "In the run up to 1992 and harmonization of European Industrial practices,

achievement of quality standards will be crucial."

To win the award (and keep it in succeeding years) each paintmaker has to undergo assessment by BSI specialists. Each company's management systems concerning quality are scrutinised.

The whole paint development, manufacturing and supply procedure, from the purchase of raw material to customer service, is reviewed. BSI check that quality controls are not just seen to be working but are 100% effective under all circumstances.

1989 Queens Awards for Export

Three raw materials suppliers to the surface coatings industry have been awarded the 1989 Queens Award for Export Achievement:

1. Allied Colloids Group Plc, Bradford, W. Yorkshire, for Industrial Chemicals.
2. Ciba Geigy Pigments Division, Paisley, Renfrewshire, for Organic Pigments.
3. ECC International (Sales) Ltd, St Austell, Cornwall, for China-clay Pigments.

Presentations will be made on behalf of the Queen by Her Majesty's Lord Lieutenants during the coming months.

Products

Class O anti-graffiti system

Tor Coatings Ltd Torlife Anti-Graffiti System has been awarded by the Warrington Fire Research Centre full 'Class O Surface' fire safety certification. The tests were carried out in accordance with parts 6 and 7 of BS 476.

For further information Enter E199

New water-based ink/lacquer resin

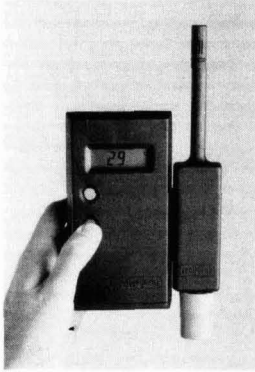
A new heat-resistant, high gloss resin for water-based inks and lacquers has been developed by Allied Colloids. It is designated LS22P, part of the Glascol range of polymers for water-based inks and lacquers, and is a hard, high melting point product.

Glascol LS22P has been developed as a vehicle for high gloss water-based overlacquers and as a let-down vehicle for high gloss inks requiring high heat resistance for use particularly on pre-print liner board. It is used as the principal component, contributing gloss, hardness and clarity.

For further information Enter E200

Equipment

New diagnostic thermo-hygrometer



A new addition to the Sheen range is the Diagnostic Mk IV Thermo-Hygrometer, which is designed for the measurement of relative humidity and air temperature.

By using the built-in slide rule on the back of the instrument, these two measurements will then give the dew point temperature. An optional extra to the instrument is a new design, fast response surface thermometer, covering the range -50 to $+100^{\circ}\text{C}$.

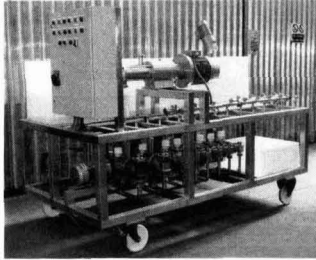
If the thermometer shows that a surface to be painted is colder than the dew point temperature (as calculated on the slide rule), then condensation is taking place. However, if the wall is warmer, then there is no condensation at the time of inspection. The instrument will be of interest to painters of steel structures in non-tropical climates (i.e. the UK) where condensation is a problem.

For further information Enter E201

Continuous liquid blending trials Facility

Bran & Luebbe have produced a transportable trials facility, which enables liquid processors to evaluate and prove complex formulations either at their own location or at Bran & Luebbe's Northamptonshire headquarters.

The trials system consists of a multi-compartmentalized tank, which can store up to eight different liquid components. Should it be necessary to accommodate more than eight ingredients, either compatible liquids can be premixed, or additional storage and pump-heads provided. The facility for heating or agitating liquids stored in these tanks is also available.

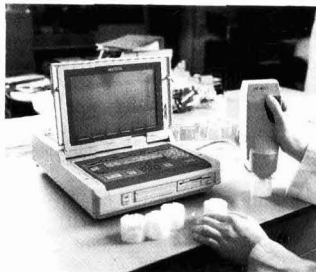


Bran & Luebbe's trials blending facility
For further information Enter E202

Minolta launch new spectrophotometer

The new Minolta Spectrophotometer CM-1000 breaks new ground with a low-priced revolutionary design. This unit comprises a measuring head connected to a control/analysis unit via a flexible electronic cable. The lightweight, portable measuring head and easy-to-handle measurements make it possible to use the CM-1000 directly on the production line for the assessment of large objects such as car bodies as it is not necessary to place a small sample in a limited measuring port. On the other hand the 8 mm measuring aperture also allows for comparisons on small objects and components to be carried out.

Minolta CM-1000



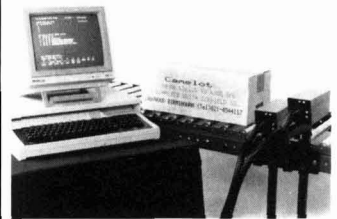
A radically new sensor system has been designed by Minolta on the basis of interference filters which are coupled to a highly sensitive silicon photodiode array; this allows the size of the measuring head to be kept very small and light when compared to other equipment which is currently available on the market.

The actual spectral measuring range covers from 400-700nm in 10nm steps and in order to keep thermal disturbances from outside as low as possible the Ulbricht sphere is made up of a fine ceramic binding material. The results of these precautions is evident in the short-term repeatability of the instrument; the maximum deviation in the reflectance data is 0.1%, e.g. a total colour deviation ΔE^*_{ab} of 0.03.

The CM-1000 is fully portable since the control and analysis unit is a "lap-top" type computer with a large liquid crystal display (dot matrix with 640×400 characters).

For further information Enter E203

Updated case ink jet printer



Alpha-Dot Ltd, designers and manufacturers of a range of large character Ink Jet Printers for case coding/marketing operations, has updated its computer controlled model, to produce the advanced Starline System. Capable of controlling up to 12 print lines in any configuration, the system has centralised control by means of a keyboard and monitor. The system allows up to 4 lines of print to be changed within seconds using the user-friendly self-help menu. A 7×5 dot matrix - 7×10 double dot (bold) offers a choice of 7 print heights from 12-50 mm with a full selection of upper and lower case characters.

For further information Enter E204

Literature

Shaw pallet control

Shaw, leading U.K. pallet makers has produced a free information booklet on "Pallets and Product Liability within the terms of the new Consumer Protection Act".

For further information Enter E205

Non-asbestos braided packings

Merkel leading global braided-packing manufacturer has published a free 32p guide on its non-asbestos braided packing used in pumps, agitators and valves.

For further information Enter E206

Literature miscellaneous

Fryma has published two leaflets — 1. **Vacumix** modified vacuum dissolver designed for mixing highly concentrated systems and applied to preparation and redispersion of pigment mixers, pastes. 2. **Vacuum Deaerator** designed for the deaeration of liquid and pasty products.

For further information Enter E207

A brochure describing the new **ACS Chroma Sensor CS-5** and **ACS Chroma Sensor CS-3** has been issued by **Applied Color Systems Inc.** of New Jersey, USA. The ACS Chroma Sensor CS-5 is a dual-beam continuous scanning spectro-photometer.

For further information Enter E208

Health and Safety commission

April 1989. Approved code of practice "Rider operated lift trucks — operator training" available from HMSO, price £2.75.

Health and Safety Executive Guidance Note GS46 "In situ timber treatment using timber preservatives" available from HMSO.

BS6949: 1988. Spec for bitumen-based coatings for application, excluding use in contact with potable water. To purchase call 0908-220022.

Meetings

FSCT Paint Show

The FSCT paint show will be held at both the Exhibition Centre of the New Orleans Hilton and at The Rivergate on 8-10 November 1989.

The New Orleans Hilton is conveniently located next to The Rivergate, and will also be the site of all technical programming during the 67th Annual Meeting of the Federation, which will be held concurrent with the Paint Show.

The theme of the annual Meeting, "Coatings Worldwide: Meeting the Needs of the Nineties," underscores the coatings industry's heightened awareness that it is part of a global marketplace, and that all areas of interest and endeavor are being viewed from an increasingly international perspective. OCCA members wishing to present a paper on behalf of the Association please contact the General Secretary.

For further information contact the FSCT at 1315 Walnut St. Philadelphia, PA 19107, USA or telephone 215-545-1506.

Flexo printing

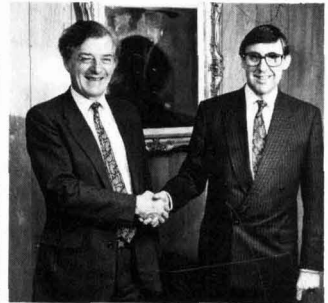
A one day seminar on "Flexo Printing & the Environment" will be held by EFTA on 13 June 1989 at the Redwood Lodge Hotel, Bristol. Developments in flexo inks will be detailed. Price £69. For further information call Jack Birch on 0272 878090.

Eurobondex '89

Eurobondex '89 an exhibition and conference organised by FMJ International will be held at the Heathrow Penta Hotel (Conf 19-21 June '89, Exh. 21, 22 June '89). The exhibition will highlight trends and developments in raw materials, manufacture, application and end use of adhesives and sealants. The conference organised by Dermil Research Ltd, will be on 'Speciality Hot Melts and Sealants'. For further details, call Mike Tarrant on 0737 768611.

People

Samuel Banner appoints a new Director



Stuart Lloyd (right) being congratulated on his new appointment by Christopher Banner, MD Samuel Banner.

Samuel Banner the vegetable oil refining company/solvent, chemical and fuel distributor has recently formed a new division in speciality chemicals/contract packing. Stuart Lloyd has been responsible for developing this business during the last five years. Mr Lloyd joined Samuel Banner 13 years ago in their Liverpool laboratory and in 1977 he joined the Solvents Marketing Department selling commodity chemicals. Mr Lloyd has been appointed to the board of Samuel Banner from 3 April 1989.

The new division of Samuel Banner is an expanding area of the company and Mr Lloyd looks forward to developing the future potential. The division already has agencies for Angus Chemicals, Du Pont, Eastman-Kodak and PPG.

Binks-Bullows appointment

Reg Pyatt has been appointed Export Sales Manager for Binks-Bullows Limited of Walsall, West Midlands.

Mr Pyatt's new responsibilities will include export sales and marketing in Eastern Europe and Asia, and will be developing the growing markets for product finishing equipment in the Middle and Far East.



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Why protect structures and buildings?

by C. Ian Smith, Ian Smith (Consultancy) Ltd., Warlaby Lane, Ainderby Steeple, Northallerton, North Yorkshire, DL7 9JX, UK

Introduction

The main purpose of this paper is to introduce various uses of surface coatings in fire protection, and to define some of the "terminologies" which are used in legislation, testing and assessment of performance.

The breadth of the subject is considerable, and there are numerous applications of surface coatings in fire protection such as:

- Their use to improve the fire spread characteristics of substrates which are combustible in nature. This could encompass a variety of applications and substrates including timber and other lining materials, polymers, electrical cables, and even textiles, and floor coverings.

- Their use to maintain the fire spread characteristics of non-combustible substrates which need to be coated for other reasons, e.g. colour, durability and mechanical behaviour.

- Their use to improve the fire resistance of substrates and materials, e.g. loadbearing and non-loadbearing components, including structural steelwork, cast iron, wrought iron, bulkheads on ships and offshore structures, concrete and other floors, structural aluminium, and cable and service penetrations in walls and floors.

There are two principal reasons why structures and buildings are protected against the effects of fire, namely:

- Life safety.
- Minimising financial loss.

Legislation like the Fire Precautions Act, the various Building Acts, and Offshore Guidance Notes generally outline requirements for fire design related to safety of the public and rescue services, while specific requirements of insurance companies attempt to minimise the financial consequences of major fires.

Despite this legislation, many fires occur in public buildings and other structures on a regular basis. In the last four years several major well publicised fires have occurred in the UK like Bradford Football Club¹ in May 1985, King's Cross² in November 1987, Piper Alpha³ in July 1988, and the second Donnington Warehouse fire in April 1988.

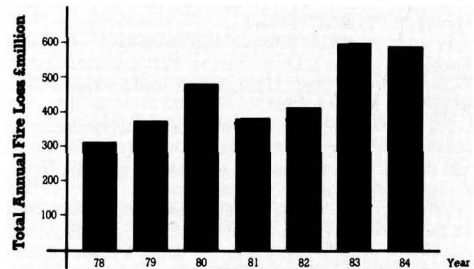
The statistics indicate that approaching 1,000 fatalities occur in the UK on an annual basis (Figure 1). However, it should be noted that the majority of fatalities arise in

domestic buildings, as opposed to the industrial, commercial assembly and institution buildings where legislation plays a major role in the choice of materials and forms of construction.

The statistics indicate that the financial loss which occurs as a result of fire approaches 600 Million Pounds per annum, however, only a small proportion of this loss arises from domestic building fires (Figure 2).

Figure 2

Summary of fire losses in the UK over the period 1978-84.



Fire Design of buildings and structures should include a wide variety of measures as follows:

1. Prevention of fire.
2. Detection of fire.
3. Restriction of fire growth.
4. Provision of means of escape.
5. Smoke control provisions.
6. Fire resistance of the structure.
7. Compartmentation of the building.
8. Prevention of conflagration.
9. Portable extinguishing devices.
10. Fixed extinguishing systems.
11. Fire brigade assistance.
12. Management including fire safety management.

Consequently structural fire protection, and the control of fire spread forms only part of an overall design approach to ensure fire safety in buildings and structures.

The England and Wales Building Regulations⁴ are now expressed in functional terms and Schedule 1 of Statutory Instruments 1985 No. 1065 entitled "Building and Buildings, the Building Regulations 1985". Part B deals with Fire Spread. The wording of the requirements listed in Clauses B2-B4 inclusive are outlined in Appendix 1.

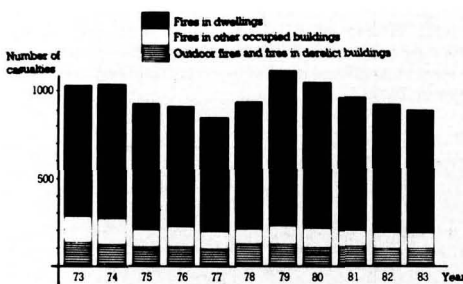
The importance of surface coatings in fire protection arises from consideration of requirements to:

- prevent fire spread within the compartment of fire origin
- prevent fire spread to neighbouring compartments
- prevent fire spread across external surfaces of the building
- retain the stability of the building.

The Approved Document B⁵ presents practical guidance on how the functional criteria can be satisfied by reference to

Figure 1

Fire casualties in the UK over the period 1973-83.



specific criteria for various types and sizes of building for various different types of construction encountered.

The fire process is traditionally described as a three stage procedure namely ignition, growth, and the fully developed phases. Fire spread across vertical and horizontal surfaces relates to the growth phase, and materials and performance criteria are characterised and defined by "Reaction to Fire Tests". When the fire is "fully developed" temperatures of the order of 1,000°C can be encountered and test methods used to establish "Fire Resistance" are appropriate. Hence it is appropriate to discuss the contributions of fire protection materials under the headings "Reaction to fire", and "Fire Resistance".

Reaction to fire

A variety of test procedures are described in British Standards for the evaluation of the reaction to fire characteristics of materials used to line walls and ceilings in buildings. They include:

BS 476 : Part 5 : Method of Test for Ignitability⁶.

BS 476 : Part 6 : Method of Test for Fire Propagation for Products⁷.

BS 476 : Part 7 : Method for Classification of the Surface Spread of Flame of Products⁸.

In other countries different testing methods are adopted, for instance in the USA the Tunnel Test described in ASTM E 84, in France, the Expiradiateur, and in Germany, the Brandschacht test is used.

All these test methods involve the use of an ignition source, possibly with some form of radiant heating of the specimen and the test monitors the rate at which fire spreads across the surface, and/or with any heat release.

Essentially these test methods are used to classify the Performance of Materials used for Walls and Ceilings, and in the UK acceptable performance is defined in the Approved Document for specific areas in buildings by reference to Class 3, Class 1 and Class 0 performance.

The BS 476 : Part 7 test procedure classified products as having performance of Class 4, 3, 2 or 1 depending upon the extent of flame spread.

The BS 476 : Part 6 test defines indices of performance are allocated at various stages of the test to quantify the amount of heat released, namely the i_1, i_2, i_3 and I values.

Class 0 performance as required by Regulations is not defined in any British Standard, but is defined in Approved Document B, Appendix A as-

"Either a non-combustible material as defined by BS 476 : Part 4⁹ : 1970, or a product which achieves a Class 1 performance in the BS 476 : Part 7 test AND indices of performance i_1 less than 6 and I less than 12 in the BS 476 : Part 6 test procedures.

Several major fires have occurred which have led to multi-fatality incidents, principally as a consequence of the choice of materials used for surfacing walls and ceilings.

Some specific examples are as follows:

The Joelma Building fire in Sau Paulo, Brazil¹⁰ which occurred on the 1 February, 1974, caused 179 fatalities. Fire spread rapidly between floors due to the highly combustible nature of the wall and ceiling lining materials.

The Cing Sept Disco' fire at Saint Laurent du Pont, France¹¹, which occurred on the 31 October, 1970, caused 146 fatalities. The walls and ceilings of this disco' were covered in expanded foam to give the impression of a grotto.

The Stardust Disco' fire in Dublin¹² on the 14 February, 1981, resulted in 48 fatalities. The subsequent investigation and test work conducted by the Fire Research Station indicated that the combustible wall linings contributed to the very rapid rate of fire spread within the building.

More recently the King's Cross Underground fire² which

occurred on the 18 November, 1987, caused 31 fatalities, highlighted the importance of combustible materials around the escalators, although the use of fluid dynamic computer modelling was necessary to predict the very rapid rate of fire spread into the ticket hall.

It is therefore most important that appropriate materials should be selected to provide linings in modern buildings. If specific combustible materials are required then surface coatings represent one of the methods available to improve their fire spread characteristics. Several of the papers at this meeting are dedicated to consideration of this aspect of performance.

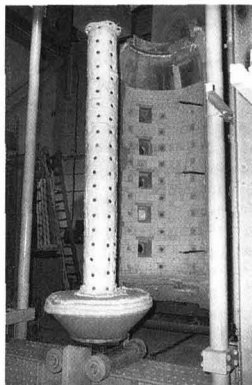
Fire resistance

The other major application for surface coatings is associated with the use of materials which improve the fire resistance of the underlying substrate.

The fire resistance of a loadbearing element of structure is evaluated using the BS 476 : Part 20¹⁴ and 21¹⁵ procedures. (BS 476 : Part 8¹³ has now been superseded) BS 476 : Part 20 is entitled "Method for determination of the fire resistance of elements of construction (general principles), and presents general principles, while Part 21 is entitled "Methods for determination of the fire resistance of loadbearing elements of construction" (Figure 3), and presents specific guidelines

Figure 3

"BS 476 : Part 20/21 Test Furnace for Columns". The specimen shown is a circular hollow section column protected with a ceramic fibre blanket supported from a welded stainless steel mesh.



for loadbearing elements. These procedures were formerly described in BS 476 : Part 8¹³. Similar test procedures are described in ISO 834, DIN 4102 Part 2, and other national standards. This test procedure generally involves column, beams, and/or floor constructions, which are tested under load (generally the maximum permissible value). The test member is heated using the internationally agreed temperature curve which was aimed at simulating the thermal exposure encountered in a fire involving cellulosic materials is shown in Table 1.

Table 1

Time (mins)	Temperature (°C)
5	576
10	678
30	842
60	945
120	1049

The member is deemed to have failed when it cannot support the test load which in the case of beams and floors is defined as either deflection greater than $L/30$ or a rate of deflection criteria ($L^2/9000d$) for deflections in the range $L/30$ to $L/20$ (Figures 4-6).
Where

- L = Specimen Span
- d = Depth of the Construction.

In the case of loadbearing elements of structure which are also used as separating elements, Integrity (gaps and openings in the construction should not ignite a cotton pad or should not exceed a given size in the case of uninsulated constructions), and Insulation (temperature rise on the unexposed face should not rise by more than 140°C on average or 180°C at any point), failure criteria are introduced.

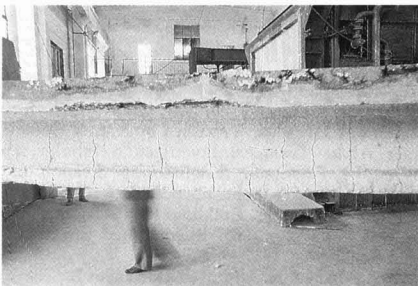
Figure 4

The appearance of an unprotected beam following a BS 476 : Part 20/21 fire resistance test. Deflection in the centre of the beam has reached the $L/30$ failure criterion.



Figure 5

Appearance of a steel beam protected with a cementitious spray following a fire resistance test. While the coating is cracked it has remained in place around the section.



In certain situations, for instance offshore structures, a heating curve simulating a hydrocarbon fire¹⁶ is frequently adopted. One such heating curve (Figure 7) has been defined by the Fire Research Station and the Norwegian Petroleum Directorate¹⁷ and is shown in Table 2.

Table 2

Time (mins)	Temperature(°C)
3	880
5	945
10	1033
15	1071
30	1098
60	1100
120	1100

In the case of offshore structures and ships the test procedure is modified slightly and is generally described in IMO Resolutions¹⁸ and Lloyds¹⁹ / DNV Rules²⁰, and performance criteria are defined using terminologies B15, A60 and H60, etc. This terminology is frequently used for bulkhead and deck constructions.

"A" class divisions are those divisions formed by bulkheads and decks tested using a "cellulosic" heating curve (Figure 7) which comply with the following:

1. They shall be constructed of steel or other equivalent materials;
2. They shall be suitably stiffened;
3. They shall be so constructed as to be capable of preventing the passage of smoke and flame to the end of the one hour standard fire test;
4. They shall be insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 139°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

Class "A60"	60 minutes
Class "A30"	30 minutes
Class "A15"	15 minutes
Class "A0"	0 minutes

"B" class division are those divisions formed by bulkheads, decks, ceilings or linings which comply with the following:

1. They shall be so constructed so as to be capable of

Figure 6

The strength vs temperature relationship for a BS 4360 Grade 43A steel. Values determined using the anisothermal method.

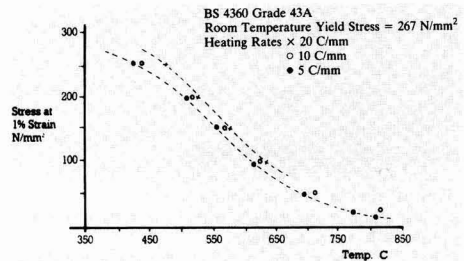
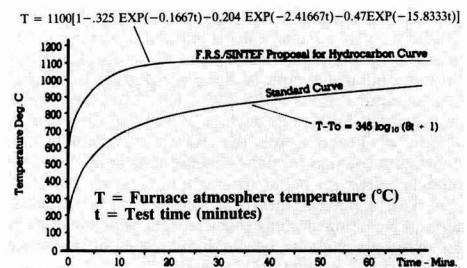


Figure 7

Comparison of the standard heating curves for cellulosic and hydrocarbon fires.



preventing the passage of flame to the end of the first half hour of the standard fire test;

2. They shall have an insulation value such that the average temperature of the unexposed side will not rise more than 139°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 225°C above the original temperature, within the time listed below:

Class "B15"	15 minutes
Class "B0"	0 minutes

3. They shall be constructed of approved non-combustible materials and all materials entering into the construction and erection of "B" class divisions shall be non-combustible, with the exception that combustible veneers may be permitted provided they meet other requirements.

Selection of fire protection material

A variety of types of coating materials can be adopted for structure fire protection applications, including the following:

- dry applied boarded systems including batts of mineral or ceramic fibre
- spray applied wets coating containing vermiculite or mineral fibres and cements
- Active intumescent or subliming coatings. The intumescent products foam and swell under the influence of heat to form a protective meringue which prevents passage of heat to the substrate while the subliming components absorb heat as a consequence of chemical transformations which occur within the coating, i.e. endothermic reactions. The various products have various attributes and disadvantages and the type of product to be used could be carefully considered bearing in mind all aspects of the application.

A number of factors influence the choice of the type of coating system, including

- Cost, durability and strength
- Appearance
- Method of installation
- Adequate fire performance in fire, either fire resistance or reaction to fire
- Space constraints
- Compatibility with the substrate
- Sound absorption, sound reduction and cleanliness
- Warmth and thermal insulation

Surface texture, particularly where products form part of the interior decoration system.

Other factors which are specific to the end application.

The selection of system should involve materials which are difficult to ignite and will not contribute to fire growth and fire spread, particularly when they form part of the structure or its fixtures and fittings.

British Standards have been issued regarding the use of coatings, including mineral and intumescent coatings describing the use of the materials for fire protection applications. These standards describe some practical aspects of the use these materials for fire protection applications.

BS 8202 : Part 1 issued 1987 is entitled "Coatings for Fire Protection of Building Elements. Code of Practice for the Selection and Installation of Sprayed Mineral Coatings"²¹, while the draft version of BS 8202 : Part 2 has the proposed title "Coatings for Fire Protection of Building Elements Part 2 Code of Practice for the Assessment and Use of Intumescent coatings for providing fire resistance"²², and was issued as a draft for public comment in October 1988.

The Part 1 presents practical guidance on installation of materials including meshing requirements while the draft Part 2 also presents guidance on durability testing of intumescent coatings using "accelerated" methods.

Future developments

The next five years should see some significant developments with respect to surface coatings used in fire protection. European harmonisation is in the forefront of our thoughts, and as a consequence of the proposed unification of the testing methods and performance criteria used throughout the EEC.

A significant amount of work is required to harmonise testing methods and eventually requirements, particularly with respect to "reaction of fire". Numerous tests are currently used in different countries, and the problems introduced by harmonisation are significant. On the other hand the fire resistance tests used in different countries generally follow the ISO 834 procedure, and hence the technical problems associated with harmonisation will not introduce dramatic changes in test method. However, some changes in interpretation of data may be necessary.

In recent years the move towards quality in the construction industry BS 5750 Quality assurance procedures have been introduced to cover the manufacture of products. Such schemes are being run by the major testing laboratories in conjunction with BSI and cover both manufacture and technical appraisal of the performance of the product. The next few years should see the introduction of BS 5750 Quality Assurance procedures²³ during installation in order to ensure that the product installed is of the same reliable nature as that evaluated in the original test.

It should be recognised that the test procedures which are described in Standards and used in legislation are sometimes arbitrary in nature and complying with requirements do not necessarily guarantee safety. This can only be achieved by a variety of measures including all the aspects of the fire safety system as outlined above.

Surface coatings play a most important role in the development phase of fire growth, and post flashover. Their impact on safety standards therefore plays a most important role in the global fire system approach to design.

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Appendix 1

EXTRACT FROM STATUTORY INSTRUMENT 1985

No. 1065

Building and Buildings The Building Regulations 1985 Schedule 1

“FIRE

Internal Fire Spread (Surfaces)

B.2 In order to inhibit the spread of fire within the building, surfaces of materials used on walls and ceilings —

a) shall offer adequate resistance to the spread of flame over their surfaces; and

b) shall have, if ignited, a rate of heat release which is reasonable in the circumstances.

Internal Fire Spread (Structure)

B.3 (1) The building shall be so constructed that, in the event of fire, its stability will be maintained for a reasonable period.

(2) The building, or the building as extended, shall be subdivided into compartments where this is necessary to inhibit the spread of fire within the building.

(3) concealed spaces in the structure or fabric of the building, or the building as extended, shall be sealed and sub-divided where this is necessary to inhibit the unseen spread of fire and smoke.

(4) A wall common to two or more buildings shall offer adequate resistance to the spread of fire and smoke.

External Fire Spread

B.4 (1) The external walls of the building shall offer adequate resistance to the spread of fire over the walls and from one building to another, having regard to the height, use and position of the building.

(2) The roof of the building shall offer adequate resistance to the spread of fire over the roof and from one building to another, having regard to the use and position of the building.” ■

Continued from p.180

room measuring approximately 4 metres long × 2.4 metres wide × 2.4 metres high with a simulated door opening in one of the smaller walls. The product to be evaluated is used to line the walls and ceiling of the room. A large ignition source is positioned in one corner of the room and the combustion gases produced during the test are drawn through an extract duct where measurements of various parameters are made. The measured data enables an accurate continuous calculation of rate heat release to be made using oxygen calorimetry techniques. Continuous measurements are also made of smoke density and CO and CO₂ concentrations. These measurements, in conjunction with the visual observations made of the performance of the linings to the walls and ceiling of the test room, provide very useful information on the probable performance of the lining product under real fire conditions. The technique is particularly valuable in comparing different types of linings and could certainly be used to quantify the retardation of fire growth caused by the use of flame retardant paint finishes.

The conductance of such tests would enable the effectiveness of flame retardant paint finishes to be more meaningfully evaluated and would hopefully demonstrate that the information being developed in the Standard tests can be used with confidence. ■

Continued from p.189

fire test behaviour is subject to a good deal of random variation, and that there are a considerable number of variables that must be measured on each formulation variation, it is therefore necessary to have available a piece of apparatus that will as far as possible give results equivalent to that one would expect from the fire test furnaces at any of the Test houses, and will produce a large number of data points very quickly in order to eliminate the effects of error.

What we have constructed is as shown in sectional views together with an inset photo in Figure 7. The furnace is of stainless steel sheet on a stainless steel frame. This lightweight structure allows us to run the furnace up to four times a day obtaining eight data points. Few furnaces of fire brick will cool sufficiently for more than one run a day. The sample plates are 150x150x5mm³. This allows the collection of data on samples fired on realistic heat sinks which accord approximately with results obtained from full scale furnaces. The panels are small enough for realistic fire test results to be obtained from lab samples as small as 1 litre.

Clearly the one sided panels and their small size fits in with normal panel preparation practiced in any paint laboratory. Thus we have equipped ourselves with the ability to collect a large number of data points on any formulation variation. This allow us to simultaneously evaluate a number of interacting variables. Every designer working in the field must have available some form of rapid assessment system. Certainly the 1 metre cube furnace employing 1 metre columns is far to slow and cumbersome to be a development tool and should only be reserved for the final stages of evaluation prior to moving to full scale fire tests.

In conclusion, any successful thin film intumescent needs to be jointly designed by the technical , marketing and sales department working together, with a full knowledge of the whole fire protection market and a full understanding of the complexity of the product and market. Theoretical and experimental systems need to be developed to allow the formulator to understand and control the complexity of the product he is faced with.

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The use of flame retardant coatings on walls and ceilings

by R. J. Shaw, Warrington Fire Research Centre, Holmesfield Rd, Warrington WA1 2DS, UK

Multiple fatalities caused by single fires increase the awareness of authorities and the general public of the need for adequate levels of fire safety. In recent years the fires at Bradford City football stadium, Manchester Airport, King Cross underground station and the Piper-Alpha oil platform have all highlighted the horror of fire. The publicity given by the media to the high number of deaths within domestic dwellings, caused mainly by foam-filled upholstered furniture, has made the general public more aware than previously of the dangers surrounding them, even in their own homes.

Functions of different types of 'fire protective' paints

This increased awareness has led to a significant increase in the use of coatings specifically formulated to give improved fire characteristics. Such coatings are developed to fulfil two main functions, and are commonly described as either 'fire resistant' or 'flame retardant'.

The main application for 'fire resistant' coatings is the protection of structural steelwork. Such coatings are usually of the intumescent type, which under normal, non-fire, situations are very similar in appearance to normal paint finishes but when they are exposed to sufficient heat they react by changing their physical and chemical structure. During this process the coating swells and foams, resulting in a dramatic increase in thickness, to produce a carbonaceous char which acts as an insulating layer between the fire and the steel member.

'Flame retardant' paints or coatings are usually applied to walls, ceilings or other surfaces to give acceptable ignition resistance, flame spread and/or heat release properties. Some paints are designed to be used over traditional non-combustible surfaces, whilst other specialist paints are designed to upgrade some combustible substrates to required performance levels. These specialist paints tend to be either of the intumescent type, having a similar principle of operation to the 'fire resistant' versions, or incorporate flame retardant chemicals to improve the ignition resistance properties of the composite.

Stages of an uncontrolled fire

Fire is a complex phenomenon, its growth and ultimate severity depending upon a number of inter-related factors. There is an old saying that 'no two fires are ever the same' and a number of unfavourable situations usually have to occur simultaneously for a serious fire to develop. The development of most uncontrolled fires can be divided into the following four stages (Figure 1):

(a) *Initiation*, which is in the process of heating some material to ignition and therefore establishing a fire.

(b) *Growth* (or spread, or propagation), which involves the continued release of flammable vapours from the surrounding materials or surfaces, leading to combustion. During this stage flames may spread over the surfaces of the contents, walls and ceilings and heat may be released both from the burning areas and from surfaces which are being heated by the fire. The fire growth will continue to accelerate, at an exponential rate, until it is limited by the available quantity of either fuel or air. This is the stage which is most significantly affected by the use of 'flame retardant' paint finishes.

(c) *Steady state*, which is the stage at which the fire may be said to be 'fully developed' and all combustible materials are

burning steadily, the rate of consumption of fuel being in equilibrium with the rate of supply of oxygen. The oxygen availability is usually the controlling factor. This is the stage where 'fire resistant' paints are protecting the structural stability of the building.

(d) *Decay*, during which the fire is burning itself out.

'Flash-over'

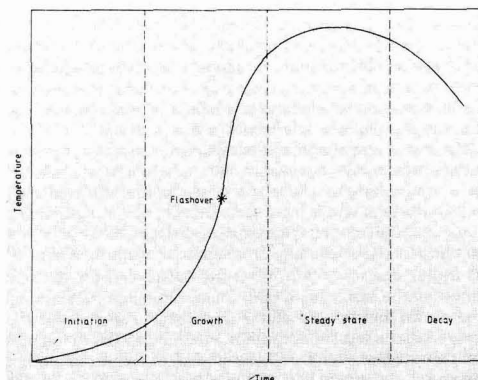
During the growth stage of a fire in an enclosed compartment a 'flash-over' may occur. 'Flash-over' is defined as a stage in the development of a contained fire at which fire spreads rapidly to give larger merged flames throughout the space. The occurrence of 'flash-over' is very dramatic and essentially means that the whole of the interior of the compartment suddenly becomes a mass of flame. Any occupants of the compartment during a 'flash-over' will stand very little chance of survival.

Typical growth of a fire

Paint finishes to walls and ceilings can have a significant effect on the rate and extent of development of a fire. For example, if a fire occurs in one area of a room, say in a metal waste paper bin adjacent to a wall, flames from the waste paper fire may impinge on the surface of the wall. If the characteristics of the painted wall are such that ignition of the surface is difficult, then the fire may extinguish, without any spread away from the waste paper bin. If, on the other hand, ignition of the surface does occur then it is possible that flames may spread both laterally and vertically over the wall, leading to further generation of heat and flammable vapours.

If the flames reach to the ceiling, then a dramatic spread of flame may occur because the hot gases which have been generated will have risen to the top of the room and preheated the ceiling area. When flame spread occurs over the ceiling, heat is radiated downwards onto other surfaces of contents and walls and these are again heated and may release flammable vapours which in turn may ignite. In an enclosed room a critical point may be reached when the mixture of flammable vapours reaches the temperature which causes instantaneous ignition of the vapours and the whole of

Figure 1
Stages of an uncontrolled fire.



the room is a mass of flame. This is the 'flash-over' point and can be regarded as 'the point of no return'.

If 'flame retardant' paints are used on wall and ceiling surfaces (instead of conventional paints) there is usually a greater chance of the development of the fire being confined or at least slowed to enable the occupants of the room to escape. Firstly, the surface of the wall may not ignite in the area of flame impingement of the waste paper bin fire. Secondly, if ignition does occur and the rate of spread of the fire is only slow, then the occupants of the building will have a longer period to escape or, in some cases, may be able to extinguish the fire. Finally, in the case of a slowly developing fire which has been discovered at a relatively early stage, the fire brigade will have a greater chance of extinguishing the fire with the minimum of damage to the building.

Requirements of building regulations

In the UK, as in most other countries, we have Building Regulations which are intended to prevent the rapid growth and spread of fire within buildings. The main purpose of Building Regulations in the UK is to protect the occupants of the building and to encourage materials and constructions to be used which will reduce the risk of a serious fire and will provide sufficient time for escape.

The Building Regulations for England and Wales relating to fire spread over internal surfaces are very brief and apparently simple in that they require that the surfaces of materials used on walls and ceilings:

- (a) shall offer adequate resistance to the spread of flame over their surfaces; and
- (b) shall have, if ignited, a rate of heat release which is reasonable in the circumstances.

This enables a flexible approach to be made to fire safety in buildings, and increasing numbers of architects are utilising this flexibility. In practice, however, the vast majority of buildings are designed and constructed to comply with the requirements of Approved Document B to the Building Regulations which is entitled 'Fire Spread'.

The Approved Document gives guidance on methods of complying with the principles of the Building Regulations and specifies required fire performance levels for various situations. Factors taken into consideration are the type of the building, the size of the building or room and the distance of the building from the boundary. The requirements are based mainly on test results obtained by exposing the material, product or construction to various British Standard fire test methods. The tests which are relevant to fire growth over painted surfaces are BS 476: Part 7 and BS 476: Part 6.

Test methods

BS 476: Part 7 is entitled 'Method for classification of the surface spread of flame of products' and is used to determine the tendency of materials to support the lateral spread of flame over their surfaces (Figure 2). The test is intended for the classification of the exposed surfaces of walls and ceilings according to the rate and extent of flame spread.

The test is very simple in principle and exposes a specimen of the product to be assessed to heat radiation from a 900 mm square radiation panel. The specimen measures 900 mm long by 230 mm high and is mounted vertically and at right angles to the radiation panel. This exposes the specimen to varying heat flux levels which range from approximately 40 kW/m² at the hotter end to 4.5 kW/m² at the cooler end for the first minute of the test a small pilot flame is applied over a small area at the hotter end of the specimen. The specimen is exposed to the test conditions for a total period of 10 minutes and the rate and extent of flame spread, as measured along a horizontal reference line 75 mm from the bottom of the

specimen, are recorded (Figure 3). Six specimens are tested and effectively the specimen which gives the greatest rate of flame spread is used to assess the classification for the product. The classifications given by the test range from best result of Class 1 to a worst result of Class 4. For all practical purposes where flame retardant paints may be used, the only result which would be acceptable is class 1.

The long-awaited revision of BS 476: Part 7 has now been introduced (Figure 4). The basic concept of the test has not changed but modifications have been made which are intended to improve the repeatability and reproducibility of the test.

The most important modifications are as follows:

- (1) A different type of gas fired radiant panel is used.
- (2) The specimen is contained within a water cooled specimen holder which eliminates some of the problems which have previously occurred with edge effects and also assists in retaining thermoplastic specimens for longer periods.

Figure 2

Surface spread of flame test – BS 476: Part 7: 1971.

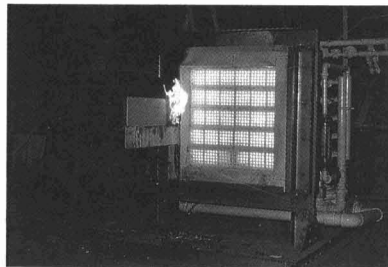


Figure 3

Specimen being tested to BS 476: Part 7: 1971.

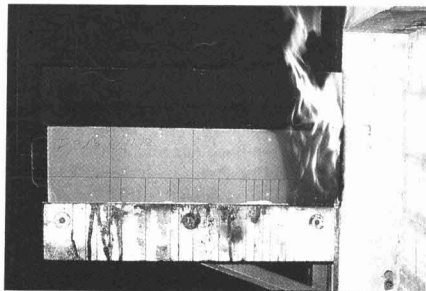
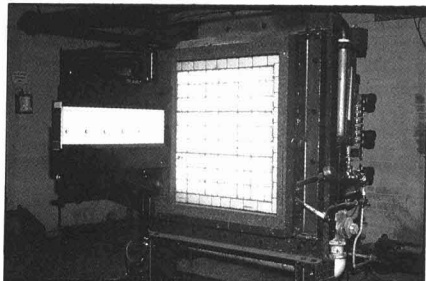


Figure 4

Test apparatus – revised version of BS 476: Part 7.



(3) An impinging pilot flame is used instead of the present flame which is held vertically just off the surface of the specimen.

(4) Definitions of transitory flaming and flashing are given which remove some of the subjectivity associated with the interpretation of flame spread.

A considerable number of tests have been conducted to compare the results of the old and new tests and the results indicate that the classification of painted panels will not change.

BS 476: Part 6 is entitled 'Method of test for fire propagation for products' and specifies a method of test that provides a comparative measure of the contribution to the growth of fire made by a product (Figure 5). The test is again primarily intended for the assessment of the performance of internal wall and ceiling linings.

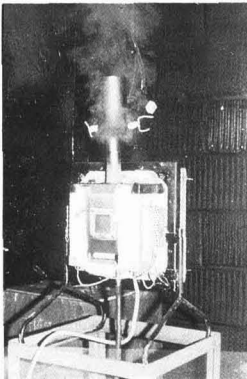
This test takes account of the combined effect of factors such as the ignition characteristics, the amount and rate of heat release and the thermal properties of the product in relation to their ability to accelerate the rate of fire growth.

The test specimen measures 225 mm square and is mounted vertically in a special combustion chamber to which is attached a chimney and cowl. Inside the combustion chamber are a gas burner and two electrical heating elements. The specimen is submitted to a prescribed heating schedule lasting 20 minutes and throughout that period the temperatures of the flue gases are measured by thermocouples positioned in the chimney and cowl. The test result for the product is obtained from a formula which relates the pattern of the flue gas temperatures obtained during the test to the pattern obtained when a specified non-combustible material is in the combustion chamber in place of the material under test. Three specimens are tested and the results are averaged to obtain the final result, which is expressed in terms of a fire propagation index that is the summation of three time-based sub-indices. The higher the fire propagation index, the greater is the influence of the product on accelerating the growth of fire. The method of computation of the sub-indices ensures that an early contribution of heat is penalised much more severely than the same amount of heat generated at a later stage.

Class 1 and Class 0

For the purposes of Building Regulations, there are essentially two important classifications which may be required for the control of painted surfaces. The first is Class

Figure 5
Fire propagation test – BS 476: Part 6.



1, as defined by the BS 476: Part 7 test method, and is easily understood since the test report will include the classification. The definition of 'Class 0', however, causes much confusion, mainly because it is a definition given in Approved Document B and not by a British Standard.

A product having a 'Class 0' surface is defined in paragraph A8(b) of Approved Document B as a product which achieves a Class 1 result when it is tested in accordance with BS 476: Part 7 and a fire propagation index (I) of not more than 12 and a sub-index (i_1), of not more than 6 when it is tested in accordance with BS 476: Part 6. 'Class 0' surfaces are usually required in sensitive areas, mainly in 'circulation spaces' such as staircases and corridors which may be used as escape routes during a fire. The use of 'Class 0' products should ensure that rapid spread of flame will not occur over the surfaces of walls and ceilings and that heat release from the surfaces is within acceptable limits. These limitations should delay, or hopefully prevent, the spread of fire and 'flash-over' within the area.

Use of test results

The conductance of a test and the publication of the relevant test report is only part of the determination of whether a product or construction complies with the relevant requirement of the Approved Document. Interpretation of the test report and comparison with the situation which applies in practice can often be very difficult.

If a fire test is correctly designed and conducted it may be the only available indication of the behaviour of the product in a given fire situation. Due to the complex behaviour of fire, however, the ability of a fire test to provide information should be over-estimated. It can virtually never predict the course of an actual fire and can only predict the behaviour of the test product in the restricted situation of the test itself. This means that a single fire test cannot evaluate fire hazard, though it can contribute to the assessment of part of it. A fire test result that shows an acceptable performance by the test specimen can never guarantee a safe situation.

The most important principle which must be appreciated in interpreting a test report on a product incorporating a paint finish is that the test result applies only to the particular specimen which has been tested. This means that the test result is only valid if the substrate to which the paint is applied is identical to that which was tested, any preparation to the substrate has been carried out, and each of the paint layers has been applied in the correct manner and at the correct application rate. The formulations of paints supplied must obviously be identical in every way to those which were tested. Even if everything is identical there are some aspects which the Standard testing procedures do not cover, such as the effect of ageing of the system of exposure of the system to weather or high humidity conditions.

Substrates

The variations which can occur in substrates in practice is a constant problem. The paint supplier usually has no control or even knowledge of the substrates which are to be covered with his paint and it would not be practicable to test all possible substrates which could be encountered.

If normal building practices in the UK are considered, the vast majority of buildings are constructed from brick or block walls with a gypsum plaster finish or from plasterboard skimmed with gypsum plaster. It is reasonable, therefore, to test specimens consisting of plaster skimmed plasterboard with the appropriate paint finish and to accept that this result will also apply to plastered brick or block walls. That result would not apply, however, to the paint system applied directly to paper faced plasterboard. There is an increasing

trend in the use of plasterboard with only a thin slurry coat and this situation would not be covered by a test on a skimmed plasterboard substrate.

The performance of paint finishes on combustible substrates is much more complex since different combustible substrates will react differently in absorption of the paint finish and will also react differently during the test and under real fire situations. For example, it is often easy to upgrade a cellulose fibre insulation board from its usual Class 4 result to BS 476: Part 7 to Class 1 because the flame retardant paint is easily absorbed into the product. On the other hand it is often difficult to upgrade hardboard because the hard resin layer on the surface of the hardboard resists absorption of the paint.

Previously painted surfaces

Provided that a new, previously untreated, substrate is being considered it is a relatively simple matter to conduct Standard fire tests to determine the spread of flame and heat release properties of the decorated composite. When previously painted surfaces are being redecorated, however, it is almost impossible to predict with confidence how that system, overcoated with the flame retardant paint system, will react under the Standard tests or, more importantly, under real fire conditions. The problem is compounded if the nature of the substrate is uncertain.

The main problem lies in the unknown characteristics of the existing decorated surface. Paint types and formulations have changed considerably over the years and almost certainly fire performance was not considered in developing the formulation. Although the contribution of the paint layers themselves to flame spread and heat release is important, the main problem is the danger of delamination occurring at some interface within the previously painted surface. When specimens incorporating old paint layers are subjected to the BS 476: Part 7 test method it is not uncommon for delamination to occur within the various coats, causing a blistering of the surface. Once blistering occurs ignition or more rapid spread of flame is much more likely to occur and the presence of a surface coating of a flame retardant paint may be significantly less effective. In extreme cases it is possible for large areas of paint layers to peel away to expose old paint surfaces or even the original substrate.

Very little research has been undertaken to attempt to answer some of the unknowns regarding the fire characteristics of old paint systems and to do so would require many specimens of existing painted surfaces to be tested. The main problems in conducting such an exercise would be in obtaining a sufficient variety of previously painted surfaces and in determining the nature of the paint layers which had been applied over the years.

In view of the difficulties in obtaining specimens which include old paint coatings some paint manufacturers have, quite logically, attempted to provide some information by conducting Standard fire tests on specimens incorporating modern multi-coat systems. The results will not necessarily be applicable to all previously painted surfaces, however, since it is unlikely that those previous paints will have the same formulation as modern paints, which have obviously changed over the years to improve many of the required characteristics. Even if the paint formulations were identical to those which were tested no information has been gained on the effect of ageing of the paint surfaces or of the effects of accumulated grime, grease or other factors. In practical situations it is not uncommon for one or more of the layers, particularly the first, to be applied without sufficient preparation or in unsuitable environmental conditions, leading to some delamination, even under non-fire situations.

There is no obvious answer to the problem of existing paint finishes, apart from stripping the painted surface back to the

substrate or overdrawing the existing surface with a suitable wall lining. Both alternatives are obviously expensive, and it may be that such actions are only necessary in 'sensitive' areas such as circulation spaces or areas where the public gather in large numbers. It is unlikely that the addition of a flame retardant paint to an existing painted surface will down-grade the performance of the surface in a real fire and most of the test information which is available suggests that some improvement will usually result, although the quantification of the improvement is not possible without testing every situation.

Perhaps a compromise solution would be the development of a small portable fire test unit which would expose a small area, say 100 mm diameter, of the wall surface to a specified heat flux. This would serve two purposes: firstly it would determine whether ignition of the surface occurs under that exposure condition, and secondly it would provide an indication of the possibility of delamination occurring within the existing paint layers. Such a tool could only be used by experts, of course, because there is obviously a danger that its use could actually cause the fire that it is trying to prevent.

Method and rate of application

The method of application and the rates of application of the paint layers can have a very significant effect on the test result which is achieved. In the case of standard paints it is generally true that the greater the rate of application, the worse the test result will be. In the case of flame retardant paints, of course, the reverse is normally true, an increased rate of application increasing the degree of intumescence or increasing the levels of flame retardant chemicals which are available during the combustion process.

One additional aspect which must be considered is re-decoration of surfaces which have been previously decorated with a flame retardant paint. Care must obviously be taken not to apply a standard paint over a flame retardant paint unless the properties of the complete system have been evaluated. Similarly it should not be assumed that one type of flame retardant paint can be automatically applied over another type and maintain the protection; interactions may occur which could cause a problem.

To assist in assessment of the fire properties of painted surfaces in the future it would be advantageous if log books were kept detailing all painting work undertaken. Perhaps paint manufacturers could encourage this, particularly in areas such as hospitals and hotels.

More meaningful tests

In common with all relatively small scale standard fire tests, the BS 476: Part 6 and 7 test methods have their limitations. In the case of painted specimens, one deficiency is the absence of significant convection currents which usually occur during the growth stage of a fire. Such convection currents could erode away the intumescent char layer which provides the protective barrier, thus exposing the combustible substrate. The design of the fire propagation test apparatus is such that intumescent products either cannot be classified or, more commonly, give erroneous results because they expand onto the gas jets of the apparatus, causing distortion of the flames impinging onto the surface of the specimen.

It would be very interesting to observe the performance of flame retardant paint finishes, particularly over combustible substrates, when they are exposed to relatively large scale semi-natural fire tests. Facilities certainly exist but without the pressure of regulatory requirements, suppliers of paint systems, understandably, have no incentive to undertake such tests. One suitable test facility is that which is commonly referred to as the 'ISO Room'. This consists of an enclosed

Continued on p.176

Intumescent coatings: protection of steel

by F. Allman, W. & J. Leigh & Co, Tower Works, Kestor St, Bolton BL2 2AL, UK

Introduction

Intumescent coatings are not new, the first patent on the topic was granted in 1948 but developments have generated a new interest in their use.

What are intumescent?

We may all remember from our schooldays how the action of a concentrated acid on a carbon rich compound such as sugar produced voluminous quantities of a black foam. This is still the rough basis of the modern day intumescent.

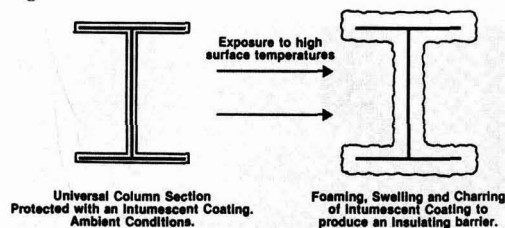
Although the principle has been around a long time practicality for the manufacturer to incorporate this into coating technology with acceptable performance has taken quite some time. The inherent defects of early products were very high water sensitivity, high coating thicknesses and poor application from relatively underbound films. The development of resins and raw materials has provided a new generation of intumescent, although high build in paint terms they are relatively thin in the terms of the old intumescent coatings and now provide a practical alternative for fire protection.

Intumescent formulation

In basic principles an intumescent coating is required to expand to form a cellular foam with good insulating properties (Figure 1). A typical generic formulation is produced from the following:

- Catalyst – Source of Mineral Acid.
- Carbonific – React with Acid to produce char.
- Binder – Melts at required temperature to facilitate expansion.
- Spumific – Liberates gases to expand.

Figure 1



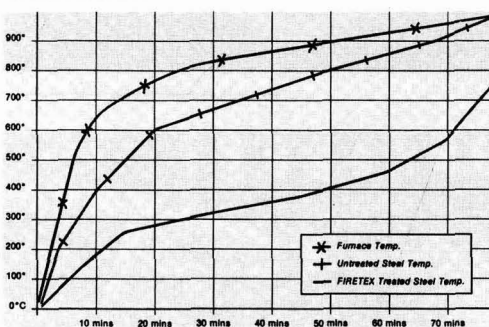
Dynamics of protection

Figure 2 illustrates the effects of an intumescent coating under fire test conditions. The top line is the B.S. heating curve – the furnace temperature. The middle line is the temperature achieved within the furnace of uncoated steel. The steel would lose its load bearing characteristics at about 550°C – a temperature achieved after approximately 15 minutes. The bottom line illustrates the same steel section protected by an intumescent coating.

Initially heating of the steel is slightly retarded but at approximately 200°C the intumescent reaction starts and this

effectively forms a plateau along the heating curve so that, in this case, the failure temperature is not reached until well after the 60 minute point.

Figure 2
Loaded column test.



The thermodynamics of how the coating works in practice is complex, the following is offered as an explanation:

As heat develops there is normal thermal conduction through the coating, the rate of heating depending on the thickness and specific conductivity of the original coating. The coating and steel contrive to heat up until the reaction temperature is reached. The mineral acid produced in-situ then produces the intumescence. This is a surface reaction that progresses through the coating as the heat is conducted. The rate of heat conducted has, however, slowed dramatically because of the enthalpy of the reaction, energy being absorbed to produce the phase change.

On completion of the reaction through the coating to full intumescence there is a return to normal thermal conductivity through the coating but at a new rate dependent upon the specific heat of the foam. The time for protection is, therefore, dependent upon the following factors:

- Thickness of original coating
- Steel section factor Hp/A
- Thermal conductivity of the steel
- Enthalpy of phase change reaction
- Thickness of foam
- Steel failure temperature
- Section shape

Intumescent system

The specification for the intumescent system is at first sight no different to that for any other High Performance Coatings but there are specific points to consider:

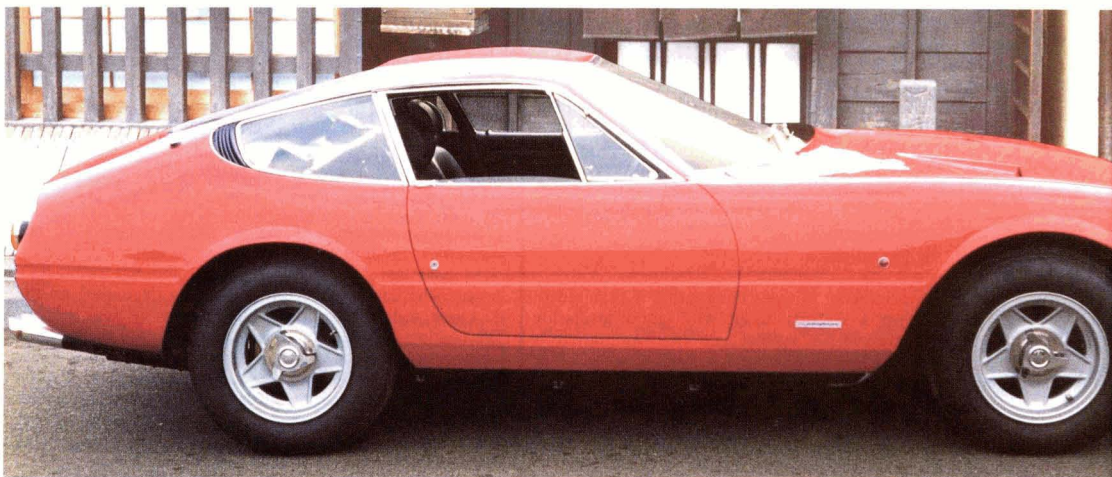
'Steel must be Blast Cleaned to Sa 2½' – a standard procedure.

'Prime' – Compatibility with the primer is essential, not only as far as overcoating is concerned, but in order that there is no delamination under fire test conditions.

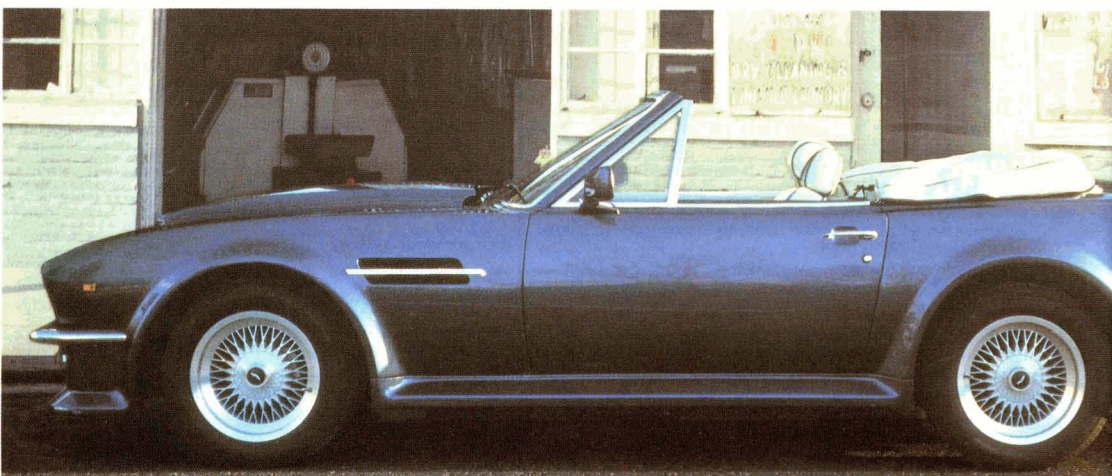
'Apply Intumescent' – to the right d.f.t. target for the section size, orientation and shape.



FORD THUNDERBIRD 1955



FERRARI DAYTONA 1978



ASTON MARTIN VANTAGE VOLANTE 1988



WHAT HELPS MAKE AN AUTOMOBILE A CLASSIC?



Great styling? Quality manufacture? Fine materials? Cardura is now in its third decade as a fine raw material widely used in the manufacture of the highest quality automotive coatings. After 25 years, Cardura has become a classic in its own right.



Shell Chemicals

Finally, 'Apply the Sealer Coat' - There are no situations with these generic types of materials where we would recommend omitting the sealer coat. The intumescent still contain some water sensitive ingredients. The service life must be considered. Sealercoats when applied can, however, provide adequate exterior protection during the construction phase.

Practical protection

The fact that intumescent work are adequately covered by the British Standard Tests, Fire Certificates, and Independent verification schemes but the question still remains how practical are they in paint terms.

The critical factor is dry film thicknesses and the old chestnut of how to measure it and with what degree of accuracy. The need to specify nominal or target thicknesses and tolerances is essential. Results on d.f.t. measurements are reproducible if basic calibration and use criteria are followed and this is more critical for the higher d.f.t. ranges.

Measuring d.f.t. in microns brings us into the realms of engineering tolerances, 25 microns is one thousandth of an inch, a measurement the industry was happy with for decades. We must be careful not to be too critical. No paint sprayer or manufacturer under controlled laboratory conditions can possibly achieve total accuracy to specific d.f.t. requirements.

Steel sections for fire testing have to be practically prepared within practical tolerances before they can be fire tested. The foam produced in the fire test is not perfectly uniform, it tends to follow the line of least resistance. D.f.t. requirements are not absolute. They are nominal or target thicknesses to be assessed within practical tolerance guidelines and standard deviations are covered in the draft British Standard for the use of intumescent.

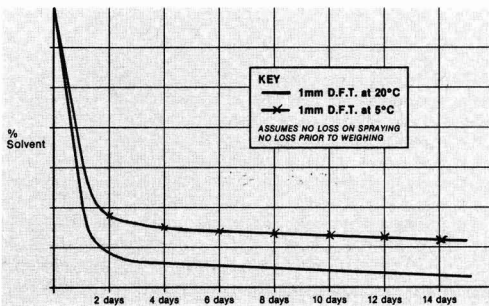
Normal high build paint coatings are considered to be in the 250 microns plus range - in intumescent this would only cover the 1/2 hour rating. For 1 hour ratings, d.f.t.'s of 675 microns for I sections and up to 3.5 mm for tubes are required. This in its own right can lead to problems in d.f.t. measurement if the drying cycle is not fully understood - particularly where it is necessary to apply multicoats.

Drying time

Thin film intumescent are normally based upon non-convertible resin systems, drying is by solvent loss.

Figure 3 illustrates the effect of temperature on the drying process. As would be expected the lower temperatures reduce evaporation and hence slows the drying. This graph, based on percentage solvent loss is virtually independent of film thickness. The significance of this is obviously with the

Figure 3
Temperature/solvent loss

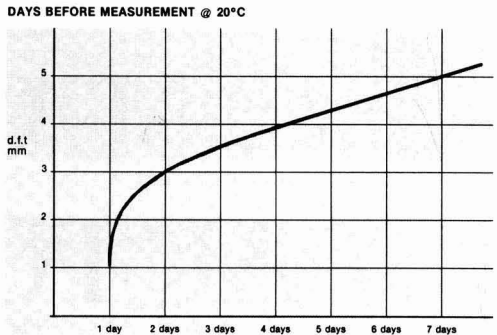


high d.f.t.'s, i.e. 5 mm, the solvent retention is still relatively high even after a week and the film may still be subject to shrinkage and this must be appreciated in measuring the d.f.t.

Dry film thickness measurements

Figure 4 is based upon practical results. At the lower end of d.f.t. requirements, 1 mm/2 mm, measurement is relatively trouble free. The higher the d.f.t. requirement the

Figure 4



greater care needed in measuring the d.f.t. against the standard. If for example a 5 mm coating is at the low end of the specification at 7 days it could shrink sufficiently on full through drying, which could take as much as 28 days or more, to take it out of the specification.

Note: Dry film thickness measurements must be made using shims to prevent the probe indenting into the film. This is essential with the higher thicknesses.

Conclusion

Intumescent coatings do provide a practical means of fire protection particularly for the 1/2-hour and 1-hour requirements with the following advantages:

- Proven fire protection materials.
- Lightweight and decorative.
- Available in a full colour range.
- Fast to apply.
- Easy to maintain and repair.

Continued from p.195

and Williams, I., "Fire engulfment tests on a 5 tonne LPG tank", *Journal of Hazards Materials*, 1988 20, 55.

3. Billinge, K., Moodie, K. and Beckett, H., "The use of water sprays to protect fire engulfed LPG storage tanks". 5th International Loss Prevention Symposium, Cannes, September 1986.

4. Williams, I., "Fire protection of pressurised LPG tanks", Conference on Transport and Storage of LPG and LNG, Brugge, 1985.

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6. Ramskill, P. K., "A description of the 'Engulf' computer codes to model the thermal response of an LPG tank either fully or partially engulfed by fire". Conference on Major Hazards in the transport and Storage of Pressure Liquefied Gases, New Brunswick, Canada, August 1987.

7. U.S. Code of Federal Regulations. Title 49, 179, 105-4, 405-407, 1981.

The design and development of intumescent coatings for structural fire protection

D. C. Aslin, Intumescent Product Development Manager, Mebon Ltd, Blackwell Road, Huthwaite, Sutton-under-Ashfield, Nottinghamshire NG17 2RL, UK

The largest growth area in surface coating products for fire protection is in thin film intumescent coatings. The interest is such that most paint manufacturers dealing in structural steel protection will have considered the possibility of entering this market. However, the first step that must be made in the development of intumescent coatings is to stop calling them paints. It is important to start from the basis that one is about designing fire protection. Formulators should not be designing a paint like product that might be made on existing plant merely to fill spare capacity.

It should be noted that the market leader in the supply of thin film intumescent is not a paint manufacturer, as might be understood by convention.

To successfully design and market fire protection products requires that a new philosophy and a new set of skills be acquired in addition to the normal skills of those involved in the formulation and sale of conventional surface coatings.

However, the design of intumescent coatings follows the same principles as for the design of any commercial technical product. That is quite simply to design the product to meet market requirements. A market-led design is far more likely to be commercially successful than a technology-led design.

This of-course implies that knowledge of the market must be acquired before formulation commences. As the fire test certification costs will be in the order of £50,000 before any product can be sold it is therefore quite important to get it right first time.

The structural fire protection market is one of that minority of markets where the manufacturer rarely sells to the end user. If the end user is the owner or occupier of the building, he probably is not aware of the existence of the form of fire protection present on the structure.

What the occupier requires is a fire safe building. There is not a legal requirement to maintain the fire protection on a structure, it is merely required to be present at the time of construction. It is probable that the last thing that the occupier of a building is interested in is the qualities of the intumescent coating or the novel or esoteric chemistry that may have painstakingly been built into the product.

The Marketing people have to sell the qualities of the product to the specifier, who will be either an architect or a structural engineer, but the man who actually pays money to the manufacturer is the applicator. He will only be interested in how cheaply he can buy the product and how little he needs to use.

The dry film thickness efficiency that the applicator requires is counter optimal to the environmental stability that the architect and structural engineer want¹. Certainly the durability of intumescent is one of the major areas of doubt in the minds of the more sophisticated applicators. However, the applicator is not really the end user. The nearest one can get to an end user is the main contractor. The main contractor is the man who pays the man who buys the product. The main contractor is interested in how quickly, efficiently and cheaply the fire protection that has been specified can be installed and how quickly he can get that particular trade off of his site. When a particular trade has left a construction site the last event the contractor wants is to call a particular trade back for repairs or rectification.

The requirements of the applicator is a design constraint that the technical designer may not be interested in taking into account in the design of a product. However, there is

little point in designing a product that is the most environmentally stable fire protection with the lowest of DFT requirements, if the man who is going to pay the bills can't get the stuff to spray except with a compressor that would drive a jumbo jet or requires ten brush coats to achieve the requisite DFT. The applicator will not be very happy, and unhappy people do not pay bills very quickly.

Such considerations must be a part of an integrated product design in which the technologist must both talk to and listen to the marketing and sales man. Quality is about meeting requirements and this starts with finding out what the market needs.

However, it can be argued that the present current interest in intumescent coatings in the UK is an artefact of the success of the marketing policy of British Steel. In a construction climate largely financed by speculative construction by the financial institutions, rapid or 'fast track' construction is greatly facilitated by steel frame designs. This, coupled with the slackness or flexibility of the fire test and assessment system in the UK, has led to the current growth market in intumescent, which has not been reflected in other European markets.

Part of product design is understanding what the competition is. It is essential to be aware of how diverse the fire protection market is and how many other products one is competing with.

If the product is being designed for the onshore internal fire protection market, where the product is to be certified for performance to the cellulose curve, then there are more than just other intumescent coatings to compete with.

In this market a number of passive systems such as sprayed vermiculites and sprayed mineral fibres as well as cladding systems compete with thin film intumescent. The fire protection required will have rating requirements from 1/2 to 4 hrs, for both internal and external use on the complete range of steel profiles over a wide range of massivity factors.

Acceptable prices for the installed fire protection may range from £8 to £50 per sq metre depending on what the specifier is looking for.

Hence the competition is not only other intumescent, and therefore the market sector for fire protection is greater than that which intumescent currently occupy, providing additional qualities can be built into the product to allow it to compete with the other systems. It must however be emphasised that within this wide range there will always be a niche for a product that with a USP to obtain some market share.

For example consider the product my company markets. It covers the middle range of the market, with an ability to deal with higher HP/A values up to 1 1/2 hour fireratings, a wider range of steel sections coupled with a tolerance of environmental exposure. This does not mean it will compete across the market profile. It merely represents the way this product was designed. Nor does it mean we consider that we must always design in this way. It depends on what the Marketing and Sales divisions require according to their market intelligence.

In order to discuss the effect of tailoring product design to meet market requirements it is useful to base this on the consideration of a particular formulation. Picking one that anyone who has briefly scanned the literature will be familiar with, consider the formulation given² in Table 1.

Table 1
Sample formulation

Pioliite Resin	10.0
70% Solid Chlorinated Paraffin	8.0
Ammonium Poly Phosphate	25.0
Di-Pentaerythritol	7.5
Melamine	7.5
Rutile titania	9.0
Mineral Spirits	32.6
Thixotrope	0.3
Methanol	0.1
	100.0

The literature gives the option of grinding or High shear dispersion to obtain this product.

Such a formulation will give a one hour rating on the standard 170 HP/A beam with about 1.8 mm dry film thickness under BS 476 conditions. This is more than twice that required by the product with the lowest DFT requirements on the UK market.

This formulation as it stands takes about a month to through dry and produces vast volumes of smoke under fire conditions. It probably needs topcoating under all conditions.

It also entrains large quantities of air when put through an airless spray gun, and drags and tacks when brushed.

Nevertheless, such a product is still being offered on the UK market, with little modification from the above.

Most products on the UK market at first sight do not vary a lot from this formulation published some twenty years ago, but in all cases they show signs of "tweaking" in the style of a traditional paint technologist. There is very little evidence of new technology being introduced into current commercial formulations.

However at the other end of the scale of sophistication there is available a range of formulations based on 4,4 Dinitrosulphanilide, patented in 1977 by Sawco and Riccitiello³ working at the Ames laboratory for NASA. These formulations are available under (I believe free) licence from NASA.

These clever intumescent salts turn out to be quite disappointing.

Under intense and rapid heat they do indeed intumesce quite spectacularly. However under the more gentle temperature ramp such is deemed to be typical of a cellulosic fire, they just smoke and melt in a most unimpressive manner.

All the foregoing leads to the need to develop methods that will allow design of these products as an integrated holistic systems.

One of the advantages of the conventional phosphate catalyzed formulations typified by that given above is that the optimisation plateau is quite flat. This means one can alter the formulation quite considerably without substantially affecting its fire performance. It also means that considerable changes have to be made before substantial improvements can be found.

My approach in attempting to simultaneously compromise a series of conflicting requirements is to consider intumescent products as a material that is required to under go a series of sequential states and transitions. These may be defined as shown in Table 2.

Thus under the analytical scheme I use intumescent coatings are a material with critical properties in 5 states linked by 6 transitions.

The area that most formulators tend to concentrate on is Transition 5, however it will be shown below how this form of reductionism predisposes towards a certain type of performance, whereas our practice of designing properties to

Table 2
State/Transition analysis of Intumescent Coatings

State 1		Raw materials
State 2	Transition 1	Manufacture
	Transition 2	Wet product
	Transition 3	Storage
State 3		Application
		Dry film
	Transition 4	Environmental degradation
State 4	Transition 5 (a)	Melt
	(b)	Foam formation
	(c)	Char set
State 4		Carbon char
State 5	Transition 6	Fire degradation
		residual refractory

enhance performance during Transition 6 leads to a very different overall fire performance.

The inclusion of the raw materials as State 1 may appear naive but it is quite valid because in common with other products where the manufacturing process is a blending operation, the properties of the finished product are to an extent predictable from the raw materials.

However, if the product is designed to compete with the market leader, there may be difficulties because melamine has been on allocation from one supplier for a considerable period since the use of this product for combustion modified PU foam became a significant market factor.

Again dipentaerythritol is in short supply on the world market.

If the product being designed such that it will compete with the current market leader, approximately 60 TPA each of dipentaerythritol and melamine are required. It is unlikely the extra demand for the two commodity products cited could be accommodated in the short to medium future.

From the above analysis a variables list for the various states and transitions is prepared. This list contains all the dependent and independent variables with the system boundaries taken as widely as possible. For example the dry film (State 3) variables list would include hardness, flexibility, dirt retention, gloss level, substrate/superstrate comparability, DFT against HP/A, and installed cost vs. competitive systems. Such lists are relatively easy to generate, once the analysis has been made in the form given. What is more difficult and the key to easier formulation with less blind alleys is the elucidation of the interactions between each part of the system. The complete system analysis is in fact too involved and detailed to be described here.

It is emphasised that the whole system is interactive and any attempt to make additions of alterations in a reductionist manner that concerns any one particular state or transition will undoubtedly effect the system at some other point quite severely.

The other point that should be borne in mind is that of scatter and random error throughout the system. Within the system a large number of probabilistic variables are encountered. As the fire tests that are the final measure of success are subject to scatter by as much as 15%, designing a product where the final measure of performance is a lottery requires a peculiar mentality.

As an illustrative example of the effects of these interactions, it is possible to incorporate molybdenum oxide into intumescent formulations, with some beneficial effect. This acts to suppress smoke emission and increases the strength of the carbon char by retaining greater quantities of carbon residues in the foam/char.


Consider then the effects of the addition of molybdenum oxide using the scheme given above.

No wonder the Bear in the Air couldn't miss the Rubber Duck.



BaSO ₄ content	DIN 55911	approx. 99%
Oil absorption	DIN 53189	13g/100g
Sieve residue %*	DIN 53195	<0.001
Specific surface	DIN 66132	3m ² /g
Mean particle size	(Sedigraph)	approx. 0.7µm
Brightness	DIN 53163	approx. 98
Dispersibility		excellent
Gloss		very good

*Test sieve 45 µm

Blanc fixe 

When you see a truck that stands out for miles, you're probably looking at the dazzling results of using Sachtleben's Blanc fixe micro[®]. It is, in fact, a versatile, high grade, micronised barium sulphate extender. So fine are the particles, and so excellent the dispersibility, that it produces an exceptionally high gloss, even in very thin layers. Blanc fixe micro[®] is very attractive environmentally too. Harmful solvents are reduced by increasing the solid content of the paint. Chemical and weatherproof paints end up with a better finish. And powder coatings achieve optimum rheology and adequate

adhesion during curing. In fact, only drivers of big red trucks who want to be inconspicuous, are likely to have a problem. Still, with the world's most comprehensive range of white pigments and extenders, and our continuous R&D programmes, we do find cost-effective solutions to most of our customers' problems. Chances are, if you have a problem, we may have already solved it. Call us now. And call us first.

**Commitment: It's our formula
for success.**

»SACHTLEBEN«

Molybdenum oxide has an S.G. of 4.69 and is sold at a particle size of about 6 microns. Given that the typical intumescent formulation shown has an SG of 1.15 and a static viscosity of 300 poise then the standard settlement formulae:

$$v = \frac{2(ps-p)r^2g}{9n}$$

where

v=velocity through medium
 ps=sg of particle
 p=sg of medium
 r = particle size
 g=acceleration due to gravity
 n=static viscosity or yield point

This equation gives the settlement rate of the molybdenum oxide as 0.14 cm/day.

This means that at the end of six months the entire molybdenum content of a 25 litre drum will be at the bottom of the can in a solid lump. Now while the effect of adding molybdenum oxide to the product may well give low DFT for equivalent steel sizes (State 3), which might look very good on paper in comparison with competitive products, the relationships with applicators is going to be severely effected when they try to reconstitute two tonnes of settled product in the middle of a building site (Transitions 2&3).

Taking this example further, while the addition of a molybdenum oxide may well increase the weight of foam/char produced initially (State 4), it tends to weaken the residual refractory and causes faster degradation of the char under longer exposure times at higher temperatures (Transition 6). The effect of this is to reduce the DFT required at shorter exposure times and with heavier sections and to limit the usefulness of the product with lighter sections and longer exposure times (State 3). Thus before making a decision to include the effect of a product with a significant effect as molybdenum oxide consideration is required of the effects it would have on the application qualities and the required marketing profile.

Alternatively, other corrective measures may have to be taken with the formulation or process sequence to overcome the detrimental effects. These alternatives will fan out to other parts of the system. Unless an understanding of these interactions has been acquired or can be predicted then the formulator has serious problems, which to most easily overcome by using the approach outlined above.

As a second example, intumescent coatings are applied to partially completed buildings. The conditions of application are very different from the conditions inside the laboratory in which the product was developed (see Figures 1 and 2).

The conditions of application are of contamination with cement dust, dirt from dry unscreeded floors, variable temperatures, high humidities and water and rain penetration from uncompleted walls and roofs.

The formulator has two options: he can deny that any one could work in these conditions and require that the building be near finished before his product is applied or the product can be designed to be tolerant of the conditions that a construction worker would expect to work in, and pertains to most of the new constructions.

Normally, applicators are always under pressure to finish even in inclement weather, have always got following trades round their ears and, there are always unplanned changes to schedules. If the former approach is adopted the service team is going to spend a lot of time looking at coatings peeling off or running down on the floor.

If at that point you attempt to tell the site agent in the presence of your applicator that the product really was not meant to be applied in those conditions, you will get very little thanks from anybody.

Figure 1

Conditions prior to application of fire protection.

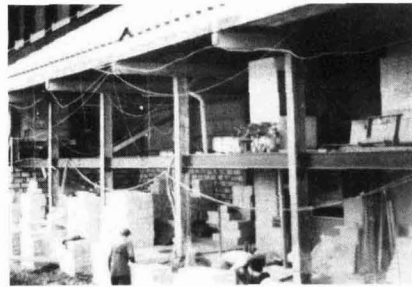
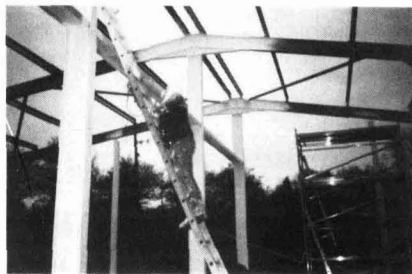


Figure 2

Application to exposed steel.



Further, buildings do develop leaks and moisture pockets. High levels of humidity can build up in concealed compartments. Hence, there is not really any difference between external and internal exposure because fire protection is supposed to work at any time irrespective of whether a pipe or guttering has sprung a leak or ventilation has been inadvertently blocked. The point of this discussion is that there is not really a difference between external and internal exposure and the more tolerant the coating is both during and after application the more useful and the less service commitment it will require.

As a final illustration of the need for an integrated approach with respect to formulation, consider the following experiment.

About three years ago a certain raw material manufacturer challenged us to compare our standard product with the best formulation that their laboratory had been able to produce.

This laboratory formulation was based on the results of an extensive study of TGA and DSC work. The product was optimised simply from the point of view of reaction efficiency. I will call this the chemists formulation. Their lab specimens were carefully prepared by slow build up of a perfectly even deposit.

We asked a site sprayer to apply about 2.5 mm WFT of the standard product onto the panels, under site conditions using site equipment. I will call this the technologists formulation.

The panels were fired on the DIN 4102 prt 8 furnace. This particular rig may not be familiar to UK based formulators but consists of a horizontal tube 1 metre square down which is fired a single central gas burner. The samples are flat plates set either side of the furnace heavily insulated at the rear to prevent heat loss. The furnace appears as shown in Figure 3.

The furnace is operated to the standard ISO curve and the thermal response of the two specimens was as illustrated in Figure 4. This is the original plot from the chart recorder.

It will be noted that the comparatively early occurrence of

Figure 3
DIN 4102 Pt 8 test furnace.

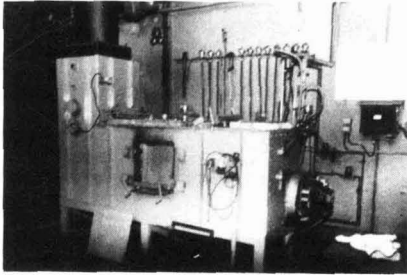
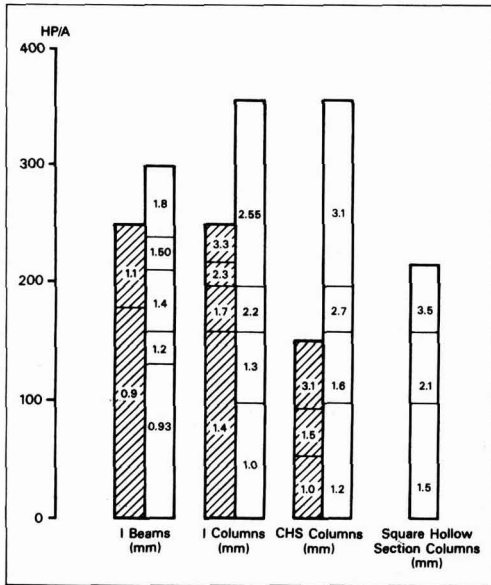


Figure 4
Comparative thermal response from DIN 4102 Pt 8.



the knee in the thermal response on the chemists formulation, compares to the technologists formulation where a slower more controlled response occurs. This is followed by a rise in temperature, such that the two curves converge until the responses of the two specimens are equal at 45 mins. The Mebon sample remained under the critical 550°C for 80 mins. The panels had approximately 3.5 kgms/sq metre on each.

After firing the specimen plates appeared as shown in Figure 5. The fast response material has collapsed and shed most of the foam/char onto the floor of the furnace. The more controlled product with the longer achieved rating has retained all the char on the plate. It was even possible to cut sections away and remove them intact as shown by the square holes left in the char. These two extremes in the logic of formulating these products do carry through to commercial products on the UK market. Compare the two histograms shown in Figure 6.

Here the top coat requirement to the first product is added to the DFT of the fire protection and the thickness for the second (Mebon) product is reduced by the amount of airation that is normally entrained, so that the products are compared on an approximately equivalent basis.

Figure 5
Specimens after firing: 'Chemists' formulation on the left, 'Technologists' formulation on the right.

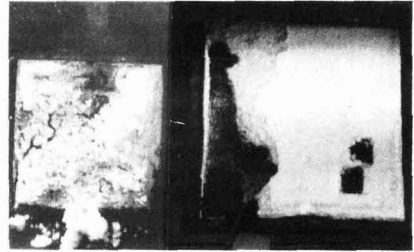
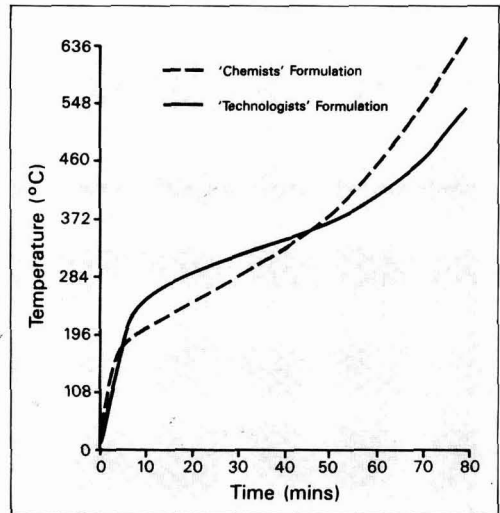


Figure 6
Comparative d.f.t. between fast blow high rise type intumescent (as represented in the striped rectangles of the columns) and slow blow low rise type intumescent. The numbers in the columns indicate the d.f.t.'s on the solid coating with topcoat added where applicable from published data.



The data for the competitive product was collected from data sheets. However this is very difficult to interpret without reference to the original test report, particularly as it is known that two different assessment systems were used to interpret the original fire test data. The DFT required by the data are then shown for various sections against HP/A.

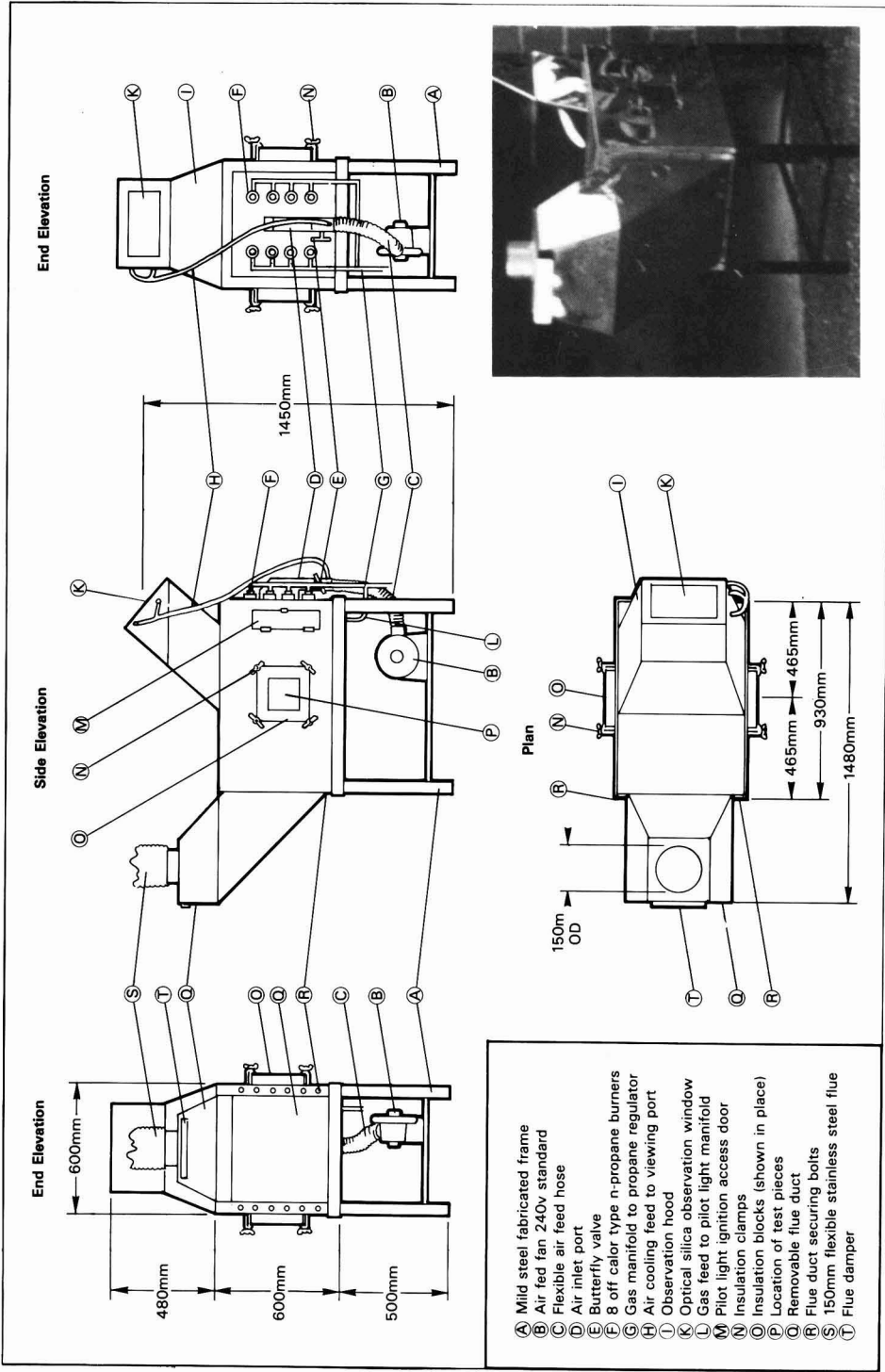
The Mebon formulation certainly requires more material at lower HP/A values but has a far wider application range than the other product. Of course the Mebon product, by virtue of its design also will produce a reasonable histogram for a 90 minutes fire rating.

The advantage here is that there is a reduced need to mix systems when fire protecting a building with multiple requirements on different parts of the structure. Certainly management contractors like the concept of one product and one applicator for one project.

Finally, I want to describe the apparatus we use evaluate our products. Realising as has been mentioned before that

Continued on p.176

Figure 7
 Mebon small scale test furnace - sectional views and photo of furnace prior to installation.



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The role of insulating coatings in the fire protection of LPG vessels

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Liquefied Petroleum Gas (LPG) represents a convenient and widely used source of fuel. LPG is mainly commercial propane or commercial butane and it is a liquid fuel usually stored under its own vapour pressure in pressurised containers.

LPG is used in a wide range of situations in a wide range of container sizes. At the smaller end of the range, LPG is used as a propellant in aerosol containers, as a fuel in refillable cigarette lighters and in non-refillable (throw-away) light weight cartridges for attachment, for example, to paint strippers, camping stoves and flambé units. A heavier form of vessel construction is found in LPG cylinders ranging in size from c.5 to 50 kg and widely used as a source of heat in caravans, boats, tents, site huts etc and for purposes such as oxy-fuel welding and cutting.

Continuing up the size range, one has the smaller type of fixed installation (1/4-1 or 2 tonnes) typically found at domestic premises, farms, hotels etc without access to mains gas supplies; road tankers, for bulk delivery; through to major storage installations where horizontal tanks or spheres containing up to several hundred tonnes may be found.

All such installations are pressurised storages at ambient temperatures. LPG is stored at near atmospheric pressure under refrigeration in a few very large installations but this paper will concern itself only with pressurised storage.

The properties of LPG which make it a useful and convenient fuel also make it a considerable fire hazard.

If the pipework of an LPG installation develops a leak, through a faulty shut off valve, a defective flange or mechanical damage for example, then the resultant discharge of LPG will have the following characteristics.

1) Because the liquid is stored under its own vapour pressure, the pressure in the system will be maintained and a sustained discharge will result.

2) After a short initial phase of liquid discharge, conditions at the point of discharge may be such that the LPG is in the liquid phase, or in the vapour phase, or exists as a two phase system. Where it is liquid, or predominantly so, relatively high mass rates of discharge will occur.

3) On leaving the pressurised system, the pressure drops to atmospheric and the liquid phase will rapidly flash evaporate giving a highly turbulent jet or cloud of residual chilled liquid, mainly in the form of an aerosol, and vapour.

4) If the discharge is ignited immediately, a jet flame will result; if ignition occurs after a delay, a large turbulent cloud of flammable mixture may exist and under conditions of partial or total confinement an explosion may result.

A total vessel failure can give rise to additional effects:

□ the stored pressure energy within the vessel can cause vessel fragments to fly for considerable distances.

□ an air blast results from the release of pressure energy,

□ the sudden release of the vessel contents gives rise to a highly turbulent cloud which, if ignited, creates a fireball. This fireball can cause damage to people and to property through a pulse of thermal radiation and through flame engulfment.

As a guide, the diameter of a spherical fireball (D metres) is related to the mass of fuel in the fireball (M kg) by the

relationship:

$$D = 6 M^{1/3}$$

that is to say, a 1 kg release will give a 6m diameter fireball and a 1 tonne release will give a 60m diameter fireball.

On the whole, LPG has a reasonably good safety record in the UK. Relatively small-scale incidents involving fatalities occur from time to time but to date there has been no major incident.

Abroad, in the major fire at an LPG storage installation near Mexico City in 1984, 6 storage spheres, each containing several tonnes of LPG, and 54 horizontal tanks, each containing up to one hundred tonnes of LPG were destroyed, at least 500 people were killed and more than 7,000 people were injured; in the USA several incidents with large railcars of LPG have occurred.

Clearly, a product such as LPG can only be used in reasonable safety if due attention is given to the proper design, construction, maintenance and use of storage vessels, connecting pipework and appliances. Satisfactory guidance on these features is readily available.

Beyond these features, attention must be given to siting, layout and design of storage facilities as a whole and to additional safety features that will minimise the consequences of a leak or a fire if one should occur.

The following safety features are available to mitigate the effects of an external fire on a storage tank:

Pressure relief valves: Valves that open at a set pressure and reseal when the pressure drops as a result of partial discharge of vessel contents. As the vessel is heated by an external fire, the vapour pressure of the contents rises and this excess pressure can be relieved through a PRV. If the PRV is adequately sized, the vessel contents may be discharged in this way, thereby preventing catastrophic vessel failure. The material discharged through the PRV would normally ignite in the presence of an external fire giving rise to a jet of flame perhaps 2m long for a small cylinder and 5-6 metres long for a 1 tonne vessel.

Earth mounding or burying: Either of these techniques is a means of giving protection to storage vessels against the effects of an external fire.

Water sprays: Such sprays are designed to be actuated in the event of a fire in the vicinity of the vessel and to apply an even spray of water over the vessel surface. The cooling effect of the sprayed water reduces the heat transfer to the vessel contents and keeps the vessel shell at a temperature of about 100°C, thereby preventing the loss of strength that comes with increased temperature.

In the UK, all LPG cylinders of 4.8 kg or greater in capacity are, or will soon be, fitted with PRVs, as are all storage vessels. Automatic fixed water sprays (or an equivalent standard of protection) are required by the Health and Safety Executive for an LPG storage vessel of 50 tonnes capacity or greater, or a total inventory in excess of 50 tonnes, for new installations. Non-automatic means of applying cooling water, eg the use of water monitors, is required for LPG storage vessels from 25 to less than 50 tonnes, for new

installations.

Given this range of safety features what is the potential role for insulating coatings in the fire protection of LPG vessels?

Each of the above techniques has its limitations in terms of reliability and applicability.

PRVs are highly reliable mechanical devices but they have been known to fail to danger, i.e. not open when required. The codes for selecting PRV size appear to be satisfactory but, in the event of a prolonged fire, weakening of the vessel walls may lead to failure at a much lower pressure; vessel failure can then occur even with a correctly functioning PRV. This effect is much more likely with an aluminium cylinder than a steel one.

For mobile systems such as road or rail tankers, a roll-over accident is possible. This has two effects on the PRV — the burning discharge, instead of being upwards, may now be horizontal, thereby endangering firefighters and the PRV may now discharge liquid rather than vapour; the discharge of liquid puts up the heat release of the flare and reduces the cooling effect within the vessel because no vaporisation is taking place. The latter effect will lead to a more rapid pressure rise and the possibility of vessel failure. Similar considerations apply to portable cylinders, e.g. they may be knocked over.

Earth mounding (at ½m thick) and burying are expensive techniques. They present inspection difficulties for the requisite periodic pressure vessel inspections and prevent the free ventilation of the volume around the vessel so that in the event of a small leak on pipework, for example, flammable vapour/air mixtures may be created.

Exposure of a buried tank to ground water may cause tank or pipework damage by corrosion or by floating the tank. Damage may also be caused by earth movement.

Fixed water spray protection is also an expensive technique. The quantities of water required for effective protection are such that an independent water supply from an on-site reservoir may be necessary for larger installations. There are reliability problems associated with the integrity of the water supply, through maintenance requirements, pump failure possibilities, spray nozzle blockage etc.

In qualitative terms, for UK purposes, one can therefore say that insulating coatings if adopted would be used in conjunction with PRVs as an additional means of protection. For vessels of 50 tonnes or greater, surface coatings would be competing with fixed water sprays, earth mounding and burying and would therefore be doing so on grounds of cost effectiveness and reliability. The concept of equivalent protection to water sprays would be used as a yardstick for the degree of protection required. For mobile systems and for fixed vessels less than 25 tonnes in capacity, insulating coatings would be offering an additional degree of protection above current practice.

The potential benefits of insulating coatings in the fire protection of LPG vessels against fire engulfment or thermal radiation from a fire at a distance are:

1) The reduction of heat transfer to the vessel contents. This will reduce the boil off rate of LPG vapour, assisting the PRV to cope with the vapour flow, keeping internal pressures close to the PRV operating pressure and reducing the heat output from the ignited discharge. It will also delay the time at which the PRV first operates, which could be beneficial in many circumstances.

2) The maintenance of lower vessel wall temperatures. By placing an insulating medium between the vessel wall and the external fire, the wall temperatures may be substantially reduced. The critical regions of the vessel walls are those in contact with the vapour space; the wetted regions will be fairly close to the liquid temperature but the non-wetted regions can attain high temperatures and lose mechanical strength. Insulation can therefore assist in preserving the

vessel strength.

The effectiveness of insulation against jet flame impingement has not yet been established.

Apart from the cost-effectiveness, the following properties are also important:

3) Durability: One potential advantage of an insulating coating is that it is ever present and available on demand. To maintain this advantage, the coating must have durability, good weather resistance, good lifetime adhesion (where appropriate), toughness, resistance to reasonable impacts.

4) Weight: An insulating coating is an additional load that would affect vehicle payload, vehicle stability, strength of supports required for fixed vessels etc.

5) Inspection: LPG vessels are pressure vessels requiring periodic inspection. An insulated vessel must have provision made for these inspections.

6) Corrosion resistance: Clearly, the coating must not interact with the vessel walls and initiate corrosion or allow ingress of water which could cause corrosion.

7) Stability under fire exposure conditions when subjected to high pressure water jets or the heating/cooling effects of fire exposure.

8) The requirement for heat input from the environment to sustain normal vapour offtake.

There are many complex interactions in the fire protection of LPG vessels. PRV technology and standards are reasonably well defined but beyond that there are various alternative approaches, as outlined above. To assist in the understanding of these interactions, the Health and Safety Executive has been carrying out a comprehensive programme of research at its Explosion and Flame Laboratory, Buxton. Much of this research has been in conjunction with Shell Research Ltd.

The general procedure has been to submit the vessel under test, with a charge of commercial propane, to total fire engulfment in a kerosene test fire (Figure 1). The following series of tests have been carried out so far:

A: Uninsulated vessels with PRVs, vessel sizes from 500 litres to 5 tonnes.

B: Uninsulated vessels with PRVs, 500 litre vessel size, water spray protection.

C: Insulated vessels with PRVs, 500 litre vessel size, with a range of commercially available and development systems.

Series A

In this series, fire engulfment tests were carried out with

Figure 1

Total fire engulfment in a kerosene test fire.



500 litre, 1 tonne and 5 tonne vessels fitted with appropriately sized PRVs. The general procedure was the same in each case:

The uninsulated vessel was instrumented with thermocouples attached to the vessel walls, thermocouples within the vessel in both the vapour and liquid regions and pressure transducers to measure the internal pressure. The vessel was supported above a pool of kerosene of sufficient size to ensure that, when the kerosene was burning, the flames totally engulfed the test vessel with flames at least 1 metre thick.

The instrumentation for the two larger vessels was more elaborate, with load cells used to determine LPG discharge rates, heat transfer measurements within the fire and radiation measurements outside the fire.

The duration of a test was determined by the volume of kerosene initially placed in the pool; a remotely controlled fire extinguishing arrangement could be used to terminate the test at an earlier stage if required.

Tests were carried out with commercial propane in the vessel, with initial fill ratios of 40% of the 500 litre vessel and 20, 40 and 80% in the larger vessels^{1,2}.

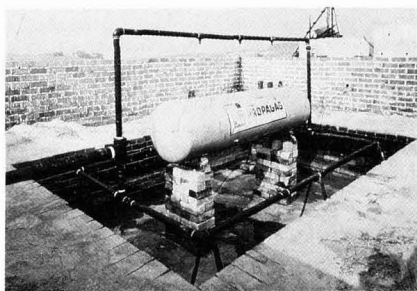
Series B

Tests were carried out using a 500 litre vessel, with a 40% fill ratio, with water spray protection nozzles installed to give good coverage over the vessel surface (Figure 2). Test conditions were as for Series A except that the water sprays were turned on after the initial test fire was ignited, at a time when thermocouple measurements showed that vapour space wall temperatures had reached 200-250°C.

Tests were carried out with spraying rates equivalent to 0.12, 0.16 and 0.24 l/m².s; the recommended minimum spraying rate is 0.16 l/m².s³.

Figure 2

Test vessel supported above a pool of kerosene showing water spray protection system.



Series C

Tests were carried out using a 500 litre vessel insulated in a variety of ways with a 40% fill ratio. Test conditions were as for Series A^{4,5}.

As the materials were under consideration for a transport application, only those meeting appropriate weight and impact resistance criteria were tested.

The following insulation systems were tested:

Material	Description
A	10 mm coating of intumescent paint

B	9 mm coating of sublimation paint
C	12 mm thick blanket of ceramic fibre having a density of 64 kg/m ³ . Enclosed in a stainless-steel sheath
D	25 mm thick blanket of ceramic fibre having a density of 128 kg/m ³ . Enclosed in a stainless-steel sheath
E	10 mm coating of intumescent paint on 12 mm of mineral blanket having a density of 64 kg/m ³ .
F	Ceramic blanket composite, clad with stainless-steel sheet
G	15 layers of expanded aluminium mesh, coated with intumescent paint.
H	15 mm coating of intumescent paint on 25 mm thick ceramic blanket, density 128 kg/m ³ on 2 mm of intumescent paint.
I	10 mm of sublimation paint on 25 mm thick ceramic blanket, density 128 kg/m ³ .

Results of tests

Detailed presentations of the test results have been given in references¹⁻⁵. For the present purposes, it is sufficient to consider vessel response in relation to the degree of protection afforded by the different systems. The following performance criteria are of significance:

1) Time to first opening of PRV: During an actual fire engulfment incident, the opening of the PRV is a significant event; it indicates the pressurisation of the vessel and the functioning of a safety device. It may create a local hazard, if on an overturned vehicle, by directing a jet of flame along the ground.

2) Time to the vessel walls achieving 427°C: Certain small scale fire tests for insulation systems specify that the system shall prevent the temperature of a steel plate insulated by the system from rising above 427°C for 100 minutes of flame exposure⁷. All of the systems tested in Series C had met this criterion. The significance of the criterion is that as steel is heated it loses mechanical strength; the temperature of 427°C is in the temperature range in which a significant loss of strength is beginning to occur, with a weakening of the vessel walls of the pressurised LPG container.

3) Heat transfer to the vessel contents from ignition to the time of first operation of the PRV: This is a direct measure of the effectiveness of a system as a thermal insulation medium, averaged over the stated period, that is to say taking account of any degradation of performance resulting from fire exposure.

4) As (3), but from the time of first operation of the PRV to the end of the test. This reflects performance in the later stages of the test when extensive loss of coating or deterioration of performance may have occurred.

The values of these criteria derived from the test data are summarised in Table 1, for all tests relating to the same vessel size and fill ratio, i.e. a 500 litre vessel, 40% filled with propane.

Data for the insulated tanks are listed in an order of ranking based on the time observed for performance criterion (2), with the best performance first.

It can be seen that the order of ranking is similar by each criterion and that all of the insulation systems tested outperform water sprays as a means of protection, when judged by criteria 1, 3 and 4.

The data for criterion (2) are of particular interest because they relate most closely to the hazardous conditions that could give rise to vessel failure. In the water spray tests, the vapour space wall temperatures were approximately 200°C when the water spray was turned on. For the 2 higher spray rates, this temperature reduced fairly rapidly to 90-100°C and remained there until the end of the test (c. 20 minutes after ignition). With the lowest spray rate (i.e. a rate below the minimum recommended value) this temperature dropped to 160°C and then rose steadily to over 200°C at the end of the test (18 minutes after ignition). The indications are that a water spray at the recommended rate could maintain the vessel walls below 427°C indefinitely, although, in practice, the quantities of water involved are so large that reservoir capacity becomes a problem. HSE requires from 60 minutes spraying capacity in any reservoir specific to a water spray protection system.

All of the insulation systems tested by total fire engulfment had met criterion (2) in small scale screening tests.

However, it can be seen that the wall temperature of 427°C was achieved in as little as 6 minutes by one of the systems tested and that only one system gave a value exceeding 100 minutes. This indicates that the fire engulfment test is much more severe than the small scale tests. There are two main reasons for this:

a) The fire engulfment test procedures subjects the entire system to a fire exposure test on a realistic scale. Some systems have joints which are not tested on the small scale; the stresses in the test materials and the aerodynamic forces on the materials may be greater on the larger scale.

b) In the small scale test, the rear face of the test sample is losing heat by radiation and convection to surroundings at ambient temperature. In the fire engulfment test, the lower portion of the vessel walls is losing heat to liquid LPG at c. 50°C but the upper portion is in contact with LPG vapour which may be at 200°C or more. The heat loss from the 'dry' portion of the walls is very much reduced and the walls heat up more quickly.

The heat flux from the flames to the vessel in the fire engulfment tests was estimated at about 120 kW/m², which is comparable to values occurring in small scale tests; the increase in severity does not derive from an increased heat flux at the exposed surface.

To make optimum choices of fire protection methods, one needs design methods and performance criteria. All of the test data outlined above has been analysed in considerable

detail and equations describing the system have been developed. A computer code, designated ENGULF, has been developed under contract to HSE at the Safety and Reliability Directorate⁹.

This code enables prediction of vessel response to be made for a wide range of circumstances, including the presence of a layer of thermal insulation. This enables different protection strategies to be evaluated.

Some of the systems tested in Series C were passive systems, inert insulating blankets in effect, while some were active systems e.g. epoxy resin based systems sprayed on to the vessel walls that intumesced and ablated under fire exposure. The behaviour of active systems is a complex matter which it is not easy to include realistically in the computer model. Insulation systems need to be assessed by tests involving fire exposure.

Realistically sized fire engulfment tests, as described in Series C, are expensive. Such tests are affordable for a developed product for which a market niche has been identified but expensive for tests on systems under development.

A smaller scale test is necessary for development purposes. One such test is described in the US Code of Federal Regulations⁷, based on large scale fire engulfment tests carried out in the USA. In this test, the system under examination is applied to a 4ft square steel plate, with thermocouples attached in specified places, and the sample is heated by a jet of flame. The measured temperature rise on the steel plate must not exceed 427°C in 100 minutes (see criterion (2) above); all of the systems tested in Series C had passed this test.

Some development and refinement of this test is, in our opinion, necessary but it does offer a good starting point for a screening test. At present, HSE is developing guidance on the fire protection of LPG vessels using thermal insulation and further consideration of small scale test methods is taking place in conjunction with this.

References

1. Moodie, K., Billinge, K. and Cutler, D. P., "The fire engulfment of LPG storage tanks", I Chem E Symposium Assessment and control of Major Hazards, UMIST, April 1985.
2. Moodie, K., Cowley, L. T., Denny, R. B., Small, L. M.

Table 1

Performance data for various systems in fire engulfment tests (500 litre vessel, commercial propane, 40% fill)

Criterion System	1		2		3		4	
	Time to first opening of PRV (minutes)	Time to vessel walls reaching 427°C (minutes)	Average heat transfer to vessel contents (kW)					
			a) Initiation to PRV operation		b) After PRV operation			
Uninsulated vessel (no water spray)	3	3	123		113			
Uninsulated vessel (with water spray)								
0.12 l/m ² .s	5	>20	68		115			
0.16 l/m ² .s	5	>20	55		88			
0.24 l/m ² .s	8	>20	48		82			
I	69	>100	1		3			
G	25	85	6		12			
H	70	55	2		4			
E	62	51	4		19			
F	27	33	3		10			
A	10	16	8		19			
B	22	14	9		30			
D	24	12	9		14			
C	12	6	15		24			

Continued on p.184

Porosity measurement of aqueous coatings

by J Anneveldt, General Chemical Corporation, PO Box 43051, Industria 2042, South Africa

Summary

The prize-winning entry, introduced at the annual meeting of the Southern Society for Coatings Technology, March 25, 1983 in Memphis, TN, was by Dan Adrien of the Burgess Pigment Co. on "Nigrosine as a Porosity Indicator".

Our development laboratory has evaluated this interesting test, investigated several important parameters and, as a result, come up with a proposed test method for determining the porosity index of water based coatings.

Introduction

The basic principle of Adrien's test is that an aqueous solution of nigrosine in contact with a dry (white) paint film, will penetrate and show a grey colour, which will be more intense the more porous the film structure is. The intensity of the nigrosine absorption can therefore be related to the degree of film porosity. By measuring the total reflectance (TR) or light reflectance value (LRV) of the grey colour with a reflectometer, the accurate depth of nigrosine absorption can be determined, with high TR (LRV) values indicating low absorption (low porosity) and vice versa. A comparison between TR (LRV) values of different nigrosine treated coatings will indicate the level of porosity, which we call the Porosity Index. A final refinement is to incorporate the TR (LRV) value of the paint film without nigrosine treatment. For this reason the test method as proposed is for white coatings only.

Nigrosine solution

As given by Adrien, we have standardised on a 3% (M/M) solution of Nigrosine in tap water. The Nigrosine used, was Nigrosine G140, as marketed by Imperial Chemical Industries (ICI).

Film preparation

In the prize-winning entry, published in the Journal of Coatings Technology, September 1983, no details are given on the actual preparation of the paint film. Since it was felt that smoothness of the film could have an effect on the test result, the author compared brush and roller application with film drawdown at the same wet film thickness, with the Nigrosine solution applied both ways as recommended by Adrien, i.e. pouring and swabbing (Table 1).

Effect of method of film application

Table 1

	Nigrosine			
	W.F.T. (micron)	Application	Retention	TR(LRV)
Brushing	75	Pouring	Uneven	70
Brushing	75	Swabbing	Uneven	72
Roller Applied	75	Pouring	Uneven	57
Roller Applied	75	Swabbing	Uneven	65
Drawdown	75	Pouring	Even	69
Drawdown	75	Swabbing	Even	74

60% PVC, 1 hour drying, W.F.T. equals Wet Film Thickness.

Conclusions

1. Only film drawdown ensures even nigrosine retention.
2. Pouring and swabbing gave different nigrosine retention with the former a more intense colour.

Film thickness

Two wet film thicknesses were considered, i.e. 75 and 100 microns (Table 2).

Table 2

Effect of film thickness

Micron		T.R.
75	Pouring	69
75	Swabbing	74
100	Pouring	64
100	Swabbing	70

60% P.V.C., 1 hour drying, drawdown

A practical wet film thickness of 100 Micron (equivalent to a spreading rate of 10m²/l) was selected, since at low PVC this film thickness can give a better differentiation. The film applicator (doctor blade) used must have a gap size to produce this wet film thickness. The author found the Sheen Bar Applicators very suitable for laying down films on glass panels of 100 × 200 mm, with the wet film being approximately 2/3 of the gap size, i.e. 6 Thou gave 100 Micron wet film thickness.

Panel drying time

Although 1 hour drying time would appear adequate, it was found that at higher PVC levels a drying time of 2 hours was preferable. At PVC levels over 70%, which invariably are above CPVC, polymer coalescence and internal film structure take a longer time to establish.

One hour drying time at PVC levels over 70% can result in film disintegration on immersion and washing, but this, principally, will depend on the type of polymer and type and quantity of coalescent solvents used. Also the oil absorption and the particle shape of the extender pigments and total water solubles present in the paint film will have a bearing on this aspect.

Nigrosine application

The valid observation of Adrien "as the depth of color will vary with length of time the nigrosine solution is in contact with the film" made us select a dipping application with fixed immersion — and draining times before the washing off operation (Table 3).

Table 3

Immersion	Draining	TR Value
30 secs.	30 secs.	82
60 secs.	60 secs.	79.5
90 secs.	90 secs.	77.5

30% PVC, 100 micron drawdown, 1 hour drying.

Conclusions

Even with a relatively low porous 30% PVC level, 30 secs. immersion/30 secs. draining gave adequate nigrosine retention.

As final basic parameters one therefore selected:

- 3% (M/M) Nigrosine solution in tap water
- Drawdown film application
- 100 Micron wet film thickness
- 2 Hour drying time (25°C)
- Dip application in nigrosine solution
- 30 Sec. immersion time
- 30 Sec. draining time
- Rinse panel till clear water runs off
- Measure nigrosine retention as total reflectance-LRV or TR
- Calculate LRV ratio as TR (LRV) Immersed Part

_____ to 2 decimals rounded off

TR (LRV) Unimmersed Part

- Porosity Index = (1 - LRV ratio) × 100

Experimental

A series of six white dispersion paints was made up, varying in PVC from 30 to 80%, with a PC of 20% and a NVV of 25%. One extender pigment, an aluminium silicate, was used and the level of surfactants, additives and coalescent solvents was kept constant in all six paints.

When tested, as previously described, the results as shown in Table 4 were found

Proposed test method

Using a suitable film applicator, apply a wet film of 100

Table 4

PVC	TR Immersed	TR Unimmersed	LRV Ratio	Porosity Index
30%	78	81	0.96	4
40%	75	81	0.93	7
50%	72	82.5	0.87	13
60%	63	88	0.72	28
70%	50	90.5	0.55	45
80%	36	91	0.40	60

Tentative Porosity Classification

Low porosity - P.I. below 10

Medium porosity - P.I. 10 - 30

High porosity - P.I. over 30

micrometres of material under test to a clean, smooth glass panel 200 × 100 × 5 mm. Allow to dry for 2 hours in a horizontal position under dust free conditions at a temperature of 25 ± 2°C and a relative humidity of 50 ± 4%.

Immerse half the panel in a vertical position in a 3% (M/M) Nigrosine solution in tap water for exactly 30 seconds, withdraw and allow to drain in a vertical position for exactly 30 seconds.

Wash panel front and back with a gentle stream of tap water till washwater is clean.

Dry panel at ambient temperature. When completely dry measure total reflectance of both immersed and unimmersed parts. Calculate the LRV ratio as LRV immersed part/LRV unimmersed part rounded off to 2 decimals.

Express porosity as (1 - LRV ratio) × 100.

The test shall be carried out in duplicate and results shall not differ by more than 2 units. ■

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jocday

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**12 October 1989
 Building Research Establishment, Garston,
 Watford, Herts.
 Contact John Gant on 043 871 5260
 for further information**

jocprotect



Ellinger-Gardonyi Trust

Readers of JOCCA will be aware of previous reference in this column to the Ellinger-Gardonyi Bequest. The Bequest has now provided the financial basis for the establishment of a new educational trust registered under the Association's general charitable status.

Marianne Ellinger was a loyal and active supporter of the Association and in particular was a regular attendee at OCCA technical meetings. The Bequest was entrusted to the Association as part of the settlement of Marianne Ellinger's estate and the interest was to be applied to the promotion of the science and technology of paint chemistry and in furtherance of this purpose to make an award "to that one Licentate of the Association whose dissertation in this field is considered by my Special Trustees to have been the most meritorious in the course of the calendar year immediately preceding the granting of the award".

Changes in the Association's constitution have meant that the original application of the Bequest is no longer applicable and accordingly the Association have made application to the Charity Commission for the establishment of a general educational trust within the surface coating industries. After very considerable delay the Bequest has now been registered as a charitable trust and the Association is now in the position to be able to sponsor new and developing projects of an educational nature which will benefit the Association

and the industry as a whole and without the assistance of the Trust Fund would have been unable to undertake.

The terms of the Trust Fund allow the Association to apply interest accruing from the capital base of the Trust for educational purposes and the Trustees have decided that for 1989 the sum of £10,000 will be available for such purposes. It is believed that this sum, inflated each year in line with the increase in the retail price index, can be sustained without any diminution of the capital base.

Council is very conscious of its responsibility to manage the Trust and accordingly has appointed Past President Frank Redman to advise the Trustees on its application. Frank has already undertaken preliminary consultation with leaders of the paint industry and as a result has received a number of very exciting ideas for the disbursement of the funds. Industry has responded very favourably to this initiative and it is believed that funds may be available from companies to support some of the projects put forward.

During 1989, some funds will be used to produce one or two additions to the monograph series, to finance a revision of the long established Introduction to Paint Technology and to provide additional pages for significant technical papers within JOCCA. Where a project is likely to produce income for the Association, it will be funded through a loan from the Fund with repayments being made as a first call on income from the project.

Other projects under consideration include lecture programme and meetings for young entrants to the industry, posters and publicity material for schools and training manuals.

More major projects include the production of a careers video and the exciting concept of undergraduate course modules and the eventual establishment of a Chair in Surface Coating Technology. Clearly, such projects

will not be able to be funded by the Association through its Trust Fund and it is hoped to seek funding from industry.

The Trustees are committed to making good use of the Bequest and it has been agreed that at least 50% of the funds available in any one year will be used for new projects, with the remainder going to continuing support for existing activities.

Readers of JOCCA are invited to comment on the application of the Fund and put forward their suggestions for its use. Please address your comments to Frank Redman at Priory House.

The Fund will also provide for the award of a medal to the author or authors of the best paper presented at the biennial OCCA Conference. The sterling silver medal and certificate will first be awarded at the Chester Conference in June. The Association's Awards Committee in considering papers submitted will reach their decision based on the technical content of the paper rather than its presentation, although presentation will play a factor in reaching the decision if two papers are equally worthy of consideration. The medal will carry a likeness of Dr Ellinger on the obverse with the name of the recipient and year of presentation on the reverse.

The establishment of the Ellinger-Gardonyi Bequest as a charitable education trust is a very major development for the Association and one that will have profound effect on the range of activities and services provided for members and the industry they serve. ■

ASSOCIATION AGM

Friday
23 June 1989
Grosvenor Hotel
Chester

Hull Section

Fatigue testing, accelerated weathering and salt spray

Three papers were delivered at the third meeting of the present session held on 6 December 1988 at the Duke of Cumberland, Cottingham.

Mr D. Moulton of Tioxide UK Ltd spoke about "Fatigue Testing of Weathered Paint Films". Cracking was the main problem on wooden substrates due to dimensional instability; both radial and tangential strain occurring. The "Fatigue Machine", a device developed at Tioxide and yielding numerical values for cycles to cracking failure, was described. Films on flexible metal strips are flexed in a regular fashion and the point where cracking occurs is noted. The speaker went on to discuss the effect of various parameters on the failure count including film thickness, temperature, ageing and pigmentation. A plot of $\log N_f$ cycles to failure, against \log film thickness demonstrated very well how failure occurred at lower counts with thicker films, due to greater strain in such films. Poorer performance on these linear plots is denoted by a steep gradient or lower N_f ratings at equivalent thicknesses.

Interesting differences in counts occurred with different ageing conditions. Thermal ageing resulted in relatively high counts compared to artificial weathering, due it was thought to photo-catalytic effects. The problem of cracking was more severe at higher PVC and results using carbon arc were similar to natural weathering. Lamellar pigments were less prone to cracking than rounded types. A comparison of results obtained with white and non-white wood stains employing different finishing conditions (ideal, unsealed, weathered film and single coat) was given followed by results demonstrating the good correlation between Fatigue Machine and natural weathering.

Mr Moulton finally dealt with a range of questions concerning the use of lower temperatures in

evaluating thermoplastic paints and the tendency of the latter to delaminate rather than crack, commercial availability of the machine, use of the machine for initial sorting and the effect of changing the frequency of flexing.

"Sunlight, UV and Accelerated Weathering" was the title of the talk given by Mr David Birchenough of Q Panel Company.

He began by describing his company's QUV weatherometer which incorporated temperature control, UV to simulate sunshine and condensation to simulate rain and mist. Major factors affecting natural weathering such as earth position and season were discussed together with wavelength cut-off point and reduced UV in winter.

Desirable features of UV sources were outlined. The UV-B lamp originally developed for automotive coatings contained radiant energy not present in sunlight and could be a little severe for some applications. Good correlation with natural sunshine was obtained with the UV-A351 lamp, considered to be half as severe as the UV-B but this was slow. The UV-A correlated particularly well with glass filtered sunlight.

The speaker then demonstrated how closely the wavelength distribution provided by the UV-A340 lamp matched that prevailing in natural sunlight. The result was good correlation with natural weathering in a reasonable time scale.

Data were then presented showing how, under natural conditions, the largest proportion of film wetness time was due to condensation rather than rain. The adverse effect of moisture could be accelerated, not by increasing the time of wetness but by increasing temperature.

Mr Birchenough concluded his talk with a discussion on the advantages and disadvantages of the QUV equipment.

During the question and answer session which followed, Mr Birchenough explained that sunshine wavelength distribution was similar in summer and winter, merely varying in intensity and UV content. The use of contaminating species, e.g. salt, in the water phase

used in the QUV was neither recommended nor desirable. Reproducibility which could be reduced by such addition, was considered much more important than attempting to simulate certain local conditions such as coastal salt. Following further questioning, the speaker stressed the UV-A340 should be employed for comparative purposes and not considered as representing a particular place or correlating with a particular time (which varied with coating composition anyway). It was also important not to exceed the parameters intended for the material under test.

Mr M. H. Bingham of Akzo Coatings spoke about "Realistic Testing Using The 'Prohesion' Salt Spray Cabinet".

The speaker defined the essential area of interest as the deterioration of coated metal structures due to corrosion. Coated systems consisting for example of chrome plated, PVC clad, lacquered and painted steel in many forms were extremely complex in nature. Electro-chemical methods of corrosion assessment were straightforward for a single metal in contact with a known environment but for the complex systems referred to, data were difficult to interpret.

Critical components of a range of environments were outlined: rain (which might contain dissolved sulphur dioxide), ammonia from organic decomposition, dew and sea-spray. Cycling also occurred, hot/cold and wet/dry and physical damage resulted from ice and freeze-thawing.

Practical and photographic examples of "pitting" resulting from chloride and sulphate forming a regenerating cycle in the metal surface were given. Ammonia was important because of the ease with which it moved through organic films to enhance corrosion and blistering.

Mr Bingham went on to discuss solutions which were appropriate and relevant in salt spray equipment and also the consequences of total wetness. A number of standards, employing artificial sea-water, hot 5% sodium chloride, distilled water, at various

temperatures and varying wet/dry cycles were mentioned.

He went on to describe the "Prohesion" test which incorporates a dilute ammonium sulphate/sodium chloride solution with a wet spray at 20°C followed by drying at 35°C and cycling between 1 and 4 hours.

Mr Bingham concluded by mentioning some of the strengths (good sorting test and achieving wider acceptance), weaknesses (not meaningful with very thick coatings) and also acceleration factors for different systems.

He finally dealt with a number of questions from the audience concerning severe corrosion in bridge structures, correlation with externally exposed thin films, specifying authorities and effect of UV on corrosion results.

* "Prohesion" is the registered trademark of C. & W. Specialist Equipment.

The meeting concluded with a vote of thanks to the three speakers, proposed by the Chairman, Mr B. J. R. Mayes and endorsed by the audience.

D. Robinson ■

London Section

Wax emulsions/dispersions

The second meeting of 1989 was held on Thursday 16 February at the Naval Club, Mayfair. Mr. Christopher Auger, a technical consultant with Cera Chemie BV, gave a presentation entitled: "The Use of Wax Emulsions and Dispersions in the Ink and Surface Coatings Industry".

Mr Auger began by outlining the definition of a wax and classifying the different types of wax depending upon their origin. Initial classification can be based upon those of natural or synthetic origin. Further subdivisions of the natural types is whether they are derived from vegetable, fossil or mineral. The synthetic types are divided depending upon their chemistry, i.e. hydrocarbon or non-hydrocarbon. In the surface coating industry, polyethylene waxes constitute the vast majority and the

remainder of the presentation focussed upon these.

The benefits offered by the incorporation of waxes into coating systems were then discussed. These included improved mar resistance, antiblocking, slip and formability, antisetling and antisagging, flattening, abrasion resistance and metal marking resistance. The benefits of inclusion in ink systems are improved rub resistance and scratch resistance.

A number of specific wax emulsions and dispersions were then discussed in relation to satisfying certain application and coating properties.

The techniques used to incorporate the wax into inks and coatings were discussed and the choice of technique depends largely upon the end application, the solvent and the nature of the wax. These processes included emulsification, cold milling (mechanical method), solution mechanical, solution precipitation and micronised waxes.

Two theories exist as to the mechanism of wax action. Mr Auger concluded that he believed that the true mechanism may be a complication of these two theories. One is based upon the wax acting as a roller bearing while the other assumes that the wax acts by floating.

A vote of thanks was proposed by Mr Brian Gilliam prior to the buffet sponsored by Cera Chemie BV.

G. J. Steven ■

Manchester Section

Radiation curing

The last paint lecture of the 1988/89 session, was held at the Mechanics Institute, Manchester, on Monday 6 March 1989. Forty-four members and guests attended, and a paper entitled "A Study of the Tensile Properties of Prepolymer/Monomer Blends when Cured by UV Radiation" was presented by Mr G. J. Stevens of Cray Valley Products.

Bar takings at the Mechanics Institute were considerably enhanced, as the start of the lecture

had to be delayed due to a faulty projector. Heroic action by the section secretary Mike Nixon rescued the situation. A 40-minute dash from Manchester to Stockport and back, for his own equipment meant there was only a half-hour delay. The section treasurer declined to pay any subsequent speeding fines out of the section funds, however.

Mr Stevens commenced by outlining the historic background to radiation curing, and the current trends based on acrylates, which are the most widely used IR cured systems in Europe. The different systems currently available were described, and the increasing diversity of the areas in which UV cured materials are being used outlined. In some areas, tensile properties are important, and these can be varied in two ways:

- 1) Variation of Prepolymer type,
- 2) Variation of Monomer type.

Experimentation was carried out, initially by varying the prepolymer, keeping the monomer constant, and maintaining a constant viscosity. The preparation of the tests strips using clear films on glass was outlined, and the test method briefly described. The results were weight averaged to the best results obtained with each system, and the wide variation in both elongation and tensile strength graphically described.

The degree of cure can affect tensile strength and elongation, and the variation in these properties by varying cure was outlined.

It is also possible to vary tensile properties by varying the monomer and the effect of different monomer types on both tensile strength and elongation were outlined.

In conclusion, it can be stated that the factors affecting the tensile properties of UV cured materials are complex, and varying both prepolymer and monomer can give a very wide range in tensile strength and elongation.

The lecture was followed by a very lively question and answer session, the vote of thanks was proposed by David Love, and afterwards those present were able to participate of a buffet sponsored by Cray Valley Products.

M. G. Langdon ■

Obituary

H W KEENAN PhD FRIC FTSC President 1944-47

Robert Hamblin writes:

Members of the Association will be saddened to learn of the death on 3 April of Harry Keenan, since his contribution to the Association lay not only in the distinction which he brought to the offices which he held but also in his abiding interest in technical education. Indeed, had it not been for his constant support and encouragement, as Chairman of the Working Party on Education, Training and Qualifications, it is doubtful if the proposal for an optional Professional Grade for Ordinary Members would have been adopted by the Council in 1971. Since that time, while he acted as Chairman of the *viva voce* examination panel, his understanding of the problems facing candidates at such a crucial time, his courteous, firm handling of the occasion and the way in which he was able to summarize the views of the panel endeared him to those who were privileged to serve on the panel — and, I have no doubt, also to many of the candidates.

When I first met Harry in 1951, he had already achieved so much on behalf of the Association that he might easily have decided that he would withdraw from further activity. But this was definitely not Harry's way and he continued to render assistance in a number of fields.

His first held office as Chairman of the London Section from 1940 to 1942, having been a member of the Council in 1939. As Chairman, he delivered a paper on a Sunday in November 1940 to the Section on "Technical Education" and a few months later inaugurated the Post Graduate Lectures, the first of which were given in August 1941. He served on the Technical Education Committee formed in 1943, which drew up a Report advocating the Apprenticeship Scheme, eventually adopted first by the printing ink industry and then by the paint industry. Elected President in 1944, he served for three years during which the Association expanded on many fronts against a most difficult background. In November 1944 he suggested that a meeting should be called of paint chemists in Australia to consider the formation of a Section in that country, as a result of which a petition was presented to the Council — and approved — in July 1945. While the war was still in progress he sought to effect closer ties between OCCA and the Federation of Paint and

Varnish Production clubs (FPVPC) in the USA. In the Spring of 1946 he attended a meeting of the Federation in Atlantic City, when an alliance was formed which was ratified by the OCCA AGM in July the same year. As a first outward sign of this alliance, the special exchange of monthly publications between members of the two societies commenced. Before he left the Presidency at the Buxton Conference in 1947, he had explored the possibility of closer liaison with European paint chemists. In his final speech as President he was able to report that M Ravel on behalf of the French technicians had similarly expressed a desire for co-operation and the Association welcomed this move. In October that year at an international meeting in Paris, an alliance of OCCA, FPVPC and the French technicians was proposed by Dr J Mattiello (USA) and Dr H. W. Keenan. From this small beginning grew the present day International Alliance, comprising FSCT, JSCM, OCCA, OCCAA and SLF. At home, the later war years saw the formation of the Bristol Section and the first meetings in the Midlands area. It is also recorded that Harry Keenan addressed the Manchester Section in 1945 on the topic "Co-operative Research" and this was taken up and a number of projects followed in the succeeding years.

In 1947 a momentous event was the presentation (jointly by Beck Koller & Co (England) Ltd, with which Dr Keenan was associated and Reichhold Chemicals Inc. USA) of the Presidential Insignia, incorporating the portrait of Leonardo da Vinci and the motto "Et Manu et Manu". Throughout the next three decades and beyond, Harry Keenan was to be found wherever the Association was involved in technical education — Chairman of both the Technical Education Committee and the Working Party on Education, Training and Qualifications and a member of the Professional Grade Committee. While Chairman of the Technical Education Committee, he presided over the arrangements for the compilation of the highly regarded series of Paint Technology Manuals and himself collated Part 3 "Convertible Coatings".

His advice was so valued by Council that he served three times as a Vice-President in 1955-57, 1961-63 and 1973-75. In 1968, Council conferred upon him the highest honour which the Association can bestow — that of

Honorary Membership.

Harry Keenan's long and selfless concern for the welfare of the Association and his warm personality are memories which will be cherished by all who knew him and to the members of his family the Association offers, as well as its thanks for their support, their deepest condolences in their bereavement.

Tony Jolly writes:

It was with sadness that I heard of Harry's death from an ex colleague. A chapter of my life has finally closed with the passing of the last remaining director of the long gone Beck Koller.

"Uncle Harry", as he was affectionately known to all in the B. K. Sports & Social Club, was to us not just the inventor of the B. K. Drying Recorder or the developer of the earliest resin-based seamless flooring system (Kollerphalt), but a man with the common touch who genuinely represented the club's interests on the board. Lip-service to a cause was not Harry's way — to use a local Speke phrase, "muck or nettles" was nearer the mark! I followed him as chairman of the club and also as Technical Service Department head.

Many a company or club dinner was enlivened by a hilarious speech, one full of wit, humour, excellent timing and no suspicion even of doubtful innuendo. What happy memories he leaves with not only Beck Koller and James Beadel "old boys and girls", but with those who were at Vinyl Products in those days and were involved in the legendary BK v VP annual cricket matches.

Young people of today tend to scorn conformity but seem to contradict this attitude in practice. One consequence of this is that they almost all dress and act alike even when they enter industry. The day of the "character", seems to be over and since Harry was definitely a "character", his passing has accelerated its demise.

Harry was certainly different — a PhD without a Bachelor degree and an OCCA President without having been a Manchester chairman. OCCA can thank him for developing OCCA overseas from scratch during his presidency.

Our hearts go out to Mary and we send her our sympathy and moral support at this trying time.

Newcastle Section Ladies Night



Top table members and guests. Back row, left to right: Mr F Morpeth, Chairman Manchester Section; Mrs Morpeth; Mr J Bravey, Publications Secretary Newcastle Section; Mrs Bravey; Dr S Lawrence, Chairman Scottish Section; Mrs Lawrence; Mr B Myatt, Chairman Midlands Section; Mrs Myatt; Mr C Shaw, Chairman Bristol Section; Mrs Shaw and Mr C Pacey-Day, General Secretary OCCA. Front row, left to right: Mr D J Neal, Vice-Chairman Newcastle Section; Mrs Neal; Mrs Bourne and Mr J R Bourne, President of OCCA.

The Newcastle Section Ladies' Night was held on 17 February 1989, at the Swallow Hotel, Gateshead.

The Vice-Chairman of the Section, Mr D. J. Neal read out a letter from the Chairman, Mr S. Lynn, who was unable to attend owing to illness. In it, Mr Lynn bemoaned the fact that he was not able to attend. He thanked the various companies who, once again, had given such excellent support to the function and wished everyone an enjoyable evening. Mr Neal then went on to welcome the top table guests and proposed the toast to the guests and the ladies.

The response to the toast was made by Mr J. R. Bourne, President of OCCA. He thanked the Section for inviting him and his wife, and spoke of his long-standing association with the Newcastle Section, dating back to the time when he was a Section Member.

Following the speeches, there was the usual lucky ticket draw for bottles of champagne, and as "luck" would have it, at least one prize went to each table. The star prize of a Breakaway weekend for

two, donated by Swallow Hotels, was won by Mr T. Harbottle.

The 225 members and guests then proceeded to dance the night away and a thoroughly good time was enjoyed by all.

D. J. Neal ■

New members

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

Ordinary members

Ayre, J. H. (*Manchester*)
 Bagley, G. E., BSc, PhD (*General Overseas - USA*)
 Bell, J. C. (*Midland - Trent Valley*)
 Burden, W. B. K. (*Transvaal*)
 Callaghan, A. G., BSc (*Newcastle*)
 Clarke, J. P. (*General Overseas - USA*)
 Cosgrove, M. (*Manchester*)
 Farrar, B. G. (*West Riding*)
 Gray, M., BSc (*Newcastle*)
 Hawksworth, S. M. (*Midland - Trent Valley*)

Hayes, G. (*Transvaal*)
 Heatley, P. T., BSc (*Manchester*)
 Khallaf, A. A. S., MSc, PhD (*General Overseas - Egypt*)
 Khunou, F. (*Transvaal*)
 Lloyd, T. L., BSc, PhD (*Midland - Trent Valley*)
 Maharaj, U. C. (*Transvaal*)
 Morrison, S. A. W., BSc (*West Riding*)
 Norvill, J. A. (*London*)
 O'Doherty, B. M. (*Manchester*)
 Panesar, S. S. (*West Riding*)
 Reed, T. J. (*Thames Valley*)
 Shepherd, R. D. L. (*Midland*)
 Viljoen, A. J. (*Transvaal*)
 Warren, R. L., BSc (*Midland - Trent Valley*)
 Wodhams, V. A., BSc (*Manchester*)

Associate members

Geldenhuis, L. J. (*Transvaal*)
 Hutchings, A. P. (*Midland - Trent Valley*)
 Mines, A. G. (*Transvaal*)
 Richardson, A. (*Transvaal*)
 Walker, J. (*Transvaal*)
 Wynne, R. A. (*Midland*)

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INDEX TO ADVERTISERS

Foscolor.....	Reader Reply Panel	Shell International Chemical Co
Joshua Greaves & Sons Ltd.....	191	Ltd.....
Minolta (UK) Ltd. Inside Front Cover		182, 183
NL Chemicals Europe Inc.....	175	Solex International Ltd. Loose Insert
NL Chemicals UK Ltd.....	169	Sub-Tropical Testing Service.....
OBS Machines Ltd.....	197	191
Sachtieben Chemie GmbH.....	187	Thiokol Chemicals.....
		Back Cover
		Wymark Technical Products Ltd. 191

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