A comparative study of test methods for assessment of fire safety performance of bus interior materials

Michael Försth

SP Technical Research Institute of Sweden

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Abstract

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This work concerns the assessment of fire performance of interior materials used in buses. The widely used test method ISO 3795/FMVSS 302 has received much criticism mainly based on the fact that the test specimens are oriented horizontally while much fire spread in a real bus fire occurs on vertically oriented products. Eleven (11) different materials have been investigated, nine textiles and two solid materials. Three different test methods were used: ISO 3795, ISO 6941, and ISO 5658-2. Given the existing criteria for interior materials it was found that both ISO 6941 and ISO 5658-2 place much harder requirements on the materials. While only one material failed the ISO 3795 test as many as seven and six materials failed the ISO 6941 and ISO 5658-2 tests, respectively. Further, it was found that correlation between the different methods was poor.

Key words: bus, fire, interior materials, ISO 5658, ECE 118, EU directive 95/28/CE

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Preface

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1 Introduction

The test method ISO 3795 [1] is prescribed for approval of interior material in buses according to references [2, 3]. According to this method specimens are tested in horizontal orientation and the burning rate is measured and used as the parameter to assess compliance. The method, or the similar method FMVSS 302 [4], has received severe criticism, especially during recent years [5-7]. The main part of the criticism concerns the horizontal orientation of the test sample. Fire performance is expected to be worse for products oriented vertically, such as seat backs or wall linings. As a results alternative or complementary test methods have been proposed. These are ISO 6941 [8, 9] and ISO 5658-2 [10, 11]. ISO 6941 is a method originally conceived for relatively thin textile fabrics such as curtains. ISO 5658-2 is a method for assessing the fire performance of vertically oriented materials, and it is already used by the ship [12] and train [13] industries.

In this study we have compared the three test methods (ISO 3795, ISO 6941 and ISO 5658-2) for 11 materials commonly used in bus passenger areas.

2 Materials and Methods

2.1 Tested products

All 11 products are typically used as interior material in buses. A summary of the products is given in Table 1.

Table 1 Summary of the tested products.

Prod. No.	Description	Content	Thickness [mm]	Weight per area [g/m ²]
1	Plastic	ABS	3.1	3040
2	Perstorp laminate	Paper-reinforced thermosetting plastic	5.8	8780
3	Fabric	Wool velvet blend	2.8	311
4	Artificial leather	91.5% PVC + 0.5% Polyamide	1.1	814
5	Fabric	70% PES + 30% wool	3.2	627
6	Fabric	55% Polyester + 45% wool	3.9	829
7	Fabric	Wool velvet blend	4.4	973
8	Fabric	85% wool + 15% nylon	4.3	856
9	Fabric	65% PES + 20% wool + 15% CV	3.0	676
10	Fabric	56% wool + 35% cotton + 9% nylon	4.2	826
11	Fabric	Polypropylene fibre	4.4	510

2.2 Test of horizontal burning rate (ISO 3795, ECE Reg No 118 annex 6, directive 95/28/CE annex IV)

At present products for use in the interior of buses are mainly regulated by the international standard ISO 3795. The principle of ISO 3795 is that a 100 mm × 356 mm sample is mounted horizontally in a U-shaped holder and is exposed to the action of a well-defined low-energy flame for 15 seconds in a combustion chamber. The flame is

applied to the free end of the sample, see Figure 1. The test determines if and when the flame extinguishes, or the time at which the flame passes a measured distance, resulting in a burning rate in mm/minute [6].

A similar test method is FMVSS (Federal Motor Vehicle Safety Standard) 302. The differences are very small and test results from one of the tests can be directly compared to the other. This test or variations are widely used all over the world for passenger car fire safety testing.

Figure 1 Test of Product No. 3 according to ISO 3795.

2.3 Test of vertical burning rate (ISO 6941, ECE Reg No 118 annex 8, directive 95/28/CE annex VI)

Curtain, blinds and other vertical hanging materials in buses are presently regulated by the European directive 95/28/EC; annex VI, which describes a test method which is identical to the international standard ISO 6941.

The principle of ISO 6941 is that a sample is held vertically, fastened by pins located on a steel frame. The sample is exposed from below with a 40 mm long flame for 5 or 15 seconds. At three different heights a marker thread is placed horizontally across the sample surface. The time for the flame to burn off each marker thread is measured. The vertical burning rate to each marker thread is calculated and the fastest burning rate is taken into account for classification [6], see Figure 2.

Figure 2 Test of Product No. 11 according to ISO 6941.

2.4 Test of Spread of Flame, SoF (ISO 5658-2)

To determine a product's behaviour regarding lateral flame spread the international standard ISO 5658-2 is used in the proposed European system for fire safety on trains CEN/TS 45545-2 [13]. The same test procedure but with some additional measurements is used as the main flame spread test for interior linings in passenger ships under the IMO Resolution A.653(16) [12].

The lateral flame spread is determined on vertically orientated specimens exposed to radiant heat from a methane-fuelled rectangular radiant panel at an angle to the specimen as shown in Figure 3. A small gas burner flame impinging on the sample acts as the pilot ignition source [6].

The distance of the flame spread is used for reporting the CFE-value for both trains and ships. The CFE-value (Critical heat Flux at Extinguishment) is the incident heat flux at the specimen surface at the point along its horizontal centreline where the flame ceases to advance. The CFE-value, kW/m^2 , is determined by measuring the maximum spread of flame and relating this value to the corresponding heat flux value from the heat flux profile curve, the calibration curve, which is based on measurements conducted using a non-combustible board.

The specimen were attached to a non-combustible backing-board using staples along the upper edge. During the test, the staples were hidden under the specimen holder.

Figure 3 Test of Product No. 8 according to ISO 5658-2.

3 Results

3.1 Horizontal burning rate (ISO 3795, ECE Reg No 118 annex 6, directive 95/28/CE annex IV)

The results from the tests of horizontal burning rate are given in Figure 4. A detailed account of all test results are given in Appendix A.

Figure 4 Results for horizontal burning rate according to ISO 3795.

3.2 Vertical burning rate (ISO 6941, ECE Reg No 118 annex 8, directive 95/28/CE annex VI)

The results from the tests of vertical burning rate are given in Figure 5. A detailed account of all test results are given in Appendix B.

Figure 5 Results for vertical burning rate according to ISO 6941.

3.3 Spread of Flame, SoF (ISO 5658-2)

The results from the tests of CFE (Critical heat Flux at Extinguishment) are given in Figure 6. A detailed account of all test results are given in Appendix C.

Figure 6 Results for CFE (Critical heat Flux at Extinguishment) according to ISO 5658-2 (Spread of Flame).

4 Assessment of results and conclusions

According to ECE Reg No. 118 [3] and directive 95/28/CE [2] the result of the tests shall be considered satisfactory if, taking the worst results into account, the horizontal or vertical burning rate is not more than 100 mm/minute.

According to IMO Res A.653(16) [12] and CEN/TS 45545-2 [13], Requirement 1, the average critical heat flux at extinguishment, CFE, should be 20 kW/m^2 when evaluated according to the test standard ISO 5658-2, Spread of Flame (SoF), for a material to be considered satisfactory¹. As a consequence 20 kW/m^2 has been suggested as an amendment to ECE Reg No. 118 [14].

Table 2 summarizes all test results. It is clear that ISO 3795, horizontal burning rate, is the most lenient test method given the criteria for approval above. Approximately 91% (10/11) of the products passed the requirement for ISO 3795. If the products are tested for their vertical burning rate according to ISO 6941 instead the situation is very different. Only 36% (4/11) of the products pass the requirements for ISO 6941. This could be expected since vertical flame spread is more effective due to more effective heat transfer from the flames to the specimen. Furthermore, ISO 6941 and the criterion 100 mm/min were originally conceived for curtains which typically are treated with a flame retardant. Finally 40% (4/10) of the products pass the requirements for spread of flame according to ISO 5658.

In general there is little or no correlation between the test methods and the associated test criteria. It is only for product No. 2 (Perstorp laminate) and No. 10 (fabric) that all methods give the same, positive, result.

Table 2 Summary of test results. For horizontal and vertical burning rate the worst result is presented. For spread of flame the average test result is presented.

Prod No.	Thickness [mm]/ Area weight [g/m ²]	Hor. burning rate [mm/min]	Hor. pass/fail	Vert. burning rate [mm/min]	Vert. pass/fail	SoF [kW/m ²]	SoF pass/fail
1	3.1/3040	19	pass	178	fail	1.64	fail
2	5.8/8780	0	pass	0	pass	22.8	pass
3	2.8/311	169	fail	0	pass	2.12	fail
4	1.1/814	0	pass	0	pass	17.5	fail
5	3.2/627	24	pass	578	fail	12.0	fail
6	3.9/829	10	pass	440	fail	4.35	fail
7	4.4/973	0	pass	262	fail	20.4	pass
8	4.3/856	0	pass	351	fail	27.8	pass
9	3.0/676	31	pass	505	fail	-*	-*
10	4.2/826	0	pass	0	pass	20.5	pass
11	4.4/510	79	pass	103	fail	12.0	fail

* No tests performed due to lack of material.

¹ This criterion is not required for floor coverings.

Appendix A Results horizontal burning rate (ISO 3795, ECE Reg No 118 annex 6, directive 95/28/CE annex IV)

A.1 Product No. 1

Light grey ABS plastics. The product has an area weight of 3040 g/m².

A.1.1 Observations made during fire test

Test no	1	2	3	4	5
Sample dimension, mm					
length	354	354	354	354	354
width	70	70	70	70	70
thickness	3.1	3.1	3.1	3.1	3.1
Burnt distance, mm	254	254	254	254	254
Burning time, s	960	931	815	916	870
Burning rate, mm/min	15.9	16.4	18.7	16.6	17.5

A.1.2 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

A.1.3 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

A.1.4 Date of test

September 2 and 8, 2009.

A.2 Product No. 2

Dark grey Perstorp Compactlaminate consisting of paper-reinforced thermosetting plastic (two-side high pressure laminate). The product is used in partitions. The product has an area weight of 8780 g/m².

A.2.1 Observations made during fire test

Test no	1	2	3	4	5
Sample dimension, mm					
length	320	320	320	320	320
width	70	70	70	70	70
thickness	5.8	5.8	5.8	5.8	5.8
Burnt distance, mm	-*	-*	-*	-*	-*
Burning time, s	-	-	-	-	-
Burning rate, mm/min	-	-	-	-	-

* In tests no 1 - 5 the flames died out before reaching the first measuring point.

A.2.2 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

A.2.3 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

A.2.4 Date of test

August 31, 2009.

A.3 Product No. 3

Blue (front) and grey (back) fabric consisting of wool velvet blend. The product has an area weight of 311 g/m².

A.3.1 Application

The blue (front) side of the fabric was exposed for the burner.

A.3.2 Observations made during fire test

Test no	1	2	3	4	5
Sample dimension, mm					
length	354	354	354	354	354
width	100	100	100	100	100
thickness	2.8	2.8	2.8	2.8	2.8
Burnt distance, mm	254	254	72	63	254
Burning time, s	90	122	50	42	128
Burning rate, mm/min	169	125	86	90	119

A.3.3 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

A.3.4 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

A.3.5 Date of test

September 2 and 8, 2009.

A.4 Product No. 4

Green (front) and yellow (back) artificial leather consisting of 91.5% PVC and 8.5% polyamide. The product has an area weight of 814 g/m².

A.4.1 Application

The green (front) side of the fabric was exposed for the burner.

A.4.2 Observations made during fire test

Test no	1	2	3	4
Sample dimension, mm				
length	354	354	354	354
width	100	100	100	100
thickness	1.1	1.1	1.1	1.1
Burnt distance, mm	_*	_*	_*	_*
Burning time, s	-	-	-	-
Burning rate, mm/min	-	-	-	-

* In tests no 1 - 4 the flames died out before reaching the first measuring point.

A.4.3 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

A.4.4 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

A.4.5 Date of test

September 2 and 8, 2009.

A.5 Product No. 5

Blue (front) and blue/white (back) fabric consisting of 70% PES and 30% wool. The product has an area weight of 672 g/m².

A.5.1 Application

The blue (front) side of the fabric was exposed for the burner.

A.5.2 Observations made during fire test

Test no	1	2	3	4	5
Sample dimension, mm					
length	354	354	354	354	354
width	100	100	100	100	100
thickness	3.2	3.2	3.2	3.2	3.2
Burnt distance, mm	254	254	254	254	254
Burning time, s	651	640	652	667	677
Burning rate, mm/min	23.4	23.8	23.4	22.9	22.5

A.5.3 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

A.5.4 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

A.5.5 Date of test

September 2 and 8, 2009.

A.6 Product No. 6

Blue (front) and green/black (back) fabric consisting of 55% polyester and 45% wool.
The product has an area weight of 829 g/m².

A.6.1 Application

The blue (front) side of the fabric was exposed for the burner.

A.6.2 Observations made during fire test

Test no	1	2	3	4	5
Sample dimension, mm					
length	354	354	354	354	354
width	100	100	100	100	100
thickness	3.9	3.9	3.9	3.9	3.9
Burnt distance, mm	-*	-*	-*	127	-*
Burning time, s	-	-	-	740	-
Burning rate, mm/min	-	-	-	10.3	-

* In tests no 1, 2, 3 and 5 the flames died out before reaching the first measuring point.

A.6.3 Conditioning

Temperature 23 ± 2 °C.
Relative humidity (50 ± 5) %.

A.6.4 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

A.6.5 Date of test

September 2 and 8, 2009.

A.7 Product No. 7

Dark blue (front) and dark grey (back) fabric consisting of wool velvet blend. The product has an area weight of 974 g/m².

A.7.1 Application

The dark blue (front) side of the fabric was exposed for the burner.

A.7.2 Observations made during fire test

Test no	1	2	3	4	5
Sample dimension, mm					
length	354	354	354	354	354
width	100	100	100	100	100
thickness	4.4	4.4	4.4	4.4	4.4
Burnt distance, mm	_*	_*	_*	_*	_*
Burning time, s	-	-	-	-	-
Burning rate, mm/min	-	-	-	-	-

* In tests no 1-5 the flames died out before reaching the first measuring point.

A.7.3 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

A.7.4 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

A.7.5 Date of test

September 2 and 8, 2009.

A.8 Product No. 8

Dark blue (front) and multicoloured (back) fabric consisting of 85% wool and 15% nylon.
The product has an area weight of 856 g/m².

A.8.1 Application

The dark blue (front) side of the fabric was exposed for the burner.

A.8.2 Observations made during fire test

Test no	1	2	3	4	5
Sample dimension, mm					
length	354	354	354	354	354
width	100	100	100	100	100
thickness	4.3	4.3	4.3	4.3	4.3
Burnt distance, mm	_*	_*	_*	_*	_*
Burning time, s	-	-	-	-	-
Burning rate, mm/min	-	-	-	-	-

* In tests no 1-5 the flames died out before reaching the first measuring point.

A.8.3 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

A.8.4 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

A.8.5 Date of test

September 2 and 8, 2009.

A.9 Product No. 9

Grey (front) and red/grey (back) fabric consisting of 65% PES, 20% wool and 15% CV.
The product has an area weight of 676 g/m².

A.9.1 Application

The grey (front) side of the fabric was exposed for the burner.

A.9.2 Observations made during fire test

Test no	1	2	3	4	5
Sample dimension, mm					
length	354	354	354	354	354
width	100	100	100	100	100
thickness	3.0	3.0	3.0	3.0	3.0
Burnt distance, mm	254	254	254	254	254
Burning time, s	561	547	485	507	566
Burning rate, mm/min	27.1	27.9	31.4	30.1	26.9

A.9.3 Conditioning

Temperature 23 ± 2 °C.
Relative humidity (50 ± 5) %.

A.9.4 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

A.9.5 Date of test

September 2 and 8, 2009.

A.10 Product No. 10

Dark blue (front) and multicoloured (back) fabric consisting of 56% wool, 35% cotton and 9% nylon. The product has an area weight of 826 g/m².

A.10.1 Application

The dark blue (front) side of the fabric was exposed for the burner.

A.10.2 Observations made during fire test

Test no	1	2	3	4	5
Sample dimension, mm					
length	354	354	354	354	354
width	100	100	100	100	100
thickness	4.2	4.2	4.2	4.2	4.2
Burnt distance, mm	_*	_*	_*	_*	_*
Burning time, s	-	-	-	-	-
Burning rate, mm/min	-	-	-	-	-

* In tests no 1-5 the flames died out before reaching the first measuring point.

A.10.3 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

A.10.4 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

A.10.5 Date of test

September 2 and 8, 2009.

A.11 Product No. 11

Grey needle felt fabric consisting of 100% polypropylene fibre. The product has an area weight of 510 g/m².

A.11.1 Application

The textured (front) side of the fabric was exposed for the burner.

A.11.2 Observations made during fire test

Test no	1	2	3	4	5
Sample dimension, mm					
length	354	354	354	354	354
width	100	100	100	100	100
thickness	4.4	4.4	4.4	4.4	4.4
Burnt distance, mm	254	254	254	254	254
Burning time, s	194	198	216	217	227
Burning rate, mm/min	78.6	77.0	70.6	70.2	67.1

A.11.3 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

A.11.4 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

A.11.5 Date of test

September 2 and 8, 2009.

Appendix B Results vertical burning rate (ISO 6941, ECE Reg No 118 annex 8, directive 95/28/CE annex VI)

B.1 Product No. 1

Light grey ABS plastics. The product has an area weight of 3040 g/m².

B.1.1 Observations made during fire test

See Section 2.3 for explanations of the test parameters.

Test no	1	2	3
Sample dimension, mm			
length	560	560	560
width	170	170	170
thickness	3.1	3.1	3.1
Flame exposure time, s	15	15	15
t ₁	90	118	121
t ₂	125	195	181
t ₃	-*	195	181
Burning rate v ₁ , mm/min	147	112	109
Burning rate v ₂ , mm/min	178	135	140
Burning rate v ₃ , mm/min	-	160	172
Result = max(v ₁ ,v ₂ ,v ₃),	178	160	172

* In test no 1 the third marker thread never severed.

B.1.2 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

B.1.3 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

B.1.4 Date of test

September 7 and 9, 2009.

B.2 Product No. 2

Dark grey Perstorp Compactlaminate consisting of paper-reinforced thermosetting plastic (two-side high pressure laminate). The product is used in partitions. The product has an area weight of 8780 g/m².

B.2.1 Observations made during fire test

See Section 2.3 for explanations of the test parameters.

Test no	1	2	3
Sample dimension, mm			
length	560	560	560
width	170	170	170
thickness	5.8	5.8	5.8
Flame exposure time, s	15	15	15
t ₁	_*	_*	_*
t ₂	_*	_*	_*
t ₃	_*	_*	_*
Burning rate v ₁ , mm/min	-	-	-
Burning rate v ₂ , mm/min	-	-	-
Burning rate v ₃ , mm/min	-	-	-
Result = max(v ₁ ,v ₂ ,v ₃),	-	-	-

* In tests no 1-2 the marker threads never severed.

B.2.2 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

B.2.3 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

B.2.4 Date of test

September 7 and 10, 2009.

B.3 Product No. 3

Blue (front) and grey (back) fabric consisting of wool velvet blend. The product has an area weight of 311 g/m².

B.3.1 Observations made during fire test

See Section 2.3 for explanations of the test parameters.

Test no	1	2	3	4
Sample dimension, mm				
length	560	560	560	560
width	170	170	170	170
thickness	2.8	2.8	2.8	2.8
Flame exposure time, s	5	15	15	15
t ₁	_*	_*	_*	_*
t ₂	_*	_*	_*	_*
t ₃	_*	_*	_*	_*
Burning rate v ₁ , mm/min	-	-	-	-
Burning rate v ₂ , mm/min	-	-	-	-
Burning rate v ₃ , mm/min	-	-	-	-
Result = max(v ₁ ,v ₂ ,v ₃),	-	-	-	-

* In tests no 1-4 the marker threads never severed.

B.3.2 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

B.3.3 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

B.3.4 Date of test

September 7 and 10, 2009.

B.4 Product No. 4

Green (front) and yellow (back) artificial leather consisting of 91.5% PVC and 8.5% polyamide. The product has an area weight of 814 g/m².

B.4.1 Observations made during fire test

See Section 2.3 for explanations of the test parameters.

Test no	1	2	3
Sample dimension, mm			
length	560	560	560
width	170	170	170
thickness	1.1	1.1	1.1
Flame exposure time, s	15	15	15
t ₁	_*	_*	_*
t ₂	_*	_*	_*
t ₃	_*	_*	_*
Burning rate v ₁ , mm/min	-	-	-
Burning rate v ₂ , mm/min	-	-	-
Burning rate v ₃ , mm/min	-	-	-
Result = max(v ₁ ,v ₂ ,v ₃),	-	-	-

* In tests no 1-3 the marker threads never severed.

B.4.2 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

B.4.3 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

B.4.4 Date of test

September 7 and 10, 2009.

B.5 Product No. 5

Blue (front) and blue/white (back) fabric consisting of 70% PES and 30% wool. The product has an area weight of 672 g/m².

B.5.1 Observations made during fire test

See Section 2.3 for explanations of the test parameters.

Test no	1	2	3
Sample dimension, mm			
length	560	560	560
width	170	170	170
thickness	3.2	3.2	3.2
Flame exposure time, s	15	15	15
t ₁	35	35	41
t ₂	54	53	61
t ₃	58	59	69
Burning rate v ₁ , mm/min	377	377	322
Burning rate v ₂ , mm/min	411	419	364
Burning rate v ₃ , mm/min	578	529	452
Result = max(v ₁ ,v ₂ ,v ₃),	578	529	452

B.5.2 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

B.5.3 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

B.5.4 Date of test

September 7 and 10, 2009.

B.6 Product No. 6

Blue (front) and green/black (back) fabric consisting of 55% polyester and 45% wool.
The product has an area weight of 829 g/m².

B.6.1 Observations made during fire test

See Section 2.3 for explanations of the test parameters.

Test no	1	2	3
Sample dimension, mm			
length	560	560	560
width	170	170	170
thickness	3.0	3.9	3.9
Flame exposure time, s	15	15	15
t ₁	34	70	30
t ₂	52	87	53
t ₃	79	92	74
Burning rate v ₁ , mm/min	388	189	440
Burning rate v ₂ , mm/min	427	255	419
Burning rate v ₃ , mm/min	224	163	422
Result = max(v ₁ ,v ₂ ,v ₃),	427	255	440

B.6.2 Conditioning

Temperature 23 ± 2 °C.
Relative humidity (50 ± 5) %.

B.6.3 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

B.6.4 Date of test

September 7 and 9, 2009.

B.7 Product No. 7

Dark blue (front) and dark grey (back) fabric consisting of wool velvet blend. The product has an area weight of 974 g/m².

B.7.1 Observations made during fire test

See Section 2.3 for explanations of the test parameters.

Test no	1	2	3
Sample dimension, mm			
length	560	560	560
width	170	170	170
thickness	4.4	4.4	4.4
Flame exposure time, s	15	15	15
t ₁	-*	60	-*
t ₂	-*	107	-*
t ₃	-*	119	-*
Burning rate v ₁ , mm/min	-	220	-
Burning rate v ₂ , mm/min	-	207	-
Burning rate v ₃ , mm/min	-	262	-
Result = max(v ₁ ,v ₂ ,v ₃),	-	262	-

* In tests no 1 and 3 the marker threads never severed.

B.7.2 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

B.7.3 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

B.7.4 Date of test

September 7 and 9, 2009.

B.8 Product No. 8

Dark blue (front) and multicoloured (back) fabric consisting of 85% wool and 15% nylon.
The product has an area weight of 856 g/m².

B.8.1 Observations made during fire test

See Section 2.3 for explanations of the test parameters.

Test no	1	2	3
Sample dimension, mm			
length	560	560	560
width	170	170	170
thickness	4.3	4.3	4.3
Flame exposure time, s	15	15	15
t ₁	-*	51	-*
t ₂	-*	95	-*
t ₃	-*	89	-*
Burning rate v ₁ , mm/min	-	259	-
Burning rate v ₂ , mm/min	-	234	-
Burning rate v ₃ , mm/min	-	351	-
Result = max(v ₁ ,v ₂ ,v ₃),	-	351	-

* In tests no 1 and 3 the marker threads never severed.

B.8.2 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

B.8.3 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

B.8.4 Date of test

September 7 and 9, 2009.

B.9 Product No. 9

Grey (front) and red/grey (back) fabric consisting of 65% PES, 20% wool and 15% CV.
The product has an area weight of 676 g/m².

B.9.1 Observations made during fire test

See Section 2.3 for explanations of the test parameters.

Test no	1	2	3
Sample dimension, mm			
length	560	560	560
width	170	170	170
thickness	3.0	3.0	3.0
Flame exposure time, s	15	15	15
t ₁	30	46	36
t ₂	44	56	46
t ₃	63	68	65
Burning rate v ₁ , mm/min	440	289	367
Burning rate v ₂ , mm/min	505	396	483
Burning rate v ₃ , mm/min	495	459	480
Result = max(v ₁ ,v ₂ ,v ₃),	505	459	480

B.9.2 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

B.9.3 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

B.9.4 Date of test

September 7 and 10, 2009.

B.10 Product No. 10

Dark blue (front) and multicoloured (back) fabric consisting of 56% wool, 35% cotton and 9% nylon. The product has an area weight of 826 g/m².

B.10.1 Observations made during fire test

See Section 2.3 for explanations of the test parameters.

Test no	1	2	3
Sample dimension, mm			
length	560	560	560
width	170	170	170
thickness	4.2	4.2	4.2
Flame exposure time, s	15	15	15
t ₁	_*	_*	_*
t ₂	_*	_*	_*
t ₃	_*	_*	_*
Burning rate v ₁ , mm/min	-	-	-
Burning rate v ₂ , mm/min	-	-	-
Burning rate v ₃ , mm/min	-	-	-
Result = max(v ₁ ,v ₂ ,v ₃),	-	-	-

* In tests no 1-3 the marker threads never severed.

B.10.2 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

B.10.3 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

B.10.4 Date of test

September 7 and 10, 2009.

B.11 Product No. 11

Grey needle felt fabric consisting of 100% polypropylene fibre. The product has an area weight of 510 g/m².

B.11.1 Observations made during fire test

See Section 2.3 for explanations of the test parameters.

Test no	1	2	3
Sample dimension, mm			
length	560	560	560
width	170	170	170
thickness	4.4	4.4	4.4
Flame exposure time, s	15	15	15
t ₁	128	136	139
t ₂	256	234	-*
t ₃	522	-*	-*
Burning rate v ₁ , mm/min	103	97	95
Burning rate v ₂ , mm/min	87	95	-
Burning rate v ₃ , mm/min	60	-	-
Result = max(v ₁ ,v ₂ ,v ₃),	103	97	95

* In test no 2 the third marker thread never severed.

** In test no 3 the second and third marker threads never severed.

B.11.2 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

B.11.3 Test conditions

The combustion chamber was placed in a fume cupboard according to standard.

B.11.4 Date of test

September 7 and 9, 2009.

Appendix C Results Spread of Flame, SoF (ISO 5658-2)

C.1 Product No. 1

Light grey ABS plastics. The product has an area weight of 3040 g/m².

C.1.1 Observations made during fire test

Test no	1	2
Flames at flame front went out	32:00 at 800 mm	30:00 at 800 mm
Burning droplets	none	none

C.1.2 Derived fire characteristics

Test no	1	2		Average	Surface flammability criteria
Heat for ignition, MJ/m ²	1.8	1.9		<u>1.8</u>	—
Average heat for sustained burning, Q _{sb} , MJ/m ²	2.1	2.1		<u>2.1</u>	≥1.5
Critical flux at extinguishment, CFE, kW/m ²	1.5	1.8		<u>1.6</u>	≥20.0
Total heat release, Q _t , MJ	4.7	5.3		<u>5</u>	≤0.7
Peak heat release rate, Q _p , kW	17.6	17.8		<u>17.7</u>	≤4.0

C.1.3 Heat release rates, graphs

Test 1

Figure 1 Heat release rate for test no 1.
Total heat release: 4.7 MJ. Peak heat release rate: 17.6 kW.

Test 2

Figure 2 Heat release rate for test no 2.
Total heat release: 5.3 MJ. Peak heat release rate: 17.8 kW.

C.1.4 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

C.1.5 Date of test

September 4 and October 1, 2009.

C.2 Product No. 2

Dark grey Perstorp Compactlaminat consisting of paper-reinforced thermosetting plastic (two-side high pressure laminate). The product is used in partitions. The product has an area weight of 8780 g/m².

C.2.1 Observations made during fire test

Test no	1	2
Flames at flame front went out	12:35 at 380 mm	07:30 at 340 mm
Burning droplets	none	none

C.2.2 Derived fire characteristics

Test no	1	2		Average	Surface flammability criteria
Heat for ignition, MJ/m ²	2.9	2.6		<u>2.8</u>	—
Average heat for sustained burning, Q_{sb} , MJ/m ²	4	3.5		<u>3.7</u>	≥1.5
Critical flux at extinguishment, CFE, kW/m ²	20.5	25.1		<u>22.8</u>	≥20.0
Total heat release, Q_t , MJ	3.3	3.4		<u>3.3</u>	≤0.7
Peak heat release rate, Q_p , kW	3.3	4.6		<u>3.9</u>	≤4.0

C.2.3 Heat release rates, graphs

Test 1

Figure 1 Heat release rate for test no 1.
Total heat release: 3.3 MJ. Peak heat release rate: 3.3 kW.

Test 2

Figure 2 Heat release rate for test no 2.
Total heat release: 3.4 MJ. Peak heat release rate: 4.6 kW.

C.2.4 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

C.2.5 Date of test

September 4 and 8, 2009.

C.3 Product No. 3

Blue (front) and grey (back) fabric consisting of wool velvet blend. The product has an area weight of 311 g/m².

C.3.1 Observations made during fire test

Test no	1	2
Flames at flame front went out	04:40 at 800 mm	03:40 at 680 mm
Burning droplets	none	none

C.3.2 Derived fire characteristics

Test no	1	2		Average	Surface flammability criteria
Heat for ignition, MJ/m ²	0.1	0.2		<u>0.2</u>	—
Average heat for sustained burning, Q_{sb} , MJ/m ²	0.3	0.3		<u>0.3</u>	≥1.5
Critical flux at extinguishment, CFE, kW/m ²	1.5	2.7		<u>2.1</u>	≥20.0
Total heat release, Q_t , MJ	0.1	<0.1		<u><0.1</u>	≤0.7
Peak heat release rate, Q_p , kW	1	0.9		<u>0.9</u>	≤4.0

C.3.3 Heat release rates, graphs

Test 1

Figure 1 Heat release rate for test no 1.
Total heat release: 0.1 MJ. Peak heat release rate: 1.0 kW.

Test 2

Figure 2 Heat release rate for test no 2.
Total heat release: <0.1 MJ. Peak heat release rate: 0.9 kW.

C.3.4 Conditioning

Temperature 23 ± 2 °C.
Relative humidity (50 ± 5) %.

C.3.5 Date of test

September 4 and 29, 2009.

C.4 Product No. 4

Green (front) and yellow (back) artificial leather consisting of 91.5% PVC and 8.5% polyamide. The product has an area weight of 814 g/m².

C.4.1 Observations made during fire test

Test no	1	2
Flames at flame front went out	01:53 at 400 mm	02:00 at 420 mm
Burning droplets	none	none

C.4.2 Derived fire characteristics

Test no	1	2		Average	Surface flammability criteria
Heat for ignition, MJ/m ²	0.2	0.3		<u>0.2</u>	—
Average heat for sustained burning, Q_{sb} , MJ/m ²	0.7	0.5		<u>0.6</u>	≥1.5
Critical flux at extinguishment, CFE, kW/m ²	18.3	16.7		<u>17.5</u>	≥20.0
Total heat release, Q_t , MJ	0.3	0.2		<u>0.3</u>	≤0.7
Peak heat release rate, Q_p , kW	4.7	2.8		<u>3.7</u>	≤4.0

C.4.3 Heat release rates, graphs

Test 1

Figure 1 Heat release rate for test no 1.
Total heat release: 0.3 MJ. Peak heat release rate: 4.7 kW.

Test 2

Figure 2 Heat release rate for test no 2.
Total heat release: 0.2 MJ. Peak heat release rate: 2.8 kW.

C.4.4 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

C.4.5 Date of test

September 8 and 29, 2009.

C.5 Product No. 5

Blue (front) and blue/white (back) fabric consisting of 70% PES and 30% wool. The product has an area weight of 672 g/m².

C.5.1 Observations made during fire test

Test no	1	2
Flames at flame front went out	04:46 at 470 mm	04:04 at 470 mm
Burning droplets	none	none

C.5.2 Derived fire characteristics

Test no	1	2		Average	Surface flammability criteria
Heat for ignition, MJ/m ²	0.6	0.5		<u>0.5</u>	—
Average heat for sustained burning, Q_{sb} , MJ/m ²	1.1	1.1		<u>1.1</u>	≥1.5
Critical flux at extinguishment, CFE, kW/m ²	11.9	12.2		<u>12</u>	≥20.0
Total heat release, Q_t , MJ	0.4	0.4		<u>0.4</u>	≤0.7
Peak heat release rate, Q_p , kW	6	3.7		<u>4.9</u>	≤4.0

C.5.3 Heat release rates, graphs

Test 1

Figure 1 Heat release rate for test no 1.
Total heat release: 0.4 MJ. Peak heat release rate: 6.0 kW.

Test 2

Figure 2 Heat release rate for test no 2.
Total heat release: 0.4 MJ. Peak heat release rate: 3.7 kW.

C.5.4 Conditioning

Temperature 23 ± 2 °C.
Relative humidity (50 ± 5) %.

C.5.5 Date of test

September 8 and 29, 2009.

C.6 Product No. 6

Blue (front) and green/black (back) fabric consisting of 55% polyester and 45% wool.
The product has an area weight of 829 g/m².

C.6.1 Observations made during fire test

Test no	1	2
Flames at flame front went out	11:35 at 610 mm	11:15 at 600 mm
Burning droplets	none	none

C.6.2 Derived fire characteristics

Test no	1	2		Average	Surface flammability criteria
Heat for ignition, MJ/m ²	0.6	0.5		<u>0.6</u>	—
Average heat for sustained burning, Q_{sb} , MJ/m ²	1	1		<u>1</u>	≥1.5
Critical flux at extinguishment, CFE, kW/m ²	4.2	4.5		<u>4.3</u>	≥20.0
Total heat release, Q_t , MJ	0.8	0.5		<u>0.6</u>	≤0.7
Peak heat release rate, Q_p , kW	8.5	5.4		<u>7</u>	≤4.0

C.6.3 Heat release rates, graphs

Test 1

Figure 1 Heat release rate for test no 1.
Total heat release: 0.8 MJ. Peak heat release rate: 8.5 kW.

Test 2

Figure 2 Heat release rate for test no 2.
Total heat release: 0.5 MJ. Peak heat release rate: 5.4 kW.

C.6.4 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

C.6.5 Date of test

September 8 and 29, 2009.

C.7 Product No. 7

Dark blue (front) and dark grey (back) fabric consisting of wool velvet blend. The product has an area weight of 974 g/m².

C.7.1 Observations made during fire test

Om max flamfront ej överstiger 180 mm skall inte Qsb presenteras.

Test no	1	2
Flames at flame front went out	01:20 at 340 mm	02:08 at 430 mm
Burning droplets	none	none

C.7.2 Derived fire characteristics

Test no	1	2		Average	Surface flammability criteria
Heat for ignition, MJ/m ²	0.3	0.2		<u>0.3</u>	—
Average heat for sustained burning, Q _{sb} , MJ/m ²	0.4	0.5		<u>0.4</u>	≥1.5
Critical flux at extinguishment, CFE, kW/m ²	25.1	15.8		<u>20.4</u>	≥20.0
Total heat release, Q _t , MJ	0.6	0.5		<u>0.5</u>	≤0.7
Peak heat release rate, Q _p , kW	8.9	6		<u>7.4</u>	≤4.0

C.7.3 Heat release rates, graphs

Test 1

Figure 1 Heat release rate for test no 1.
Total heat release: 0.6 MJ. Peak heat release rate: 8.9 kW.

Test 2

Figure 2 Heat release rate for test no 2.
Total heat release: 0.5 MJ. Peak heat release rate: 6.0 kW.

Test 3

C.7.4 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

C.7.5 Date of test

September 8 and 29, 2009.

C.8 Product No. 8

Dark blue (front) and multicoloured (back) fabric consisting of 85% wool and 15% nylon.
The product has an area weight of 856 g/m².

C.8.1 Observations made during fire test

Test no	1	2
Flames at flame front went out	01:20 at 290 mm	01:20 at 350 mm
Burning droplets	none	none

C.8.2 Derived fire characteristics

Test no	1	2		Average	Surface flammability criteria
Heat for ignition, MJ/m ²	0.3	0.2		<u>0.3</u>	—
Average heat for sustained burning, Q_{sb} , MJ/m ²	0.4	0.3		<u>0.3</u>	≥1.5
Critical flux at extinguishment, CFE, kW/m ²	31.5	24		<u>27.8</u>	≥20.0
Total heat release, Q_t , MJ	0.4	0.3		<u>0.4</u>	≤0.7
Peak heat release rate, Q_p , kW	8	5.3		<u>6.6</u>	≤4.0

C.8.3 Heat release rates, graphs

Test 1

Figure 1 Heat release rate for test no 1.
Total heat release: 0.4 MJ. Peak heat release rate: 8.0 kW.

Test 2

Figure 2 Heat release rate for test no 2.
Total heat release: 0.3 MJ. Peak heat release rate: 5.3 kW.

C.8.4 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

C.8.5 Date of test

September 8 and 29, 2009.

C.9 Product No. 9

No tests performed.

C.10 Product No. 10

Dark blue (front) and multicoloured (back) fabric consisting of 56% wool, 35% cotton and 9% nylon. The product has an area weight of 826 g/m².

C.10.1 Observations made during fire test

Test no	1
Flames at flame front went out	01:24 at 380 mm
Burning droplets	none

C.10.2 Derived fire characteristics

Test no	1			Average	Surface flammability criteria
Heat for ignition, MJ/m ²	0.2			<u>0.2</u>	—
Average heat for sustained burning, Q_{sb} , MJ/m ²	0.4			<u>0.4</u>	≥1.5
Critical flux at extinguishment, CFE, kW/m ²	20.5			<u>20.5</u>	≥20.0
Total heat release, Q_t , MJ	0.5			<u>0.5</u>	≤0.7
Peak heat release rate, Q_p , kW	8.7			<u>8.7</u>	≤4.0

C.10.3 Heat release rates, graphs

Test 1

Figure 1 Heat release rate for test no 1.
Total heat release: 0.5 MJ. Peak heat release rate: 8.7 kW.

C.10.4 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

C.10.5 Date of test

September 8, 2009.

C.11 Product No. 11

Grey needle felt fabric consisting of 100% polypropylene fibre. The product has an area weight of 510 g/m².

C.11.1 Observations made during fire test

Test no	1	2
Flames at flame front went out	07:36 at 450 mm	09:33 at 490 mm
Burning droplets	none	none

C.11.2 Derived fire characteristics

Test no	1	2		Average	Surface flammability criteria
Heat for ignition, MJ/m ²	0.5	1.6		<u>1</u>	—
Average heat for sustained burning, Q_{sb} , MJ/m ²	4.4	2.4		<u>3.4</u>	≥1.5
Critical flux at extinguishment, CFE, kW/m ²	13.5	10.5		<u>12</u>	≥20.0
Total heat release, Q_t , MJ	0.5	0.2		<u>0.3</u>	≤0.7
Peak heat release rate, Q_p , kW	1.9	1.4		<u>1.6</u>	≤4.0

C.11.3 Heat release rates, graphs

Test 1

*Figure 1 Heat release rate for test no 1.
Total heat release: 0.5 MJ. Peak heat release rate: 1.9 kW.*

Test 2

*Figure 2 Heat release rate for test no 2.
Total heat release: 0.2 MJ. Peak heat release rate: 1.4 kW.*

C.11.4 Conditioning

Temperature 23 ± 2 °C.

Relative humidity (50 ± 5) %.

C.11.5 Date of test

September 8 and 30, 2009.

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Box 857, SE-501 15 BORÅS, SWEDEN

Telephone: +46 10 516 50 00, Telefax: +46 33 13 55 02

E-mail: info@sp.se, Internet: www.sp.se

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