12. Appendix

12.1 Chemical and Physical properties of flame retardants

12.2 Results from UL94 Vertical Burn Test

12.3 Test standard BS 5867: Part 2: 1980

12.1 Chemical and Physical properties of flame retardants

Compound	Other Name	CAS Code	Molecular formula	Molecular weight	Partition Coefficient [Log (K_{ow})]
2-Furoic Acid	Furane-2-carboxylic acid	88-14-2	$C_5H_4O_3$	112.085	0.64
4-Hydroxybenzyl alcohol	p-Hydroxybenzyl alcohol	623-05-2	$C_7H_8O_2$	124.1393	0.25
Benzoyl peroxide	Dibenzoyl peroxide	94-36-0	$C_{14}H_{10}O_4$	242.23	-
Diethyl phthalate	Phthalic acid diethyl ester	84-66-2	$C_{12}H_{14}O_4$	222.2408	2.35
Fumaric acid	2-Butenedioic acid	110-17-8	$C_4H_4O_4$	116.0734	-0.36
Isophthalic acid	1,3-Benzenedicarboxylic acid	121-91-5	$C_8H_6O_4$	166.1332	1.15
Benzyl benzoate	Benzyl benzoate	120-51-4	$C_{14}H_{12}O_2$	212.2481	3.97
Benzoic acid	Isopropenyl benzene	98-83-9	C_9H_{10}	118.1784	2.84
Benzoin	2-Hydroxy-2-phenyl-acetophenone	119-53-9	$C_{14}H_{12}O_2$	212.25	2.53
Pentaerythritol	-	115-77-5	$C_5H_{12}O_4$	136.15	-1.7
Phloroglucinol	1,3,5-trihydroxybenzene	108-73-6	$C_6H_6O_3$	126.1118	0.87

Pyrogallic acid	Pyrogallol	87-66-1	$C_6H_6O_3$	126.1118	0.87
Benzophenone	-	119-61-9	$C_{13}H_{10}O$	182.2218	3.58
Benzyl phenyl ketone	2-Phenylacetophenone	451-40-1	$C_{14}H_{12}O$	196.2487	3.19
Catechol	1,2-Benzenediol	120-80-9	$C_6H_6O_2$	110.1124	1.01
Resorcinol	1,3-Benzenediol	108-46-3	$C_6H_6O_2$	110.1124	1.26
Salicylic acid	o-Hydroxybenzoic acid	69-72-7	$C_7H_6O_3$	138.1228	1.2
Terephthalic acid	1,4-Benzenedicarboxylic acid	100-21-0	$C_8H_6O_4$	166.1332	1.15

Compound	Molar Refractivity Refractivity [cm^3/mol]	Henry Constant	Melting point [°C]	NBP [K]	Freezing Point [K]
2-Furoic Acid	24.61	5.354	129-130	504.82	361.96
4-Hydroxybenzyl alcohol	34.36	9.034	118-122	533.75	367.11
Benzoyl peroxide	-	3.839	104-106	619.37	384.54
Diethyl phthalate	59.37	4.792	-3	577.11	348.1
Fumaric acid	24.27	10.257	299-300	558.42	450.46
Isophthalic acid	38.90	10.049	341-343	624.54	539.56
Benzyl benzoate	62.02	3.941	18-20	591.06	342.21
Benzoic acid	40.06	0.754	-24	435.73	201.39
Benzoin	62.91	8.927	135-137	622.4	395.63
Pentaerythritol	30.72	7.777	255-259	594.02	391.31
Phloroglucinol	30.72	12.605	218-221	554.37	505.94
Pyrogallic acid	30.72	12.605	133-134	554.37	505.94
Benzophenone	56.65	4.1	48-49	572.67	338.54

Benzyl phenyl ketone	60.96	4.489	55-56.5	586.93	349.81
Catechol	28.91	8.623	104-106	502.87	394.22
Resorcinol	28.91	8.623	110-112	502.87	394.22
Salicylic acid	33.90	9.336	158-160	571.2	466.89
Terephthalic acid	38.90	10.049	> 300	624.54	539.56

Benzyl phenyl ketone	207.44	> 110	-	489	489
Catechol	117.52	137	-	343	343
Resorcinol	117.52	-	-	1465	1465
Salicylic acid	138.36	-	-	1476	1476
Terephthalic acid	159.2	-	-	1547	1547

12.2 Results from flammability tests

Functional group	Organic compound name	Carrier material	Add-on [%]	SE time* [s]
Alcohols	Pentaerythritol	Water	7	7
	Di-pentaerythritol	Water	3	3
	m-Inositol	Water	5	2
Aldehydes and ketones	Benzyl phenyl ketone	Ethanol	2	1
	Benzophenone	Acetone	2	3
Anhydrides	Phthalic anhydride	Ethanol	1	3
Carboxylic acids	2-Furoic acid	Ethanol	7	1
	Terephthalic acid	Chloroform	2	1
	Isophthalic acid	Ethanol	2	0
	Adipic acid	Ethanol	2	0
	Oxalic acid	Water	1	6
Epoxies	Epikote 1001	Acetone	5	2
	Epikote 3004	Acetone	17	1
	Epikote 3009	Acetone	16	3
Esters	Benzyl benzoate	Ethanol	2	1
	Diethyl phthalate	Ethanol	6	12
Peroxides	Benzoyl peroxide	Ethanol	1	11
Phenols	Pyrogallol	Water	3	1
	Catechol	Chloroform	≈ 1	10
	Resorcinol	Water	2	3
	Phloroglucinol	Ethanol	7	1
Combinations of functional groups	4-Hydroxybenzoic acid ethyl ester	Ethanol	15	0
	Maltol	Water	2,5	0
	Vanillin	Water	5	2
	Salicylic acid	Ethanol	10	0
	Benzoin	Ethanol	1	5
	Pyrogallic acid	Ethanol	3	0

12.3 Test standard BS 5867: Part 2: 1980

BS 5867 : Part 2 : 1980
Spec for fabrics for curtains and drapes
Part 2 : Flammability requirements

Sampling
From each batch at least every 5000m.

Test procedures
The side that has the fastest flame spread will be tested.

BS 5438 Test 3 will be used:

3 samples in the machine direction and 3 samples in the cross direction using a 10 second flame application time.

Taking the two vertical trip threads as representing one trip thread in each of at least four specimens not more than one trip thread (i.e. 300mm or either or both of the vertical trip thread) shall be severed.
In either of the 2 remaining specimens not more than 2 trip threads (i.e. 300mm and 600mm, or 300mm and either or both of the vertical trip threads) are severed on any specimen the fabric shall be deemed not to comply with the requirements for Type A of this British Standard.

No part of any hole nor any part of the lowest boundary of any flame shall reach the upper edge or either vertical edge of any specimen. If it does a further 6 specimens shall be tested and all 6 must comply.

Cleaning requirements.

All fabrics shall be tested both before and after the cleaning procedure i.e. 50 cycles of the appropriate hospital laundry procedure specified in BS 5651, except that for the hospital laundry procedure (normal) water of zero hardness shall be used and IEC test detergent type 1 but without perborate, shall be used in place of soap and sodium metasilicate.

Test 2

Template of 170mm x 220mm with four holes, one in each corner 10mm from each side. Rectangular test flame but with four pins only.

Test 3

Template of 670mm x 170 mm, two rows of five holes 10mm form each edge and spaced at 10mm, 210mm, 410mm, 610mm and 660mm from bottom edge. Rectangular test flame but fitted with two vertical rows of five pins spaced 200mm, 400mm, 600mm, 650mm above the bottom row of pins.

Combined mean afterflame and afterglow times must not exceed 2.5s

BS 5438 : 1989

Flammability of textile fabrics when subjected to a small igniting flame applied to the face or bottom edge of vertically oriented specimens.

Condition test specimens at least 24h in an atmosphere having a temperature of 20 ± 5 ° C and H = 65 ± 5 %. If testing in not carried out immediately after conditioning replace the conditioned test specimens within 2 min of removing it from either the conditioning atmosphere or the sealed container.

Testing atmosphere

T = 15 ° C - 30 ° C

H = 55 ± 20 %

Air movement less than 0.2 m/s

Apparatus

Gas burner capable of being fixed vertically, horizontally or inclined at 30 °

Tip of burner 50mm from specimen

Set burner in vertical position. Adjust flame height to 40 ± 2 mm. Return burner to horizontal position and check horizontal flame reach of 23 ± 2 mm.

Preheat the burner for 2 min. before testing.

Types of tests

Minimum ignition time: face ignition.

Specimen: 200mm x 80mm

Ignite for 1s at the bottom face of specimen.

If not ignite repeat with flame application times of 2,3,4,6,8,10,15,20s until the shortest of these times, if any, is found that causes a test specimen to ignite.

Minimum ignition time: Bottom edge ignition.

Specimen: 200mm x 80mm

Ignite for 1s at the bottom edge of specimen.

If not ignite repeat with flame application times of 2,3,4,6,8,10,15,20s until the shortest of these times, if any, is found that causes a test specimen to ignite.

<u>Limited flame spread: Face ignition.</u>

Specimen: 200mm x 160mm

Ignite for 10s at the bottom face of specimen.

Note the following:

a) Duration of flaming.

b) Duration of afterglow.
c) Occurrence of any flaming debris
d) Whether, for any flame, any part of its lowest boundary reaches the upper edge or one of the vertical edges of the specimen.
e) Whether a hole develops which extends to the upper edge or one of the vertical edges of the specimen
f) Whether glowing reaches the upper edge or one of the vertical edges of the specimen.
g) Maximum extent of any holes in the horizontal or vertical direction whichever is the greatest.
h) Maximum damaged length measured
i) Which face of the fabric was subjected to the flame test.

Limited flame spread: Bottom edge ignition.

Specimen: 200mm x 160mm

Ignite for 10s at the bottom edge of specimen.

Note the following:

a) Duration of flaming.
b) Duration of afterglow.
c) Occurrence of any flaming debris
d) Whether, for any flame, any part of its lowest boundary reaches the upper edge or one of the vertical edges of the specimen.
e) Whether a hole develops which extends to the upper edge or one of the vertical edges of the specimen
f) Whether glowing reaches the upper edge or one of the vertical edges of the specimen.
g) Maximum extent of any holes in the horizontal or vertical direction whichever is the greatest.
h) Maximum damaged length measured
i) Which face of the fabric was subjected to the flame test.

If the 10 second exposure of a specimen does not cause it to ignite the specimen is believed to be of sufficient quality to pass all the tests.