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Review of Flame Retardancy of Textile Materials

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Abstract : *In recent year the field of flame retardancy in textiles witnessed a vigorous development of new processes products and materials to meet the needs of industries such as automobiles, aircraft, computer, electronics and telecommunication. Flame retardants are also used in protective clothing, special suits for fire-fighters & racing car driver, garments &apparel ,carpets, healthcare settings, hospital beds & curtains etc. Additional challenges are the growing awareness of environmental issues and the stiffening demands of consumer safety which have been put forward by governments and private agencies. New flame retardant systems are needed to meet market demands. In this study hazards and risks of fire, burning behaviour of textiles, methods of applying flame retardants finishes to fabrics, flame retardants performance test methods and finally requirements &quality standards of garments &apparel have been discussed.*

Keywords: *Flame retardant fibres, Vertical strip tester, Cone calorimeter Test, Limiting of oxygen index (LOI).*

1. Introduction:

Man has been concerned for centuries with the dangers involved with the flammability of textiles. An early description of flame proofing cellulosic materials is to be found in British patent granted to Obadiah Wyld in 1735.This patent described the use of " alum, borax, vitriol or copperas to prevent the flaming of pulps or textiles." Over the years there has been an increasing interest in imparting flame resistance to fabric and recognition of the need to protect lives and property against flammable textile materials. Flammability of textiles is major concern with respects to apparel fabrics, interior furnishing, decorative, clothing's for defence, airmen, fire fighting crew, tents cloth etc.

2. Hazards and risk of fire

Across the world a very few comprehensive statistics exist especially those which attempt to relate deaths and injuries to textile properties such as ignition resistance and burning propagation properties of textile materials. Textile related burn statistics of late nineteen sixties and early seventies produced by various organisations in US, Australasia, and the UK have been reviewed and analysis of these statistics and conclusions are listed below:

1. In 1969, Yeomen from department of health, education & welfare reported 4900 cases of textiles fires of which approximately 1200 were due to fabric ignition. In this study, 24% of the fires starting due to fabric ignition involved ignition of nightwear. Cotton was found to have been cause in 75% of the cases, blends in 7%, nylon in 8% and other synthetic in 8%[1].

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2. Cornog from the national Burn information Exchange conducted a similar survey for the year 1969. Her survey included 1200 cases of fire deaths. Fabric was believed to be the cause or a contributing factor in about 8000 incidences and the remaining 4000 or so fabric was believed to be the sole cause of injury and death [2].

3. The US department of commerce has analysed data from 406 cases investigated by US department of Health, Education & welfare. The statistical report for the year 1970 indicated that in the 406 cases, 713 separate garments were ignited causing deaths of 76 persons and injury to 504. It was also reported that children in the age group 0-5 were injured at particular high frequencies by burning of sleepwear

[3]. 4. Burn statistics collected by the Australian and New Zealand burn association in the late 1970s revealed that clothing was the primary agent ignited in 25% of children's flame burn cases and 14% for adults. For both children and adults, day clothes were involved four times as often as nightclothes [4].

The annual UK Fire statistics are some of the most comprehensive available and do attempt to provide information perhaps representative of a European country with a population of about 55 million. For instance up to 1998 these statistics have demonstrated that while about 20% of fires in dwellings are caused by textiles being the first ignited materials , over 50% of the fatalities are caused by these fire. Table 1 [5] presents the typical data during the last 17 years although since 1993 such detailed data have not been as freely available.

This shows that generally deaths from fires in UK dwellings have fluctuated at around 700 per annum between 1982 and 1988, since they have fallen to the 500-600 level.

3. Burning behaviour of textile

3.1. Fibres

The burning behaviour of fibres is influenced by and often determined by a number of thermal transition temperatures and thermodynamic parameters. Table 3.1[9] lists the commonly available fibres with their physical glass (Tg) and melting (Tm) transitions, Pyrolysis(Tp) and combustion (Tc) temperatures. The effect of heat on a fibre can produce a physical as well as a chemical change. In thermoplastic fibres the physical changes as above are a second -order transition at Tg and subsequently melting occurs at a melting temperature Tm, where as chemical changes take place at temperatures Tp at which thermal degradation (pyrolysis) occurs and a temperature Tc at which subsequent oxidation and combustion may occur.

Table 1 UK dwelling total and textile -related fire deaths, 1982-1998.

Year	Deaths in UK Dwelling fires	Clothing	Bedding	Upholstery	Floor-coverings	Total
1998	497	62	71	69	11	213
1997	566	59	51	119	8	237
1996	556	60	79	108	11	219
1995	549	85	71	108	8	275
1994	477	65	68	86	5	224
1993	536	51	85	105	19	260
1992	594	71	82	134	22	309
1991	608	59	85	127	10	281
1990	627	61	89	157	20	377
1988	732	92	141	195	20	448
1986	753	69	150	219	17	455
1984	692	59	124	167	22	372
1982	728	86	140	152	23	424

In Table 3 respective Limiting Oxygen Index (LOI) values are listed which are measures of inherent burning character of material and may be expressed as a percentage or decimal. Fibres having LOI values of 21% or 0.21 or below ignite easily and burn rapidly in air. Those with LOI values above 21 ignite and burn more slowly and generally when LOI values rise above approximately 26-28, fibres and textiles may be considered to be flame retardant and will pass most small flame fabric ignition tests in the horizontal and vertical orientations.

3.2. The effect of fabrics and yarns structures on burning behaviour:

The burning behaviour of fabrics are influenced by number of factors including the nature of ignitions source and time of its impingement, the fabric orientation and point of ignition (e.g. at the edge or face of fabric or top or bottom), the ambient temperature and relative humidity, the velocity of air and fabric structural variables. Low fabric area density values and open structures aggravate burning rate and increase the hazards of burn severity more than heavier and multilayered constructions. The weave pattern of fabric in association with the fabric mass alsoaffects

Table 3.1 Thermal-transition temperatures of some fibres.

Fibre	T_g(°C) Softens	T_m(°C) Melts	T_P(°C) Pyrlysis	T_c(°C) Combustion	ΔH (KJ/g)	LOI (Limiting Oxygen Index)
Wool	-	-	245	600	27	25
Cotton	-	-	350	350	19	18.4
Viscose	-	-	350	420	19	18.9
Triacetate	172	290	305	540	-	18.4
Nylon6	50	215	431	450	39	20-21.5
Nylon6.6	50	265	403	530	32	20-21
Polyester	80-90	255	420-477	480	24	20-21.5
Acrylic	100	>220	290	>250	32	18.2
Polypropylene	-20	165	469	550	44	18.6
Modacrylic	<80	>240	273	690	-	29-30
PVC	<80	>180	>180	450	21	37-39
PVDC	-17	180-210	>220	532	11	60
PTFE	126	>327	400	560	4	95
Oxydizedacrylic	>640	-	55	-	-	-
Nomex	275	375	310	500	30	28.5-30
Kevler	340	560	590	>550	-	29
PBI	>400		>500	>500	-	40-42

the flammability. Air -permeability considerations show that as the mass is increased the structure should provide greater resistance to heat penetration, provide resistance to burning and give a very short glow time and char length. The effect of yarn geometry and structure on burning behaviour has not been studied in depth, though some referenced works on fabric structure infer that coarser yarns will have a greater resistance to ignition. For coarser yarns the cover factor will reduce and the air permeability will increase which will have the converse effect.

The flammability of a garment made from the fabrics will influenced by garments design, launderings of the garments after use and the types of materials used in the composites structures. Close fitting garments are less liable to catch fire than loose fitted and flowing garments such as nightdress, dressing gowns and full skirted dresses.

4. Burning and Flame retardant Mechanism

Textile combustion is a complex phenomenon that involves heating decomposition leading to gasification (fuel generation), ignition, and flame propagation as shown in Fig 2

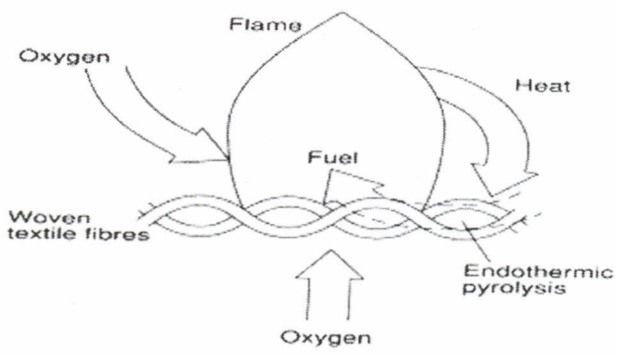


Figure: 1 Diagrammatic representation of self -sustaining textile flame [9]

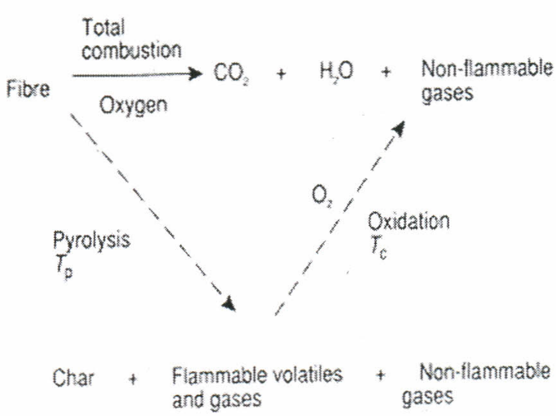


Figure: 2 Combustion of fibres [9].

A self -sustaining flame requires a fuel source and means of gasifying the fuel and mixing the gaseous fuel with oxygen and heat. When a fibre is subjected to heat it pyrolyses at Tp (Fig3) if volatile liquids and gases are combustible they acts as a fuel for further combustion .If after pyrolysis the temperature is equal to or greater than Tc and oxygen is present, the flammable volatile liquids burn to give products such as carbon dioxide and water. In fact when a textile is ignited heat from an external source raises its temperature until the structure begins to degrade. The rate of this initial rise in temperature depends on the specific heat of the fibre, its thermal conductivity and also the latent heat of fusion, or other enthalpy changes that occur during the combustion of a material.

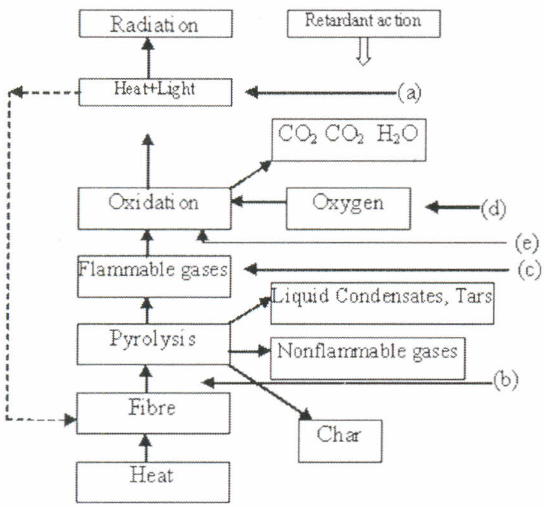


Fig:3 Combustion as a feedback mechanism with flame retardant actions.

4.1. Flame retardant strategies:

Figure 4 presents the combustion of any textile as a feedback mechanism in which fuel, heat and oxygen feature as the main components. In order to interrupt the mechanism five modes (a) -(e) are proposed and flame retardants may function in one or more of these. Each stage with a relevant flame retardant action is listed below:

a) Removal of heat: Heat may be removed or cooling applied which can be achieved by treating the material with heat-absorbing products preventing its concentration at the particular points.

b) Enhancement of the decomposition temperature: The increase in pyrolysis temperature makes the material heat -resistant. Glass, charcoal or semi- carbon fibres and aramid fibres are extremely stable and heat resistant.

c) Decreased formation of flammable volatiles, increase in char: The third way of stopping combustion is to prevent formation of combustible volatile compounds at the expense of carbonaceous residue called char. This principle is used in the solid phase active flame retardant (FR) materials based on sulphur, phosphorus or boron. Such flame -retardants decompose into sulphuric, phosphoric and boric acids which form stable non-volatile esters with hydroxyl groups on substrates such as cellulose and favour the formation of char.

d) Reduced access to oxygen or flame dilution: Combustion may be prevented by eliminating the oxygen from the combustion zone and thus stopping oxidation. Hydrated and some char-promoting retardants release water, halogen containing retardants release hydrogen halide.

e) Interference with flame chemistry and/ or increase fuel ignition temperature (Tc): Halogen containing flame retardants often in combination with antimony oxides operating in the gaseous phase are used in the flame proofing of synthetic fibres. Such FR compounds decompose on heating and give rise to free radicals. Such free radicals then combine with the air oxygen via complex reactions in such a way that this combination is not suitable for the oxidation of gases generated by burning a substrate and hence combustion is inhibited.

5. Flame retardant cellulosic Fibres

Flame retardant cellulosic textiles generally divided into three groups based on fibre genus:

1. Flame retardant cotton.
2. Flame retardant viscose (or regenerated cellulose).
3. Blends of flame retardant cellulosic fibres with other fibres usually synthetic.

5.1 Flame retardant cottons : All flame retardant cottons are usually produced by after treating fabrics chemically as a textile finishing process which depending on chemical character and cost, yield flame retardant properties having varying degrees of durability to various laundering process. Generally for cotton three types of flame retardant chemical are available which are given below:

1. Non-durable flame retardants: Non-durable flame retardants are suitable for cellulosic fibres which are not be used outdoors. The chemicals wash out of textiles when the goods are exposed to the weather, leached or laundered. Fabrics should be treated again after each laundering. Even goods which are not laundered should be retreated about once each six. Many non-durable flame retardants have been considered over the years but for various reasons only a few have been used commercially. Borax-boric acid, borax-diammonium phosphate, diammonium phosphate and ammonium sulphate are normally used as non-durable flame retardants on cottons.

2. Semi-durable flame retardants:

Semi-durable flame retardants may be defined as those which withstand one or more laundry cycles, the upper limit being about 15 mild laundry cycles. Flame retardants of this class are useful in drapes, party dress and other items which will not be laundered many times. Many semi-durable retardants were discovered unintentionally. Some of the example of semi-durable flame retardants are cellulose phosphates, ammonium phosphate-dicyandiamide -formaldehyde and phosphoryl amides.

3. Durable flame retardants:

There are two general types of durable flame retardants for cotton:

a) Those used on apparel and house hold fabrics and b) those used on industrial fabrics. Flame retardants of the first group should be unaffected by cleaning process and impart little or no adverse properties. Flame retardants for industrial fabrics should be resistant to sunlight and rain.

A) Flame retardants for apparel and households Textiles:

Phosphorus-containing compounds and polymers are generally the most effective flame retardants with respect to durability to laundering. The efficiency of these flame retardants is generally affected by other elements or groups which may be present. Three overlapping methods have been used in the application of durable flame retardants to cotton for apparel and households uses: coating of cellulose fibres, chemical reaction within the fibres and polymer formation within the fibres.

B) Flame retardants for industrial fabrics:

The flame retardant in fabrics used for tents, tarpaulins and for other outdoor purposes must be resistant to actinic degradation and other elements of weather. Several inorganic flame retardant compounds are resistant to actinic degradation but they are either too expensive to apply to fabric or they are not durable to leaching. The degrading effects of weather on flame resistant fabrics varies depending upon the season of the year, location, latitude, humidity, temperatures, atmospheric contaminants and number of less important factors. Antimony oxide-chlorinated paraffin's and antimony-titanium complex are normally used as flame retardants on these fabrics [10].

5.2 Flame retardants Viscose:

Many additives containing halogen, nitrogen and phosphorous have been evaluated as potential flame retardants for viscose but sandoflam5060 which contains both phosphorus and sulphur has been found to be commercially viable. Sandoflam

5060 is incorporated in the spinning solution to produce inherently flame proofed fibres that have high resistance to yellowing, good light-fastness, good heat insulation and good resistance to various molten metals. Chemically Sandoflam 5060 is bis(2-thiono-5,5-dimethyl-1,3,2-dioxaphosphorinayl) oxide.

5.3 Flame retarded cellulosic blends:

Flame-retardant of polyester/cellulose blends is still a complex problem owing to the differential thermal behaviour of polyester and cellulose components. On ignition cellulose chars and provides a scaffold for the molten polyester, preventing its escape from the flaming zone. Flame retardants that are active in both the condensed phase and vapour phase have been found to be very efficient on polyester/cotton blends. Antiblaze FSD(Rhodia), Flovan BU(Ciba) and Flammentin BL(Thor) are examples of non-durable salt mixtures able to flame retard polyester(and other synthetic fibre) -rich cellulosic blends because they contain ammonium bromide. In case of durable finishes phosphorus-containing flame retardants these are generally only effective on cellulose-rich blends with polyester. THP-based system like Proban CC (Rohida) are effective on blends containing no less than 55%cotton.

6. Flame retardant synthetic fibres

There are three methods of rendering synthetic fibres flame retardant:

- Use of FR co monomers during copolymerization,
- Introduction of an FR additives during extrusion,
- Application of flame retardant finishes or coatings.

6.1. Inherently flame-retardant synthetic fibres

The example of the heat and flame resistant fibres are aramid, modacrylic, polybenzimidazole(PBI), Semicarbon,phenolic,asbestos,ceramic etc.Some of this fibres are discussed below:

Aramid fibres:

Aromatic polyamides such as poly(metaphenylene isohthalaamide)char above 400°C and may survive short exposures at temperature up to 700°C. Nomex(Dupont),Conex(Teijin),Fenilon(Russian),and Apyeil(Unitika) meta aramid fibres have been developed for protective clothing for fighter pilots, tank crews, astronauts and those working in certain industries. Aramid fibres contain no FR chemicals elements i.e. phosphorus or halogen but their chemical structure is such that they do not easily break down into combustible molecular fragments and produce relatively little smoke when heated. Aramids are resistant to high temperatures for example at 250°C for 1000hours the breaking strength of Nomex is about 65% of that before exposure

Polybenzimidazole (PBI) fibres:

Celanese developed PBI a non-combustible organic fibre. Its LOI is 41% and it emits little smoke on exposure to flame .PBI can withstand temperatures as high as 600°C for short term (3-5s) exposures and longer term exposure at temperatures up to 300-350°C .It provides the same protection as asbestos while weighing half as much. It also absorbs more moisture than cotton. PBI fibre is expensive; the outstanding combination of thermal and chemical resistance and comfort makes it an ideal fibre for protective -clothing applications in which a high degree of protection is required.

Phenolic Fibres(Novoloid fibres):

Phenolic fibres are highly flame retardant with limiting -oxygen index of 30-35%.Their ignition temperature is above 2500°C .Kynol is a well -established novoloid heat-resistant fibre which is produced by spinning and post curing of phenol formaldehyde resin precondensate. The fibre is soft and golden coloured with a moisture regain of 6%.When strongly heated,Kynol fabric is slowly carbonised with little or no evolution of toxic gases or smoke.Kynol can be blended with other fibres such as Nomex, FR viscose, and modacrylic fibres to upgrade its physical properties. Such blends are being used in the production of fire-blocking material and protective fabrics.

Semi carbon fibres:

Semi carbon fibres produced by partial carbonization of polyacrylonitrile(PAN) fibres, e.g. Celiox and Panox have excellent heat-resistance and heat -stability. They do not burn in air, do not melt and have excellent resistance to molten metal splashes. After exposure to flame there is no afterglow and fabrics remain flexible. Panotex fabrics can withstand flame temperatures in excess of 1000°C, display very little shrinkage and yet breathe like wool.

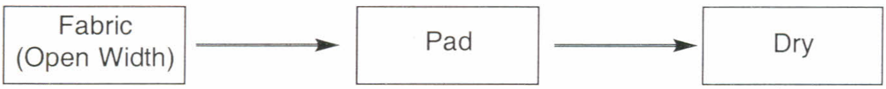
6.2. Flame retardant finishes for synthetic fibres

Polyamide, polyester, polyacrylic and polypropylene are the candidates for semi-durable and durable flame retarding finishes. There have been some developments in flame retardant finishes for polyester fabric and its blends. Flame -retardant finishes for synthetic fibres should either promote char formation by reducing the thermo plasticity or enhance melt dripping so that the drops can be extinguished way from the igniting flame. Day and co-workers have studied in depth the flammable behaviour of polyester fibre by using a series of phosphorus- and bromine -containing flame retardants as both additives and finishing agents. The Antiblaze CU products (now known as Antiblaze N or Nt in US) is clamed to be effective on polymides and polypropylene as well as polyester.

7. Methods of applying flame retardants to fabrics

Successful flame retardant finishes are those which combine acceptable levels of flame retardancy at an affordable cost and applicable to textile fabrics using conventional textile and coating equipment. Here four basic applications processes are described where feed material is open-width textile fabrics:

Process one: This simple pad/dry technique is applicable with most non-durable and water - soluble finishes such as the ammonium phosphates.

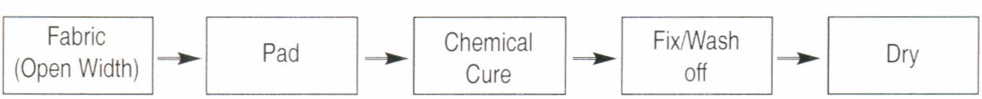


Flow diagram of process one.

Process two: This sequence is typical of those used to apply crease-resistant and other heat curable textile finishes. In the case of flame retardant finishes it finds best use for application of the phosphonamide systems such as pyrovatex(Ciba),Affamit(Thor) and the now obsolete Antiblaze TFR1(Rhodia)which are applied with resin components like the methylolated melamines. Because the process requires the presence of acidic catalyst (e.g.phosphoric acid), the wash-off stage will include an initial alkaline neutralisation stage. This same sequence without the washing -off stage may be used to apply semi-durable finishes where a curing stage allows a degree of interaction to occur between the finish and the cellulose fibre.

Flow Diagram of process two

Process three: This is the best for Proban application which requires an ammonia gas curing process in order to polymerise the applied finish into the internal fibre voids. In this way the Proban CC condensate of tetrakis(hydroxyl methyl)phosphonium chloride and urea after padding and drying onto the fabric is passed through a ammonia reactor which cross-links the condensate to give an insoluble polymeric finish. In order to increase the stability and hence durability of the finish a subsequent oxidative fixation stage is required before finally washing off and drying.



Flow Diagram of process Three.

Process four: This is one kind of back-coating process where flame retardant finishes are applied in a bonding resin to the reverse surface of a flammable fabric. In this way the aesthetic quality of the face of the fabric is maintained while the flame retardants property is present on the back or reverse face. Flame retardant must have an element of transferability from the back into the whole fabric. Application methods include blade or knife coating methods and the formulation is as paste or foam.

Flow Diagram of process four.

8. Flame Retardants Test methods

Testing methods of fire-retardency in textiles are yet to be perfected although various technical societies, governmental agencies and safety organisations in co-operation with the industry and consumer safety councils have proposed a large number of test methods to determine the flammability characteristics of textile materials. It is generally agreed that ease of ignition, glow time, rate of flame spread and amount of heat liberated are essential factors which determine the fire hazard of fabric. Some testing procedures and standards which are commonly used for various textile materials towards flammability are discussed here.

8.1 Vertical strip test:

The vertical strip test has achieved the widest acceptance for determining flammability. The British standard BS 5438:1989 "Method of test for flammability of textile fabrics when subjected to a small igniting flame applied to the face or bottom edge of a vertically oriented specimen," is a revision and development of BS5438:1976.The flammability of textile is assessed by measuring the ease of ignition, limited flame spread and rate of flame spread using Tests 1,2 and 3 of BS 5438 respectively[11].

8.2 Limiting Oxygen Index (LOI):

Limiting Oxygen Index is another method for evaluating the flammability and is widely recognised for its convenience and reproducibility. Limiting Oxygen Index is defined as "The minimal volume fraction of oxygen in slowly rising gaseous atmosphere that will sustain the burning of a stick of polymer." This fraction is often expressed as a percentage.

$LOI = O_2\ (Vol\%) / O_2\ (Vol\%) + N_2\ (Vol\%) \times 100.$

Ideally a material is considered to be flammable when LOI value is lower than 21%

flame retardancy is exhibited by materials with LOI >23.0%.The LOI value is influenced by the chemical composition of materials, area density of material, construction and moisture content etc.LOI values can be measured in different conditions e.g., keeping the chimney at a particular temperature so also gas flow pressure and uniformity in gas mixing testing the sample by igniting the upper edge where the sample burns from top to down or the lower edge where it burns from bottom to top etc. Heat transfer and flame spread can also be measured by this method

8.3 Cone calorimeter Test:

The cone calorimeter is one such instrument which has been designed on scientific principles with a view of providing meaningful data on the fire properties of materials. The greatest advantage of this instrument is that it can measure the rate of heat release from combustion materials under a range of imposed radiant heat fluxes.

The cone calorimetry technique:

The cone calorimeter is a sophisticated small-scale fire apparatus which draws the best attributes of number of earlier fire tests into one integrated package. The instrument derives its name from the geometric arrangement of the electric heater which is in form of truncated cone. ISO5660-1 and ASTM 1345 are the two most notable standard cone calorimeter test methods [12].Figure 8 shows the commercial instrument and burning zone of this instrument shown in figure 9. A general lay out of a standard of cone calorimeter is given in figure -8. During testing sample (100x100mm) is placed in a sample holder on to a mass balance which is situated below the heat source and

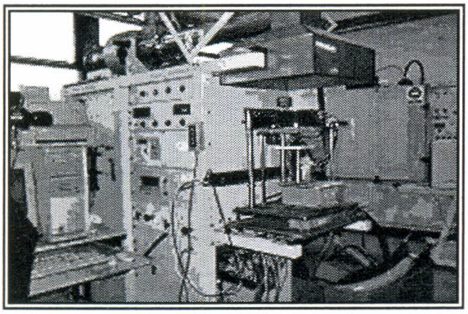


Figure 7 Commercial cone calorimeter.

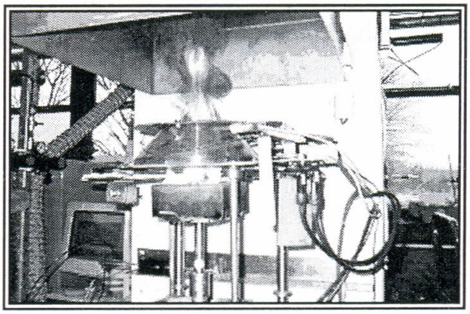


Figure 9 Burning zone of cone calorimeter

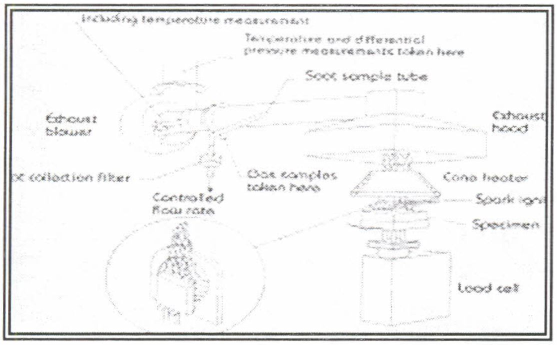


Figure 8 General Layout of cone calorimeter

Some of the parameters of the cone calorimetric data in a typical report are discussed below:

Time to Ignition (TTI):

This is the time from initial exposure to the start of sustained flaming usually reported in seconds.

Heat release rate, (HRR): This value is reported in three different ways:

1. Peak heat release rate (PHRR) is the highest instantaneous value for heat release rate during test period, expressed in kW/m^2.

2. Average heat release rate (Avg.HRR) is the average of the heat release rates calculated for defined periods starting just after the ignition and during ending at any time up to completion of the test. The unit is $kW/m^2/min$.

3. Total heat release **(THR)** is the total amount of heat releasing during the test period calculated by integrating the heat release curve from the start of the test to end of the test periods. The unit of THR is MJ/m^2.

4. Time to heat release (TTP): This is the time at which the peak heat release occurs. TTP is an important parameter as the value of PHHR is very much dependent on it. The PHHR value should always be read in conjunction with TTP value.

5. Mass loss rate (MLR): is the rate at which the mass of the specimen decreases as the specimen is consumed in the process of burning. It is computed over a period starting when 10% of the ultimate specimen mass loss has occurred and ending at the time when 90% of the ultimate specimen mass loss has occurred. It is expressed in $g/s\text{-}m^2$.Mass loss rate is an important parameter as various quantities such as effective heat of combustion , specific extinction area and oxides of carbon are measured and reported in conjunction with the mass loss rate.

6. Effective heat of combustion (Ec): is the amount of heat released per unit mass of the sample consumed in burning process. It is the heat parameter calculated in conjunction with the mass loss rate of the specimen. Thus effective heat of combustion is the calorific value of the specimen. Thus at any time t,Ec=HRR/MLR and it is expressed in MJ/m^2.

7. Specific extinction area (SEA):

This is defined as the extinction area of the smoke produced per unit mass of volatile material burned. SEA is not truly a measure of smoke rate but yield of smoke produced per mass of sample consumed. It is usually expressed in m^2/Kg.

8. CO and CO2 gases:

The cone calorimeter records the oxides of carbon as yields of units mass of gases produced from a unit mass of the material burned. The standard test report states the CO and CO2 production in Kg/Kg.

Calibration procedure:

The calorimeter is calibrated before starting the testing program. To avoid or minimize any inaccuracies in measurement of oxygen concentration, it is essential to perform daily methane calibrations.

Daily calibration procedure involves gas analyzer calibration, smoke calibration and methane calibration as specified in ISO 5660.

8.4. Fire tests for upholstered composites and mattresses:

BS 5852(part1) describes the test method for assessing the ignitability of materials assemblies of upholstered composites for seating when subjected to either a smouldering cigarette or a lighted match. The test materials shall be representative of cover, filling and any other components used in the final assembly. The cover size needed for each test is 800±10 mm x 650±10mm.The upholstery filling required for each test is two pieces ,one 450x300x75mm thick and the other piece 450x150x75mm thick. Some cushioning assembling may consist of several layers of felt, wadding or different foams. In these cases the test pieces shall reproduce the upper 75mm of the cushioning assemble. A smouldering cigarette is placed along the junction between the vertical and horizontal test pieces, allowing at least 50mm from the nearest side edge to the cigarette. The progress of combustion is observer using the clock and any evidence of progressive smouldering or flaming in the interior and /or cover is recorded.

9. Quality standards & Requirements of H&M for Garments & Apparels [13]:

Product name	Parameters to be measured	Minimum requirements
Children nightwear (Not pyjamas)	Surface flash, Time of spread	No surface flash,3rd marker thread (520mm)not severed in less than 15 seconds
Children pyjamas	Surface flash, Time of spread	No surface flash,3rd marker thread (520mm)not severed in less than 15 seconds
Babies nightwear		Should meet general req.16CFR 1610.

9. Conclusions:

Most flame-retardant textiles are designed to reduce the ease of ignition and also reduce the flame propagation rates. Conventional textiles can be rendered flame retardant by chemical after-treatments as co-monomers in their structures or use of FR additives during extrusion. High performance fibres with inherently high levels of flame and heat resistance require the synthesis of all aromatic structures but these are expensive and used only when performance requirements justify cost. The environment issues is the need to enhance FR textile performance and this will arise by maximising char formation in both natural and synthetic fibre containing textiles. This will not only increase the protective efficiency and hence safety of flame retardant textiles but will also reduce problems associated with thermo plasticity and toxic gas emission formed in fires.

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