Anti-fire Treatments

Dr N K Saxena
Sunil K Sharma
Fire Research Laboratory, Central Building Research Institute, Roorkee
Dr D R Gupta
Chemistry Department, University of Roorkee

Various natural and synthetic polymeric materials, like cellulose and derivatives plastic, rubber and foam, are extensively used in buildings. For doors, windows, decorative wall-and ceiling-linings, thermal and acoustical insulators, textile furnishings, floor coverings, room partitions, electrical fixtures and cables. Combustible, they constitute a major fire-load inside the building, and help spread fire. They *have* to be used, but if their fire-performance characteristics are correctly evaluated, suitable fire-protection treatment can be devised for them.

The spread of fire

Pinpointing the origin of fire is important if effective fire-protection treatment is to be executed. A fire breaks out when there is fuel for it – combustible building materials – when the temperature is high, above the ignition point of the materials, and when there is sufficient oxygen for it to burn. A fire cannot occur in the absence of any one of these.

The fire triangle

It can be initiated by a source as small as an electric spark, a glowing cigarette, a match flame. The ignition source raises the temperature of a small portion of the material to a critical value at which the combustion process starts, and can become self-sustaining. The fire can then spread via combustible materials, and grow.

Every fire goes through three stages – growth, full development and decay; the last, occurring when all available fuel is exhausted or the fire, itself, extinguished. Fire is controlled most effectively while it grows.

Minimising fire

Fire-extinguishing and prevention are two methods to arrest spreading fire. The conventional means of fire-fighting are water, carbon dioxide, dry chemicals, fire-fighting foam, wetting agents and sprinklers. These are administered once the fire takes place. At least one of the three essentials – fuel, oxygen, heat – should be eliminated – by starvation, or removing the fuel supply, by smothering, or removing the oxygen supply, or by cooling the system, removing its heat.

Fire is usually detected after it attains serious proportions, after which, the fire-brigade is called. By then, considerable time is lost. The problem worsens in high-rise buildings – due to the inaccessibility of their higher floors. Fire prevention must, then, take precedence over fire-extinguishing.

Fire-retardant treatment

As suitably-treated materials disallow fire spreading, several different methods for rendering a material fire-retardant have been identified – as impregnation, spraying, surface treatment, and the incorporation of chemicals during the manufacturing stage, itself. A flame-retardant treatment should possess certain characteristics:

- It should be non-toxic, and produce no toxic decomposition products.
- It should not reduce the strength or damage the finishing of the material.
- It should be easy to apply, economical, and easily available.

The chemicals largely employed for fire retardance are either compounds or mixtures of compounds – of phosphorous, nitrogen, sulphur, boron, halogen and antimony. THPC (tetrakis hydroxy methyl phosphonium chloride), APO (ziridinyl phosphine oxide), phosphorylamide, and various combinations of THPC and APO, have been all investigated. They are more efficient in resisting fires, but a single combination has not been commercialised because of their high cost, toxic nature, and several application problems.

Chemical impregnation

Fire-retardant solutions based in ammonium phosphates, sulphates, chlorides, borates, and the like, are used to render cellulose materials fire-retardant. They are either applied by immersion or spraying. Experiments have been conducted at the Fire Research Laboratory to improve their short-term durability. Cellulose materials like curtains, carpets, upholstery, bedsheets and sarees, have also been treated, and their fire performance studied by standard test methods.

Surface treatment

Two types of coatings – non-intumescent and intumescent – are often used as anti-fire treatments. Intumescent coatings work by the synergistic effect of antimony oxide and halogenated compounds. Volatile reaction products, like antimony trichloride, formed in the burning process, act as flame suppressants. They can, however, be damaged by prolonged heating as the surface film cracks and permits heat penetration.

Intumescent coatings contain, in addition to pigments, resins and plasticisers, certain basic ingredients which make them a paint. These are – a carbon, a blowing agent and a catalyst. When heat is applied, these paint films puff up and produce a tough, insulating foam that protects the coated material. The main advantage is their stability at high temperatures and under prolonged heating.

Anti-fire Treatments

Dr N K Saxena
Sunil K Sharma
Fire Research Laboratory, Central Building Research Institute, Roorkee
Dr D R Gupta
Chemistry Department, University of Roorkee

Various natural and synthetic polymeric materials, like cellulose and derivatives plastic, rubber and foam, are extensively used in buildings. For doors, windows, decorative wall-and ceiling-linings, thermal and acoustical insulators, textile furnishings, floor coverings, room partitions, electrical fixtures and cables. Combustible, they constitute a major fire-load inside the building, and help spread fire. They *have* to be used, but if their fire-performance characteristics are correctly evaluated, suitable fire-protection treatment can be devised for them.

The spread of fire

Pinpointing the origin of fire is important if effective fire-protection treatment is to be executed. A fire breaks out when there is fuel for it – combustible building materials – when the temperature is high, above the ignition point of the materials, and when there is sufficient oxygen for it to burn. A fire cannot occur in the absence of any one of these.

The fire triangle

It can be initiated by a source as small as an electric spark, a glowing cigarette, a match flame. The ignition source raises the temperature of a small portion of the material to a critical value at which the combustion process starts, and can become self-sustaining. The fire can then spread via combustible materials, and grow.

Every fire goes through three stages – growth, full development and decay; the last, occurring when all available fuel is exhausted or the fire, itself, extinguished. Fire is controlled most effectively while it grows.

Minimising fire

Fire-extinguishing and prevention are two methods to arrest spreading fire. The conventional means of fire-fighting are water, carbon dioxide, dry chemicals, fire-fighting foam, wetting agents and sprinklers. These are administered once the fire takes place. At least one of the three essentials – fuel, oxygen, heat – should be eliminated – by starvation, or removing the fuel supply, by smothering, or removing the oxygen supply, or by cooling the system, removing its heat.

Fire is usually detected after it attains serious proportions, after which, the fire-brigade is called. By then, considerable time is lost. The problem worsens in high-rise buildings – due to the inaccessibility of their higher floors. Fire prevention must, then, take precedence over fire-extinguishing.

Fire-retardant treatment

As suitably-treated materials disallow fire spreading, several different methods for rendering a material fire-retardant have been identified – as impregnation, spraying, surface treatment, and the incorporation of chemicals during the manufacturing stage, itself. A flame-retardant treatment should possess certain characteristics:

- It should be non-toxic, and produce no toxic decomposition products.
- It should not reduce the strength or damage the finishing of the material.
- It should be easy to apply, economical, and easily available.

The chemicals largely employed for fire retardance are either compounds or mixtures of compounds – of phosphorous, nitrogen, sulphur, boron, halogen and antimony. THPC (tetrakis hydroxy methyl phosphonium chloride), APO (ziridinyl phosphine oxide), phosphorylamide, and various combinations of THPC and APO, have been all investigated. They are more efficient in resisting fires, but a single combination has not been commercialised because of their high cost, toxic nature, and several application problems.

Chemical impregnation

Fire-retardant solutions based in ammonium phosphates, sulphates, chlorides, borates, and the like, are used to render cellulose materials fire-retardant. They are either applied by immersion or spraying. Experiments have been conducted at the Fire Research Laboratory to improve their short-term durability. Cellulose materials like curtains, carpets, upholstery, bedsheets and sarees, have also been treated, and their fire performance studied by standard test methods.

Surface treatment

Two types of coatings – non-intumescent and intumescent – are often used as anti-fire treatments. Intumescent coatings work by the synergistic effect of antimony oxide and halogenated compounds. Volatile reaction products, like antimony trichloride, formed in the burning process, act as flame suppressants. They can, however, be damaged by prolonged heating as the surface film cracks and permits heat penetration.

Intumescent coatings contain, in addition to pigments, resins and plasticisers, certain basic ingredients which make them a paint. These are – a carbon, a blowing agent and a catalyst. When heat is applied, these paint films puff up and produce a tough, insulating foam that protects the coated material. The main advantage is their stability at high temperatures and under prolonged heating.

TABLE I
BURNING CHARACTERISTICS OF MATERIALS

Materials	Thickness	Non combu-stibility test	Ignitabi-lity test	Fire propagation index i_1	Fire propagation index I	Flame-spread class	Smoke density (D_m) Flaming	Smoke density (D_m) Non-flaming
Kailwood	12mm	C	P	16.14	41.50	4	228.0	328.7
Plywood	6mm	C	P	7.47	25.52	3	—	—
Particle board	12mm	C	P	14.21	36.52	3	261.5	410.0
Fibre board	12mm	C	P	33.10	56.00	4	217.5	308.1
PVC profile	21mm	C	P	—	—		585.0	383.5
WC flooring	2mm	C	P	7.72	20.03	4	610.0	186.0

LEGEND:
C-Combustible P-Not easily ignitable
i-Sub-index I-Fire-performance index
Class 1-Surfaces of very low-flame spread
Class 2-Surfaces of low flame spread
Class 3-Surfaces of medium-flame spread
Class 4-Surfaces of rapid-flame spread
D_m-Maximum specific optical density of smoke generated

TABLE II
FIRE PERFORMANCE OF INTUMESCENT COATINGS

Characteristics	Standard method	Fibre board (12mm), Mango wood (12mm) Treated	Untreated	Treated	Untreated
Fire propagation index	BS 476: Part 6: 1981	i_1 = 2.33 I = 12.77	33.10 56.10	2.00– 2.12 12.77-13.00	10.34 30.95
Surface spread of flame	BS 476: Part 7: 1971	Class 1	Class 4	Class 1	Class 3
Smoke density (Non-flaming)	ASTM E662-79	D_m = 36	D_m = 308	—	—
Fire retardancy	ASTM D 1360-79				
1 Wt loss (%)		1.44-2.78	100%	1.1-2.5	21
2 Char index (cc)		0-12.80	—	0-6.75	68.5
3 After flaming (sec)		0	Continues burning	0	38-45
4 After glow (sec)		0	Continues burning	0	Continuing till burning

TABLE III
FIRE PERFORMANCE OF COTTON FABRICS

Material	After flame (sec)	After glow (sec)	Char length cm	Char area (cm^2)
Standard Test Method BS 3119:				
Curtain cloth	0	0	5.6	5.34
Bedsheet	0	0	6.1	5.79
Upholstery	0	0	6.0	5.70
(Control)	Burnt completely with flames in 18-20 secs			
Standard Test Method BS 4790:				
Carpet	0	0	*	2.0
Control	9	48	*	6.5

* Not applicable.

References:
Subodh K Bhatnagar *et al*: *Proceedings of National Workshop on Plastics & Polymers in Buildings and Building Materials Technologies and Pollution Abatement*. New Delhi, 1987.
Paul Keith: *Chemistry and Industry*. (1983).
Baker D S: *Chemistry and Industry*. (1977).
Lyons J W: *The Chemistry and Uses of Fire Retardants*. Wiley-Interscience, New York (1970).
Lewin M., Atlas S M and Pearce E M: *Flame-retardant Polymeric Materials* Plenum Press, New York (1975).
Bhatnagar V M: *Advances in Fire Retardants, Part-2*. Technomic Publishing Co Inc, Westport, Conn (1978).
Gupta J C *et al*: Indian Journal of Textile Research (1977 & 1979).
Sivriew H *et al*: *Journal of Applied Polymer Science*. (1982)