Research and Industry
Vol. 34, June 1989, pp. 111-114

Fire retardant treatments for cotton fabrics

D R Gupta*& N K Saxena
Fire Research Laboratory, Central Building Research Institute, Roorkee
Received 4 April 1988; accepted 10 August 1988

A few chemical compositions based on monoammonium phosphate, diammonium phosphate, urea and rollex-50 (a urea-formaldehyde resin) have been studied with a view to imparting durable fire retardant characteristics to cotton fabrics. The treated fabrics are tested for their fire performance, tensile strength and washability. The proposed treatments may prove quite effective in reducing fire hazards in case of cellulosic fabrics.

Fire hazards cause tremendous loss to life and property. The furnishing materials such as curtains, carpets and cushions, etc. often used in buildings for decorative purposes constitute a major portion of fire load inside a building. Usually these materials are made of cotton and are intrinsically combustible due to their cellulosic nature. To minimize losses in cotton textiles owing to fire, several chemical treatments have been tried from time to time. Most of the flame retardants used for cellulosic materials are generally water soluble salts such as ammonium salts of sulfamic, phosphoric, boric and sulphuric acids, chlorides and bromides of aluminium, tin, zinc, chromium and antimony[1-5]. Since the protection afforded by these chemicals is temporary in nature, attempts are needed to bind these compounds directly to the cellulose fabric in order to obtain a durable effect. The present paper concerns with the development of a few cheap and effective fire retardant treatments for rendering cotton fabrics as durable fire retardant.

Experimental procedure

Aqueous solutions of different concentrations of mixtures of monoammonium phosphate (MAP) or diammonium phosphate (DAP)-urea (1:2.2, w/w), phosphoric acid (sp. gr. 1.82)-urea (1:2.6, w/w) and DAP-urea-rollex-50 (1:2.2:0.64, w/w) were prepared. The weighed specimens of fabrics were immersed in the solution for one hour to obtain maximum chemical retention. The specimens were then dried completely and were cured at 130°C to 180°C ± 2°C for 1-100 minutes. They were washed with water to remove unreacted chemicals and then dried. Dry chemical retentions were determined in each case. The fire performance, tensile strength and percentage of phosphorus retained in the fabric were determined at different times and curing temperatures. The optimization of temperature and time was determined to achieve maximum fire retardancy.

Evaluation of fire performance and physical characteristics of fabrics

(*a*) *Fire performance of curtain fabrics*

The fire performance was determined by British Standard 3119 method[6a,b]. The specimens were hanged vertically in the test chamber and a standard flame was applied for a period of 12 seconds which was then withdrawn. The afterflame and the afterglow times were determined. The average char lengths were also

*Department of Chemistry, University of Roorkee, Roorkee, India

Table 1—Effect of curing temperature and time on the fire performance

Curing time (min)	Char length (cm) at					
	130°C	140°C	150°C	160°C	170°C	180°C ± 2
1	31.50	—	—	—	13.80	10.73
5	31.50	12.73	9.06	8.40	6.16	5.56
10	18.20	7.80	6.80	6.13	5.13	4.93
15	—	6.83	6.06	5.60	5.06	4.76
16	—	—	—	5.50	—	—
18	—	—	—	5.30	—	—
20	11.96	6.16	5.66	5.30	5.06	4.73
25	—	5.89	5.66	5.23	4.83	4.73
30	9.10	5.76	5.63	5.23	4.83	4.73
35	—	5.73	5.43	5.16	4.66	—
40	7.70	5.73	5.46	5.16	4.66	—
45	—	5.70	5.46	5.09	—	—
60	6.16	—	—	—	—	—
80	5.50	—	—	—	—	—
100	5.50	—	—	—	—	—
Untreated	—	Burnt completely within 18-20 seconds				

Table 2—Fire performance of carpets as per BS 4790 method

Composition	Dry chemical retention %	Curing temp and time	After flame time (sec)	After glow time (sec)	Char area (cm^2)	Remarks
DAP-urea-resin (1:2.2:0.64, w/w)	14.80	160 ± 2°C and 18 mts	0	0	2.0	No heat penetrated, self extinguished
Untreated	—	—	6	48	6.0	Heat penetrated

measured in case of MAP or DAP-urea, phosphoric acid-urea treatments at different curing temperatures and times and are recorded in Table 1.

(b) Fire performance of carpets

The fire performance of carpets was evaluated by British Standard 4790 method[7]. The specimens were placed at the bottom of the test chamber and were ignited with a hexagonal nut which was previously heated to a temperature of 900 ± 2°C. The afterflame and afterglow times and char areas were noted with specimens treated with a DAP-urea-resin system. The results are given in Table 2.

(c) Tensile strength of the fabrics

The tensile strength of the fabrics (15 × 3.5 cm) was determined by a tensometer model W, monsanto, London, at different curing temperatures and curing times. The per cent decreases in tensile strength are given in Table 3. The effect of rollex-50 on the tensile strength and fire performance was also studied. The results with respect to the fire performance and decrease in tensile strength (%) are recorded in Table 4.

(d) Effect of laundering on fire performance

Specimens of cotton fabrics were treated with the DAP-urea resin composition. The treated specimens were washed with hard water containing 0.5 per cent surf solution and were also dry cleaned as usual in order to determine the durability of the treatment against launderings. The fire performance after each washing/dry cleaning was evaluated employing British Standard 3119 method. The fire performance after 1, 10 and 15 launderings is reported in Table 5.

Discussion

The fire performance and the loss in tensile strength of the fabric are very much dependent on the curing temperatures and curing times (Tables 1 and 3). It is observed that phosphorylation of cotton fabrics takes place at 130°C

Table 3—Effect of curing temperature and time on the tensile strength of the fabric

Curing time (min)	Reduction (%) in tensile strength at					
	130°C	140°C	150°C	160°C	170°C	180°C ± 2
1	7.80	9.47	11.00	15.94	25.64	27.22
5	19.34	22.96	26.82	30.07	39.07	41.28
10	22.74	28.69	33.69	35.83	46.66	50.63
15	—	34.40	38.98	40.09	51.07	55.64
16	—	—	—	40.53	—	—
18	—	—	—	42.47	—	—
20	27.83	36.00	42.80	43.60	54.65	60.83
25	—	43.01	45.78	46.66	57.46	63.36
30	31.92	45.87	48.40	49.51	59.81	66.02
35	—	48.49	50.68	51.54	—	—
40	36.60	50.62	53.06	53.55	—	—
45	—	52.57	—	55.56	—	—
60	43.51	—	—	—	—	—
80	48.39	—	—	—	—	—

Table 4—Effect of Rollex-50 Resin on the fire performance and tensile strength of the fabrics

Addition of resin (% solid wt basis)	Dry chemical retention (%)	Reduction in tensile strength (%)	Fire performance as per BS 3119			
			Time of exposure (sec)	After flame time (sec)	After glow time (sec)	Char length (cm)
0	17.04	42.47	12	0	0	5.50
2	17.38	41.78	12	0	0	5.50
4	17.80	34.45	12	0	0	5.40
6	17.92	27.61	12	0	0	5.40
8	18.37	24.01	12	0	0	5.40
10	18.98	23.84	12	0	0	5.30
14	20.73	23.12	12	0	0	5.00
18	22.32	22.25	12	0	0	6.20
22	23.05	20.59	12	0	0	8.40
26	21.24	20.44	12	0	0	9.50

in 80 minutes to achieve effective fire retardancy whereas at 180°C only 6-8 minutes time is needed. It is evident from Tables 1 and 3 that at 160°C, only 18 minutes are required for obtaining effective fire retardancy and minimum loss in tensile strength. It is also observed that 15-18 per cent dry chemical retention or approximately 1.35 per cent phosphorus is quite adequate for maximum fire retardancy for which specimens were treated with a 38 per cent fire retardant solution for one hour and were cured at 160 ± 2°C for 18 minutes.

Table 5—Effect of launderings on the fire performance of the fabric

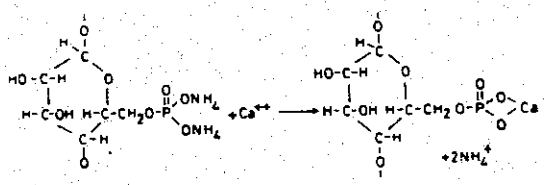
No. of washings	Washings with hard water and 0.5% surf solution			Dry cleaning with mineral turpentine oil		
	Time of exposure – 12 sec					
	After flame time (sec)	After glow time (sec)	Char length (cm)	After flame time (sec)	After glow time (sec)	Char length (cm)
1	0	0	5.40	0	0	5.40
10	0	0	5.50	0	0	5.50
15	0	0	13.80	0	0	5.40

The loss in tensile strength is 24 per cent instead of 42.5 per cent on the addition of 8 per cent resin in DAP-urea combination (Table 4). In such a system the crosslinking of resin to cellulose may be expected to take place. When higher amounts of resin are used, fire performance is reduced and specimens become quite stiff although the loss in strength is 20.44 per cent instead of about 24 per cent.

The specimens of treated carpets tested according to BS 4790 show no afterflaming, afterglow and heat penetration. The char is found to be only 2 cm^2, while untreated specimens show flame spread up to 6 seconds and after glow up to 48 seconds. The char area is found 6.0 cm^2 (Table 2). The function of phosphorus containing fire retardants appears to alter the course of decomposition of the cellulosic materials so that the lower amounts of flammable volatiles and larger quantities of char are formed[8-11], thereby reducing the

flammable characteristics of cellulosic materials.

From Table 5, it is evident that there is no change in fire performance after repeated drycleanings. The performance is, however, affected by washings with hard water and detergents. The phosphate esters obtained by the esterification of cellulose might have ionic character and the salts might exchange with metallic ions. On immersion in hard water, the calcium salts of the cellulose phosphate may be formed[12]. Such a replacement of the ammonium groups with metal ions to form salts which do not decompose to release free acid at the combustion temperature reduces or even entirely destroys the flame retarding effectiveness.



Conclusion

The fire retardant treatments proposed in the present paper are quite effective in reducing the burning characteristics of cotton fabrics. The treated specimens neither show any surface spread of flame nor afterflow combustion on removing the ignition source and the specimens remain self extinguished. However, charring is observed only where the flame is in contact with the specimens, while the untreated specimens completely burn within few seconds.

References

1 Lewin M, Atlas S M & Pearce E M, *Flame Retardant Polymeric Materials* (Plenum Press, New York), (1975) 20-27

2 Bhatnagar V M, *Advances in Fire Retardants* Part-2 (Technomic Publishing Co. Inc., Westport), (1978) 10-11

3 Dev I & Kumar S, *J Timb Dev Assoc*, 28 (1982)

4 Jain J P *et al*, *Fire Eng*, 9 (1984) 31

5 Anand C Lalit, *Popu Plast*, 29 (1984) 11

6 (a) British Standard 3119 (British Standard Institution, London), (1959)
(b) Codes and Standard National Fire Protection Assoc 701 (Boston, USA), (1977)

7 British Standard 4790 (British Standard Institution, London), (1972)

8 Franklin W E & Rowland S P, *J Appl Polym Sci*, 24 (1979) 1281

9 Bakes D S, *Chem Ind*, 14 (1981) 485

10 Kishore K & Mohandas K, *Fire Sci Tech*, 2 (1982) 81

11 Kishore K & Mohandas K, *J Fire Sci*, 1 (1983) 177

12 Lewin M, Atlas S M & Pearce E M, *Flame Retardant Polymeric Materials* (Plenum Press, New York), (1975) 36