7/8

FORMER FIRE REGULATION IN BUILDING IN EUROPE

FIRE REGULATION: WORLD OVERVIEW

We have devoted lots of energy to set up this document and probably all the updates are not in – hope however it will help you to catch the big picture of the complex fire standards and regulation

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1 FRANCE

The “reaction to fire” tests classify the material in 5 categories from M0 to M4. The specific standard that is applicable depend of the intended use (see table below). Class M0 is assigned if the requirements for class M1 are met and the heat of combustion (upper calorific potential test by NF P 92-510[95]) does not exceed 2500 kJ/kg (typical M0 material are concrete, blaster, mineral based product). To determine the classifications M1 to M4 and NC, series of test is conducted.

Table 1: building material fire classification and test methods for all materials excepted lining material [2]

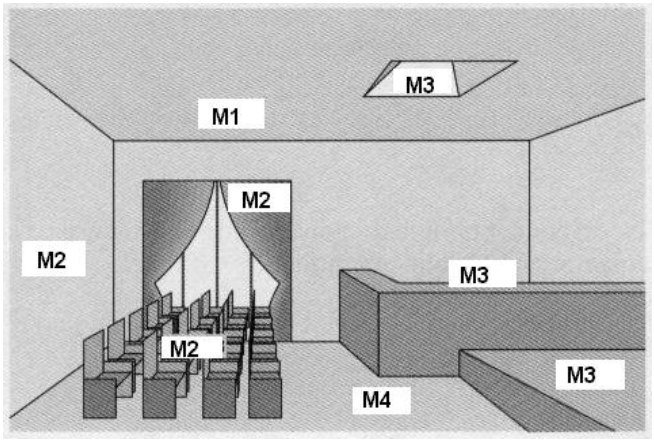
Class	Test
MO Non-flammable (Calorific value < or = to 2508 kJ/kg)	NF P 92 510 [95] Determination of upper calorific potential NF P 92 501 [90] Radiation test used for rigid materials, or for material on rigid substrates (finishes) of all thicknesses, and for flexible materials thicker than 5 mm NF P 92 503 [91] Electrical burner test used for flexible materials 5 mm thick or less
M1 Non-flammable (Calorific value > or = to 2508 kJ/kg)	NF P 92 510 [95] Determination of upper calorific potential NF P 92 501 [90] Radiation test used for rigid materials, or for material on rigid substrates (finishes) of all thicknesses, and for flexible materials thicker than 5 mm. NF P 92 503 [91] Electrical burner test used for flexible materials 5 mm thick or less NF P 92 504 [92] Speed of spread of flame test used for the materials which are not intended to be glued on a rigid substrate - complementary test – NF P 92 505 [93] Dripping test with electrical radiator, used for melting material - complementary test-
M2 Low flammability	NF P 92 501 [90] Radiation test used for rigid materials, or for material on rigid substrates (finishes) of all thicknesses, and for flexible materials thicker than 5 mm. NF P 92 503 [91] Electrical burner test used for flexible materials 5 mm thick or less NF P 92 504 [92] Speed of spread of flame test used for the materials which are not intended to be glued on a rigid substrate - complementary test- NF P 92 505 [93] Dripping test with electrical radiator, used for melting material - complementary test-
M3 Moderately flammable	NF P 92 501 [90] Radiation test used for rigid materials, or for material on rigid substrates (finishes) of all thicknesses, and for flexible materials thicker than 5 mm. NF P 92 503 [91] Electrical burner test used for flexible materials 5 mm thick or less NF P 92 504 [92] Speed of spread of flame test used for the materials which are not intended to be glued on a rigid substrate - complementary test- NF P 92 505 [93] Dripping test with electrical radiator, used for melting material - complementary test-
M4 High flammability	NF P 92 501 [90] Radiation test used for rigid materials, or for material on rigid substrates (finishes) of all thicknesses, and for flexible materials thicker than 5 mm. NF P 92 503 [91] Electrical burner test used for flexible materials 5 mm thick or less NF P 92 504 [92] Speed of spread of flame test used for the materials which are not intended to be glued on a rigid substrate - complementary test- NF P 92 505 [93] Dripping test with electrical radiator, used for melting material - complementary test-

Notes: The NF P 92 504 [92] and 505 [93] tests are used when some unusual phenomenon’s (fall of burning droplets for example) are observed.

Table 2: building material fire classification and test methods for lining materials [2]

Class	Test
MO Non-flammable (Calorific value < or = to 2508 kJ/kg)	Same test as building material, Table 1
M1 Non-flammable (Calorific value > or = to 2508 kJ/kg)	Same test as building material, Table 1
M2 Low flammability	Same test as building material, Table 1
M3 Moderately flammable	NF P 92 506 [94] Radiant panel test for flooring
M4 High flammability	NF P 92 506 [94] Radiant panel test for flooring

Figure 1: French requirement in public building: theatre [124]



The NF P 92-501 test method is one of the main test use for predicting the M rating. The M rating is connected to a q value calculated via a formula (1) integrating the ignition time It, the height of flame spread H (in cm) and the flaming persistence time (T)

$$Q = (100 \times H) / (It \times [T]^{0.5}) \quad (1)$$

Table 3: M values according to the q determination during the NF P 92-501 test

q	M rating
< 2.5	M1
2.5 < q < 15	M2
15 < q < 50	M3
> 50	M4

The contribution to fire of the material is mainly based on the ignition time It. Indeed, a 50 % variation of It lead to a 100% variation of q.

Table 4: the influence of parameters

Parameter	Variation	q variation
H	-50 %	-50 %
It	-50 %	+ 100 %
T	-50 %	+ 41 %

Table 5: current requirements [3]

Building part	Class
Ceiling	M0-M1
Wall cladding	M2
Floors	M3-M4

The NF P 92-504 and 505 test method are complementary tests which have to be done when some unusual phenomenon's (fall of burning droplets for example) are observed. In this case, the results obtains with these two test are exploited to set up the M rating.

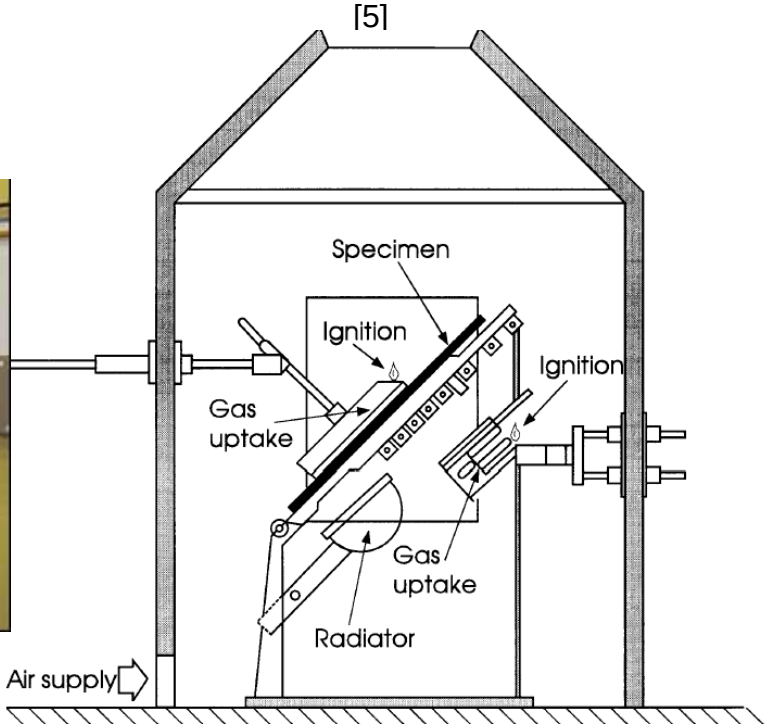
Table 6: M rating according to the NF P 92-504 and 505 requirements

Test	Requirements				
NF P 92-505	-	No ignition of cotton	No ignition of cotton	Specimen drips, ignites cotton	Specimen drips, ignites cotton
NF P 92-504	No dripping of melted material	Non flaming droplets	Flaming dripping	Non flaming droplets	Flaming dripping
No flaming persistence	M1	M1	M2	M4	M4
Flaming persistence < = 5 s	M2	M3	M3	M4	M4
Flaming persistence > 5 s + flame spread < 2 mm/s	M3	M3	M4	M4	M4

Figure 2: the NF P 92-501 Epiradiateur Flammability test

[3]

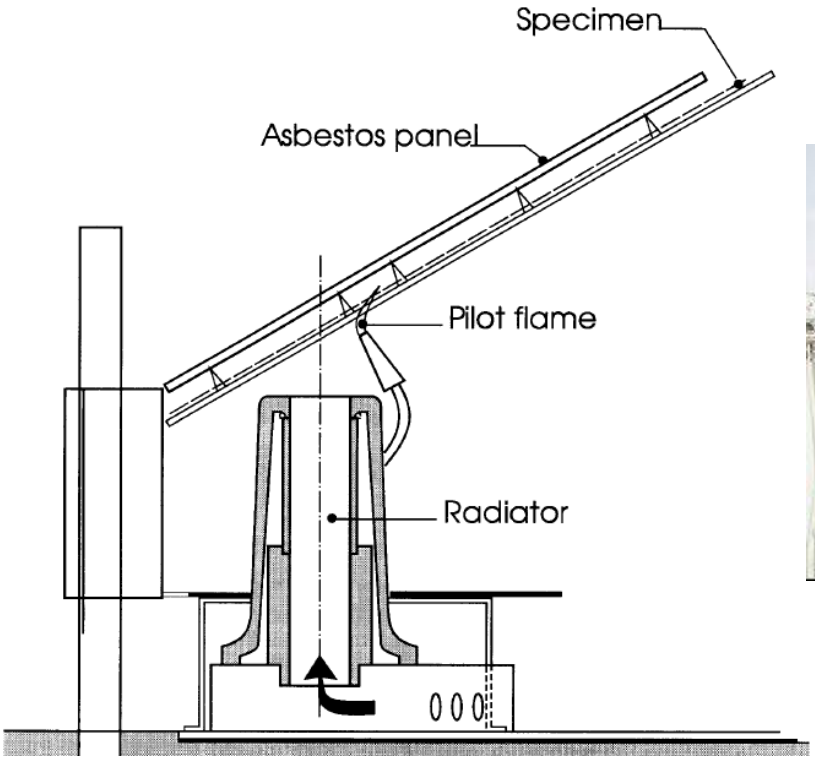
[5]



[3]

Figure 3: the NF P 92-503 Burner Test for Flexible material

[6]



[3]

Figure 4: the NF P 92-504 Bunsen burner Test for Small-ignition Source Flammability

[6]

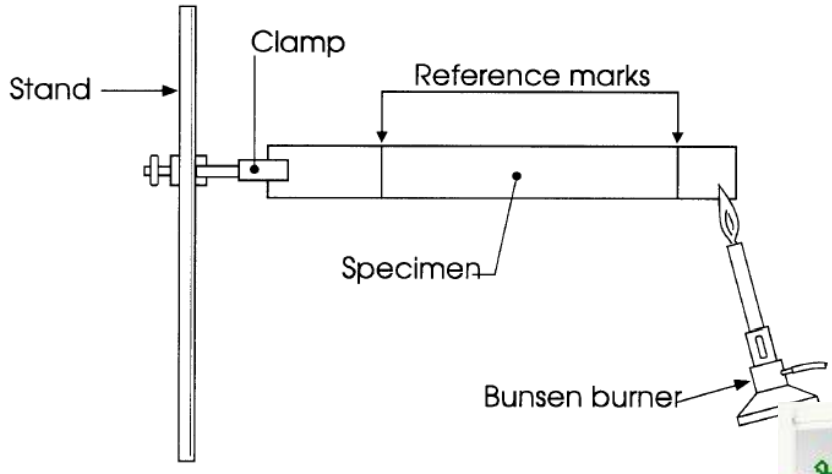
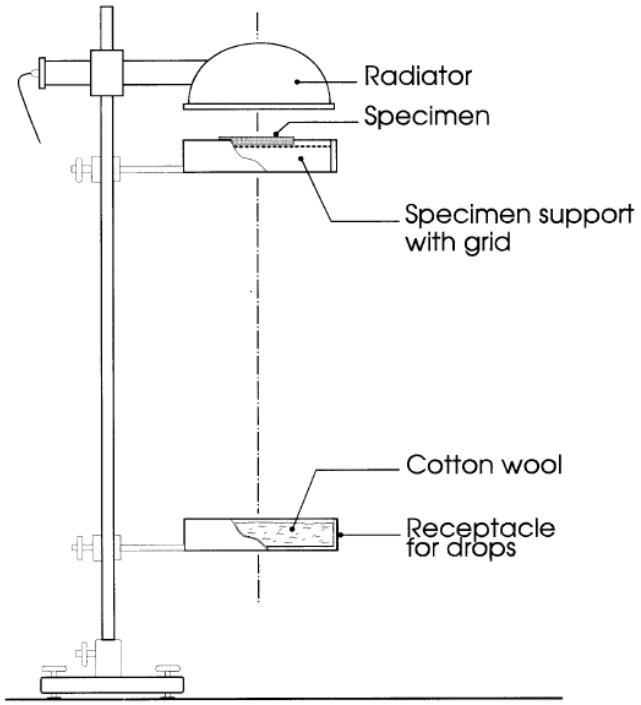


Figure 5: The NF P 92-505 Dripping Test

[6] [3]



2 Spain

The reaction to fire tests -UNE 23.727-90 Reaction to fire test for building materials- classifies the material in 5 categories from M0 to M4 (see table below). Also note that the test methods used are similar to those used in France. Besides, the calculation mode according to the NF P 92-501 test of the M value differs from the French methodology. The test are comparable but results exploitation are quite different.

Table 7: UNE 23.727-9 building material fire classification and test methods [2]

Class	Test
MO Non-flammable (Calorific value < or = to 2508 kJ/kg)	UNE 23.102-90 Reaction to fire test for building materials. Non combustibility test
M1 Non-flammable (Calorific value > or = to 2508 kJ/kg) M2 Low flammability M3 Moderately flammable M4 High flammability	**1. - Main tests (excepted lining material)** 1.1. - UNE 23.721-90 Reaction to fire test on building materials. Radiation test for rigid materials / Materials on rigid substrates of all thickness / flexible materials thicker than 5 mm 1.2. - UNE 23.723-90 Reaction to fire test on building materials. Electrical burner test for flexible materials with a thickness ≤ 5 mm . **2. - Complementary tests** 2.1. - UNE 23.724-90 Reaction to fire test on building material. Speed of the spread of flame test for materials which are not intended to be placed on rigid substrate 2.2. - UNE 23.725-90 Reaction to fire test on building materials. Dripping test with electrical radiator for melting materials **2. - Floorings** UNE 23.726-90 Reaction to fire test on building materials. Radiant panel test.

The classification methodology into the categories M1 to M4 is based on four calculated indices:

- √ The flammability index i is corresponding approximately to the inverse of the time of ignition (I=(1000/15xt1) + (1000/15xt2))
- √ The flame spread index s is corresponding to flame lengths summation over the entire test divided by 140,
- √ The maximum flame height h is corresponding to the maximum flame height divided by 20,
- √ The combustibility index c is corresponding to the product of burning time and temperature rise and is analogous to a rate of heat release.

The rating has to correspond with the choice n°1 or n°2 detailed in the followed girds.

Table 8: classification using the UNE 23.721-90 test method [6]

Choice n°1

		M1	M2	M3	M4
flammability index	i	0	-	-	-
flame spread index	s	0	< 0.2	< 1	> 1
maximum flame height	h	0	< 1	< 1.5	> 1.5
combustibility index	c	< 1	< 1	< 1	< 1

Choice n°2

		M1	M2	M3	M4
flammability index	i	0	<1	<2	>2
flame spread index	s	0	< 1	< 5	> 5
maximum flame height	h	0	< 1	< 2.5	> 2.5
combustibility index	c	< 1	< 1	< 2.5	>2.5

3 Belgium

The reaction to fire tests classifies the material in 5 categories from A0 to A4 (see table below). Also note that the test methods used are similar to those used in France.

Table 9: Belgium classification [5]

Class	Test method
A0	ISO 1182
A1	NF P 92-501 / NF P 92-504 BS 476-7
A2	NF P 92-501 / NF P 92-504 BS 476-7
A3	NF P 92-501 / NF P 92-504 BS 476-7
A4	Exceed class A3

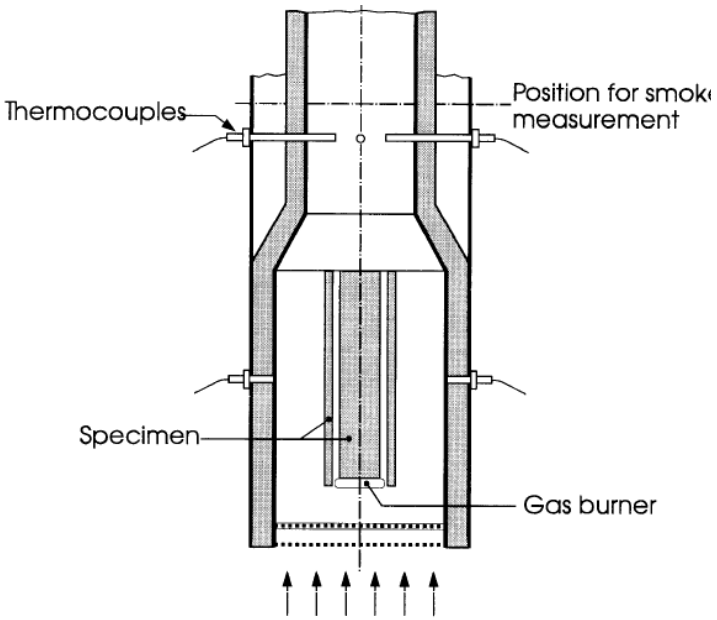
4 DEUTCHLAND

The “reaction to fire” tests classify the material in 5 categories from A1, A2 to B1, B2, B3 according to the DIN 4102 [101]. The specific standard that is applicable depends of the intended use (see table below).

Table 10: classification according to the DIN 4102 [5]

Building material class	Designation	Test method
A1 A2	Non combustible	Furnace test 750°C Brandschacht Smoke density DIN E 53436/37 [69] Toxicity to DIN 53436 [69] Calorific potential to DIN 51900 –2 Heat release to DIN 4102 Part 8 [101]
B1	Low flammability	Brandschacht and small burner test Radiant panel test for floor coverings
B2	Moderately flammable	Small burner test
B3	Highly flammable	No test

Figure 6: The DIN 4102 "Branschacht" test [6] Figure 7: the DIN 4102 Furnace test [6]



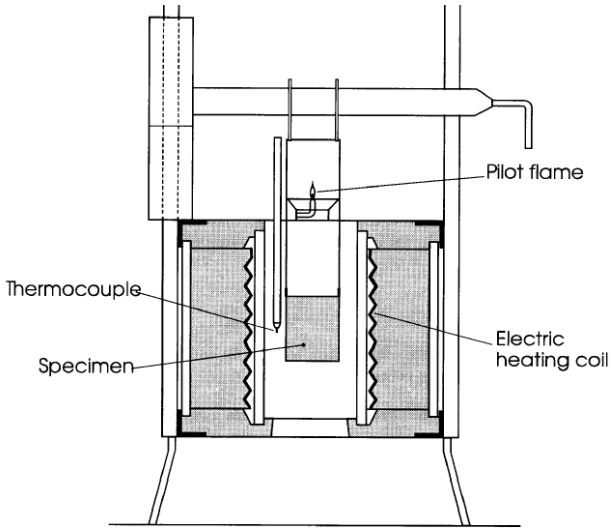


Figure 8: the DIN 53436 Toxicity Furnace Test [5]

Species analysed: CO, CO2, Halogenated species, HCN, SO_2

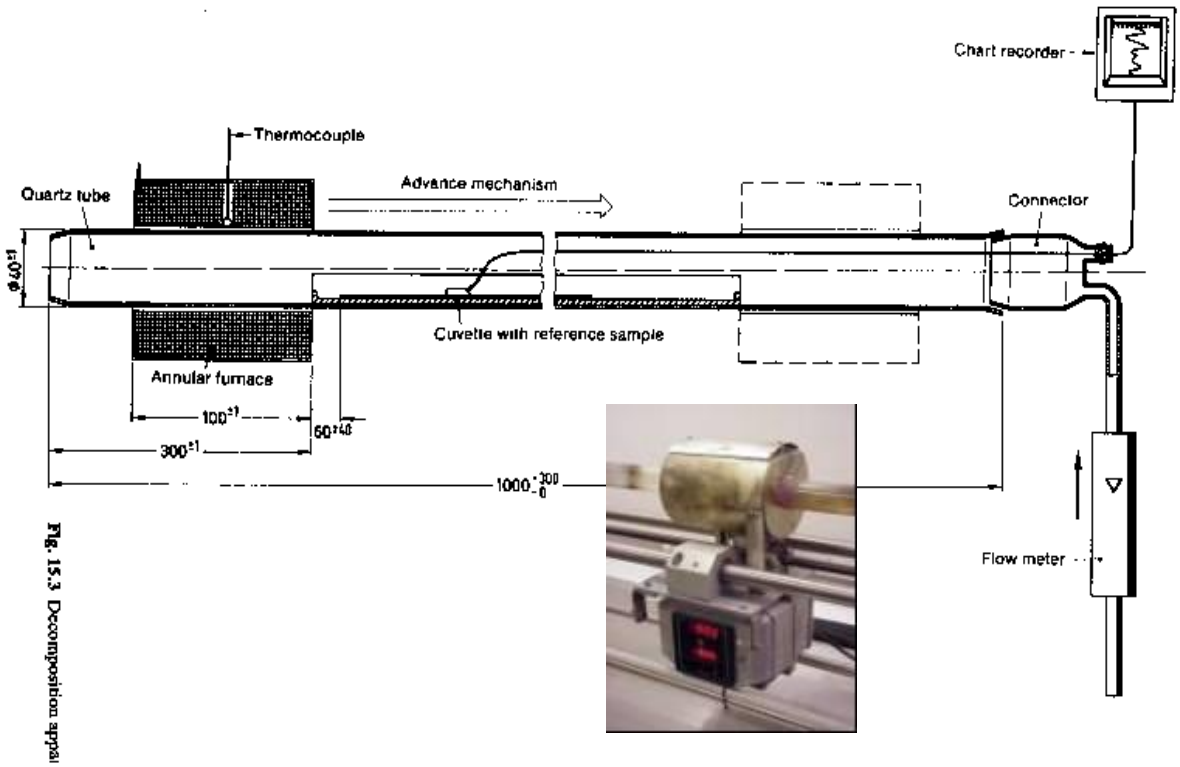


Fig. 15.3 Decomposition appa

5 ENGLAND

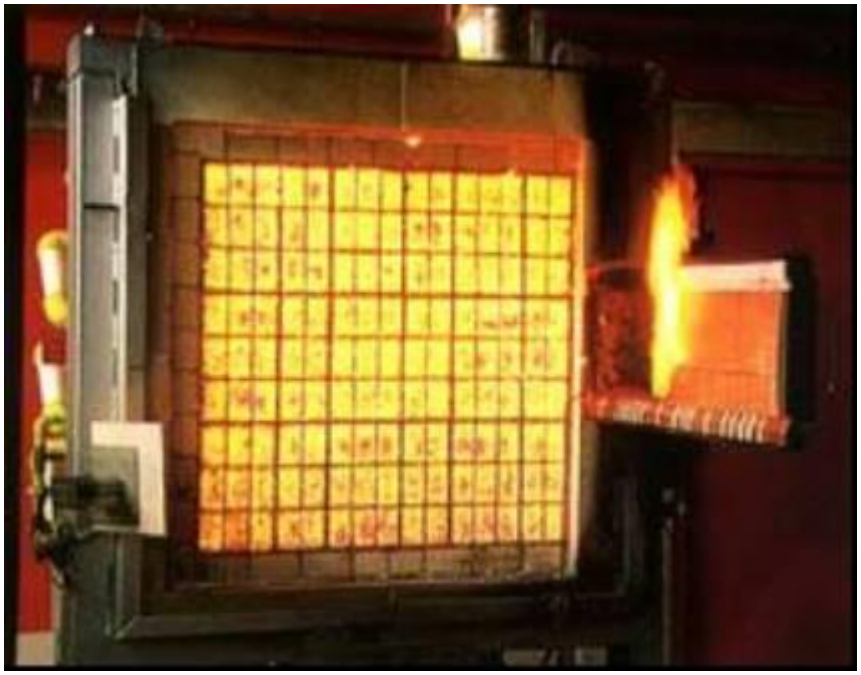
Compliance with the fire behaviour of building materials is related to performance of standard issued by the British Standards Institution tests described in British Standards BS 476: part 3 to 31 [105].

The reaction to fire tests classify the material in 4 categories from class 1 to class 4 connected with the 1.5 min and final flame spread according mainly to the BS 476-7 -surface spread of flame testing method- and to BS 476-6 –fire propagation test- (see table below).

Table 11: BS 476 Fire classification [105]

	BS 476-7	BS 476-6	Component
	Maximum final flame spread	Flame spread index FPI	
Class	Limit mm		
1	165	-	-Rooms -Circulation spaces within dwellings
1	165	FPI<12 I.E. class 0 according to BS 476-6	Other circulation spaces, including the common areas of flats and maisonettes
2	455	-	-
3	710	-	-Small rooms of area not more than 4m^2 in a residential building and 30m ^{2} in a non-residential building.
4	Exceed class 3	-	-

Figure 9: the BS 476-7 surface spread of flame testing method



6 Netherlands

All building products have to comply with the criteria of the Dutch Building Decree.

Table 12: Test methods reaction to fire presentation [2]

Product	Test method	Class
For building products expected flooring	-NEN 6065 "Contribution to fire propagation", resulting in classes 1 (best) to 5. Classification is the result of two tests: -"Flash-over box test" -"Surface spread of flame test" (similar to English BS 476-7)	From 1 to 5
	-NEN 6066 "Smoke production" (ISO dual chamber box), resulting in a smoke density measured in m^{-1}.	-
	-NEN 6064 non-combustibility (similar to ISO 1182)	-
For floorings:	-NEN 1775 "Contribution to fire propagation". Classification in T1 is the result of two tests: -"Flooring radiant panel test" (similar to ISO 9239-1, also used in the Euroclass system) -"Small flame test" (similar to ISO 11925-2, also used in the Euroclass system)	From T1 to T3
	-NEN 6066 "Smoke production" (ISO dual chamber box), resulting in a smoke density measured in m^{-1}.	-

In the Building Decree, basis requirements are given for all building products, with additional requirements near fireplaces and in chimneys, in escape routes and for facades. The smoke requirements are only valid inside buildings (see table below).

Table 13: main building requirement [2]

Example of component	Fire behaviour according to NEN 6065	Fire behaviour according to NEN 1775	Smoke density according to NEN 6066
Area ducts, chimneys	1 Non-flammable	-	-
Main escape ways	1 Non-flammable	-	< 5.4 m^{-1}
Facade up to 2.5 m above ground level for buildings with floors levels above 5m	1 Non-flammable	-	-
Main escape ways	2 Weakly flammable	T1	< 2.2 m^{-1}
Façade	2 Weakly flammable		
Floors	3 Low flammability	T3	< 10 m^{-1}
Floos from main escape routes	-		
All building materials excluding floorings	4 Moderately flammable		< 10 m^{-1}
	5 High flammability		

7 FINLAND

The Nordic countries Denmark, Finland, Iceland, Norway and Sweden cooperate within the framework of the Nordic Council in order to include harmonisation of national law while defining a overall classification of material

Table 14: Nordic council classification [4]

Component	Fire test method	Description	Classification
Material	NT 001	Non-combustibility test	Non-combustible/ combustible
Wall and ceiling lining	NT 003	Fire protection ability of coverings	K0 / K1 / K2
Interior surface finishes	NT 002	Ignitability test	Ιn 1 / Ιn 2 / Ιn 3
Exterior surface finishes	NT 004	Heat release and smoke generation test	Ut 1 / Ut 2
Roofing	NT 006	Roof fire spread	Ta 1 / Ta 2
Floor coverings	NT 007	Flooring fire spread and smoke generation	G / L

The actual classification used for Finland regulations for the fire behaviour of materials/component is described in the standard National Building Code of Finland, Part E1, Fire Safety of Buildings, 1997. 3 fire classes of building are considered (see tables below):

Table 15: building class tests for all materials excepted floorings [2]

Characteristic	Test	Assessment
Non-combustibility	ISO 1182: Fire test for building materials: Reaction to fire, Non-combustibility test	-
Ignitability	SFS 4190:E (NT FIRE 002) Fire tests. Building products: Ignitability ISO 5657 (NT FIRE 033) Fire tests- Reaction to fire. Ignitability of building products.	Class 1:non-igniting surface Class 2: slowly igniting surface Class -: non requirements
Fire spread characteristics	SFS 4192:E (NT FIRE 004) Fire tests. Building products: Heat release and smoke production	Class I: non-fire spreading surface Class II: slowly fire spreading surface Class -: non requirements

Table 16: Fire class and use of the building [2]

Object	Fire class of the building		
	High fire level requirement	**Medium fire level requirement**	**Low fire level requirement**
Dwellings: Walls and ceilings	**2 / -** Slowly igniting surface, No demands for fire spread	**1 / I** Non igniting surface, Non-fire spreading surface	**2 / -** Slowly igniting surface, No demands for fire spread
Accommodation: Walls and ceilings	**2 / -** Slowly igniting surface, No demands for fire spread	**1 / I** Non igniting surface, Non-fire spreading surface	**2 / -** Slowly igniting surface, No demands for fire spread
External surfaces of External wall	**1 / I** Non igniting surface, Non-fire spreading surface	**1 / I** Non igniting surface, Non-fire spreading surface	**2 / -** Slowly igniting surface, No demands for fire spread
Surfaces adjacent to Ventilation gaps	**1 / I** Non igniting surface, Non-fire spreading surface	**1 / I** Non igniting surface, Non-fire spreading surface	**- / -** No requirement

In residential or office buildings of class P1 with not more than 4 storeys, residential or office buildings of class P2 with 3-4 storeys and institutional buildings of class P2, materials of class corresponding to slowly igniting surface, no demands for fire spread may be used for the external surfaces of external walls if:

- ✓ The building is provided with an automatic extinguishing system,
- ✓ The spread of fire along the surface of the external wall and the ventilation gaps has been limited by partitioning elements and
- ✓ The hazard of external ignition has been taken into consideration.

8 Norway

The “reaction to fire” tests classify the material in 4 categories from In 1, In2 to Ut 1, Ut2 (see table below).

Table 17: Norway Fire classification [2]

Fire class	Fire test	Details	Fire contribution
Calorific potential	ISO 1716 Reaction to fire tests for building products.	Determination of the gross calorific value	-
Ignitability of surface material	ISO 5657 (NT Fire 033) Reaction to fire. Ignitability of building products.	Class In 1, Ut 1 or Class In 2, Ut 2	Slowly igniting material Normal igniting material
Fire spreading characteristics of surface materials	NS-INSTA 412 (NT Fire 004) Heat release and smoke generation.	Class In 1, Ut 1 or Class In 2, Ut 2:	Slow heat releasing material Normal heat releasing material
Smoke production of surface materials	NS-INSTA 412 (NT Fire 004) Heat release and smoke generation.	Class In 1 or Class In 2	slow smoke production Normal smoke production
Fire spread of floor coverings	Fire spread and smoke generation.	Class G	-
Smoke production of floor coverings	Fire spread and smoke generation.	Class G	-

9 Sweden

The Sweden regulation is described in the Swedish building code, BBR 94

Table 18: Sweden regulation and test method for medium fire safety requirement building up to two storeys [2]

Component	Test	Requirements
Facades cladding	SP FIRE 105	Requirements according to SP 105 fulfilled
Ceilings	SS 02 48 23 = NT FIRE 004	Class 1 (slight tendency to release heat and generated smoke)
walls within fire cells	SS 02 48 23 = NT FIRE 004	Class 2 (moderate tendency to release heat and generated smoke)
Escape routes	SS 02 48 23 = NT FIRE 004	Class 1 (slight tendency to release heat and generated smoke)

10 Slovakia

Fire regulations in Slovakia are defined by standard STN 730802 (Fire Protection of Buildings - Common Regulations), which is the fundamental standard for fire precautions. The STN 73 823 defines five classes of fire materials from A to C3.

Table 19: Fire classification [2]

Fire class	Test method
Flammability class A-non-flammable B-not easily flammable C1-hard flammable C2-medium flammable C3-easy flammable	STN 730861: Non combustibility test STN 730862: Flammability of building materials
Flame spread Flame spread is the key parameter (mm/min)	STN 730863: Determination of flame propagation along the surface of building materials

11 Japan

A new regulation has been set up and uses European test standards

Table 20: Japan regulation and test method [120]

	Fire performance		
Test method	**Non-combustible materials**	**Quasi-noncombustible materials**	**Fire retardant materials**
Cone calorimeter test ISO 6550-1 @ 50 KW/m^2	$q_{tot} \leq 8$ MJ/m^2 and $q''_{max} \leq 200$KW/m^2 during 20 min	$q_{tot} \leq 8$MJ/m^2 and $q''_{max} \leq 200$KW/m^2 during 10 min	$q_{tot} \leq 8$MJ/m^2 and $q''_{max} \leq 200$KW/m^2 during 5 min
In addition to the numerical criteria, the specimen shall not develop cracking enabling fire penetration.			
	OR		
Non-combustibility test ISO 1182	$\Delta T_{furnace} \leq 20$ K [1)] and $\Delta m \leq 30\%$	-	-
Model box test ISO CD17431	-	$Q_{tot} \leq 50$ MJ and $Q_{max} \leq 140$ KW During 10 min	$Q_{tot} \leq 40$ MJ and $Q_{max} \leq 140$ KW During 5 min
The non-combustibility test and the model box test are alternatives for the cone calorimeter test.			
	AND		
Gaz Toxicity test on 8 mices	Movable time > 6.8 min	Movable time > 6.8 min	Movable time > 6.8 min

q_{tot} : total heat evolved
q''_{max} : maximum value rate of heat release

Q_{tot}: total heat evolved
Q_{max}: maximum value rate of heat release

1) Defined as the difference between the maximum temperature during 20 min and the final temperature in the end of the test.

Figure 10: cone calorimeter overview

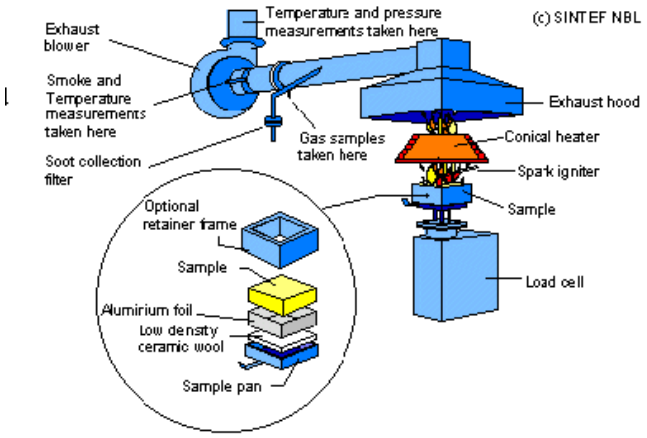
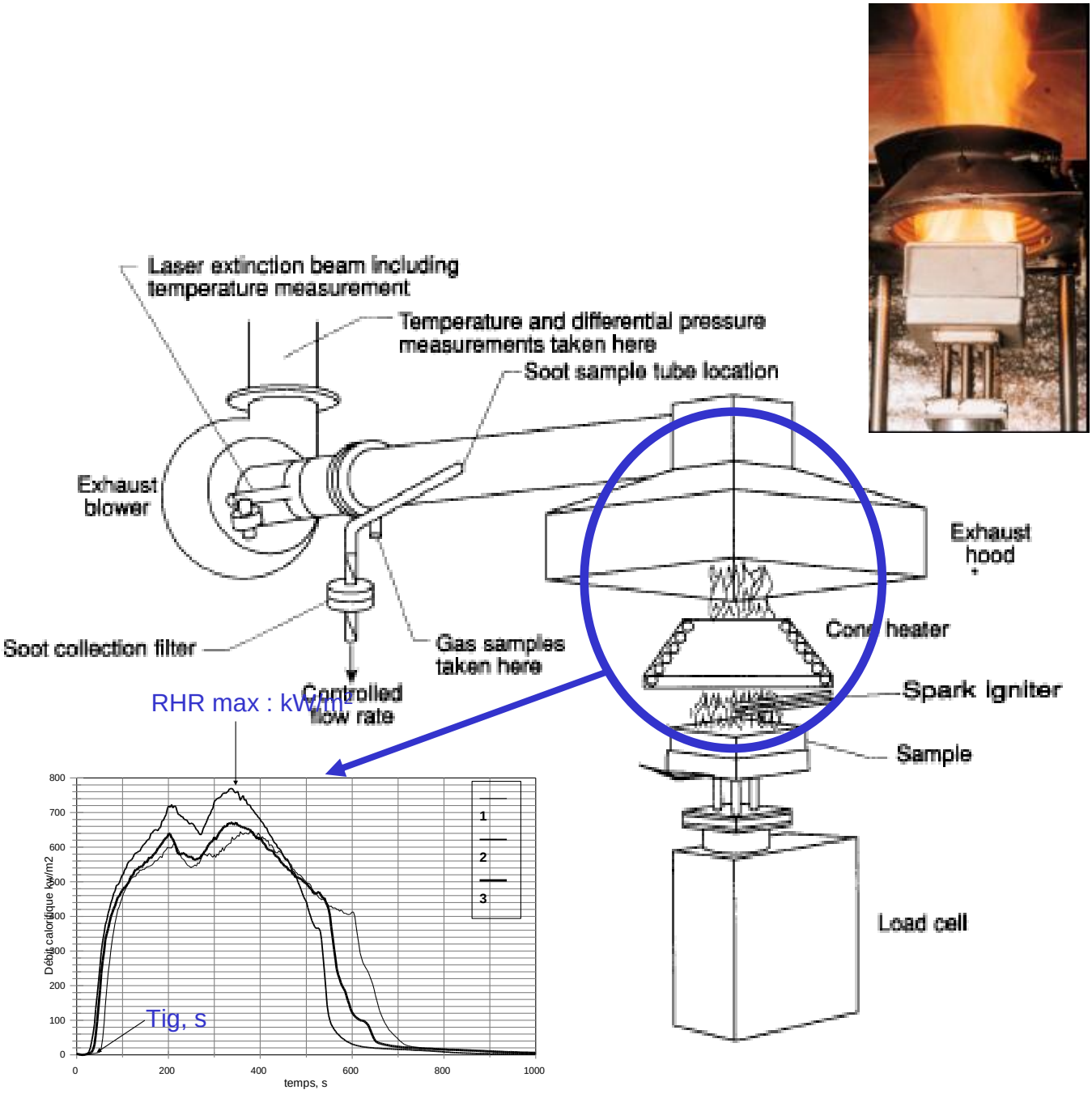


Figure 11: The ISO 5660 cone calorimeter test method [16][18][35]



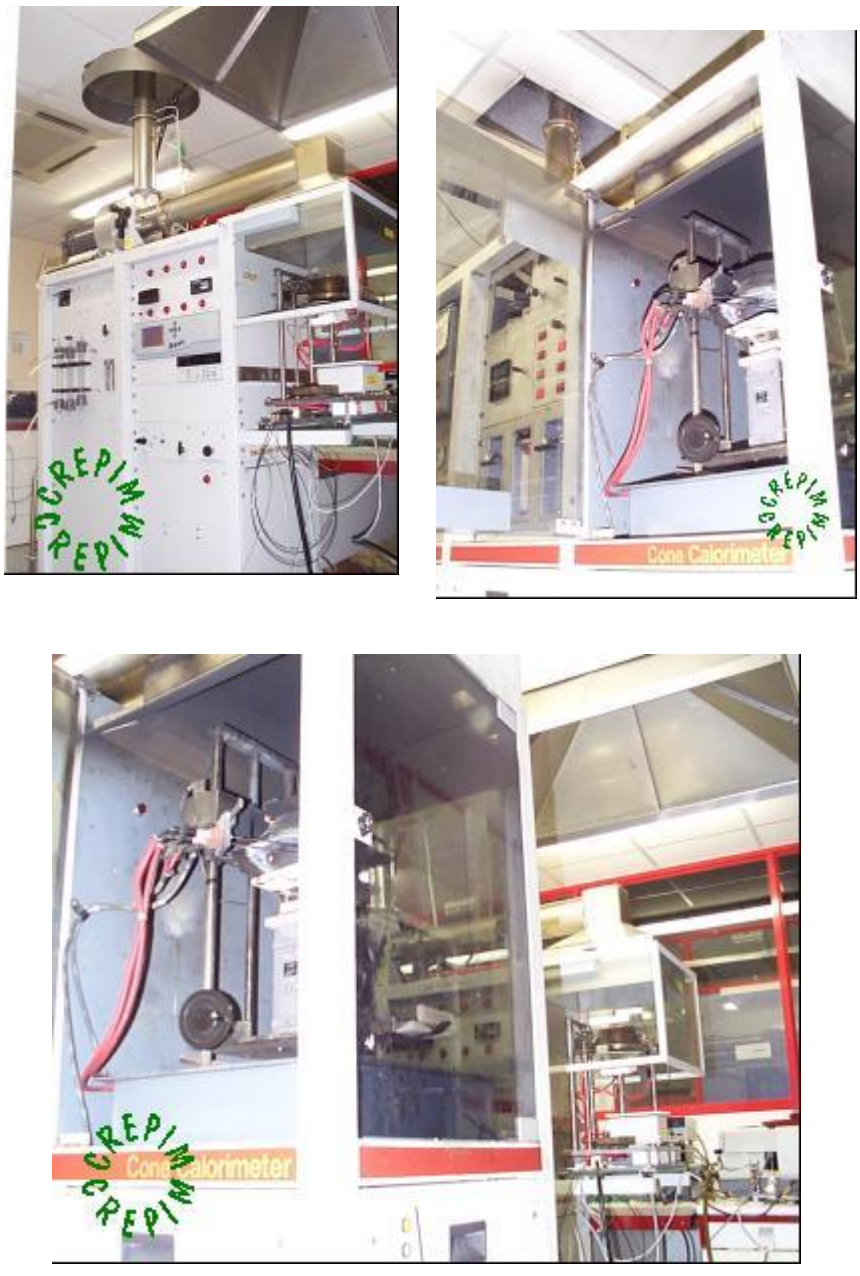
The principle of the cone calorimeter is based on the relation between the oxygen consumption and the heat release during the combustion. The ratio between the heat release and the weight of oxygen consumed is a constant (Huggett constant) equal to 13100kJ/kg.

On this relation, Babraukas [4] have conceived and build the first prototype of the cone calorimeter at the laboratory of NIST in the 80's. A heat flux is applied on a sample that is placed on a load cell. Gases and smokes are collected in an exhaust pipe where the measures of oxygen consumption, of temperature, of opacity of smoke take place.
Samples (100 x 100 mm) are exposed under a heat flux of corresponding to the fire conditions simulated. An electrical spark igniter ignited volatile gases from the heated specimen. The test gives the opportunity to evaluate:

- ✓ RHR: Rate of Heat Release,
- ✓ Weight loss,
- ✓ Emission of CO and CO_2,
- ✓ VSP: Volume of Smoke Production,
- ✓ Soot mass.

The cone calorimeter test is, for the moment, the most advanced method for assessing materials reaction to fire.

Figure 12: The ISO 5660 cone calorimeter test method



12 Italy

The Italian regulation is based mainly on four testing methods:

Table 21: brief overview of the Italian testing method

Test method	Description	Assessement
ISO 1182	Non combustibility furnace	Increase of temperature
CSE RF 1/75/A	Small burner test	After flame time Afterglow time Extent of damage Time for drippings to extinguish
CSE RF 2/75/A	Vertical small burner test	After flame time Afterglow time Extent of damage Time for drippings to extinguish
CSE RF 3/77	Spread of flame test	Rate of flame spread Extent of damage Afterglow time Time for drippings to extinguish

These tests are used in combination to measure the contribution to fire of material from class 0 (Non combustible material) to class 5 (high fire contribution material).

13 USA

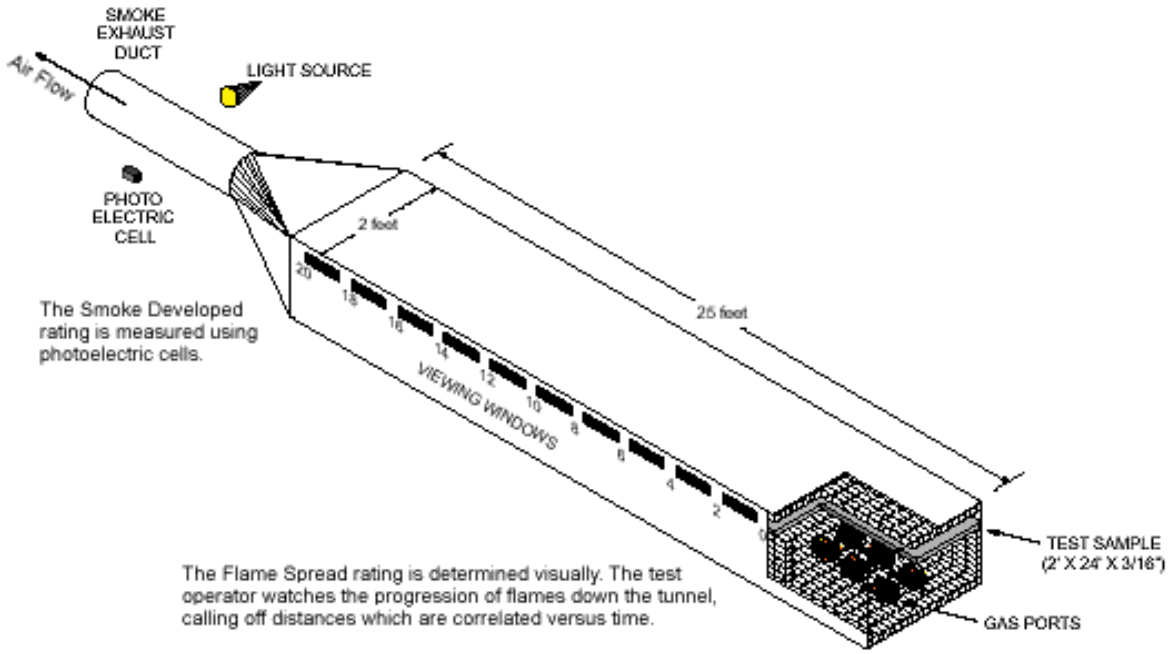
To appreciate the status of performance fire codes in the USA, one needs to understand a little about the fire and safety regulatory- system. The USA is a union of 50 sovereign states and responsibility for fire state rests at the local level. However, 2 main test assessing the spread of flame can be easily identify:

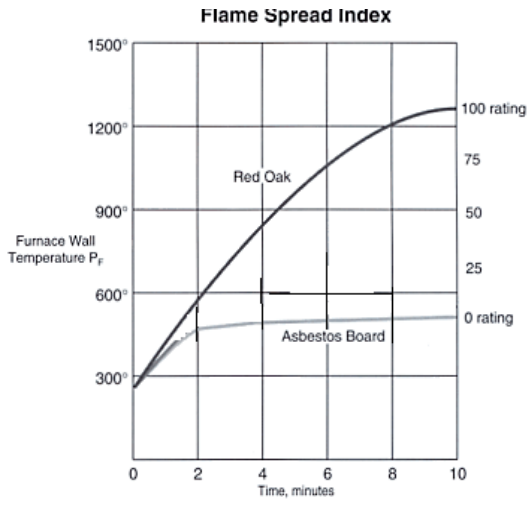
- Steiner tunnel test according to the ASTM E 84 [37]

The tunnel test compares surface burning characteristics of tested materials to those of asbestos cement board and untreated red oak lumber. A rating of 0 is assigned to asbestos cement board and a rating of 100 is assigned to untreated red oak flooring. Flame spread ratings of various species of untreated lumber range from 60 to 230. During this test, smoke emissions are also measured and ratings are assigned on the same scale. These ratings are established during the first 10 minutes. However, unlike for fire retardant coatings, building codes require that the test be extended from 10 minutes to 30 minutes and the flame spread not progress more than 10.5 feet beyond the burners and show no evidence of progressive combustion.

The test is achieving on a 7.6 m x 0.51 m specimen mounted in the ceiling position.

Figure 13: the tunnel test method





The determination of spread of flame forms the basis of classifying interiors finishes contained in all the building codes. It differs from code to code but now largely agree (see table below).

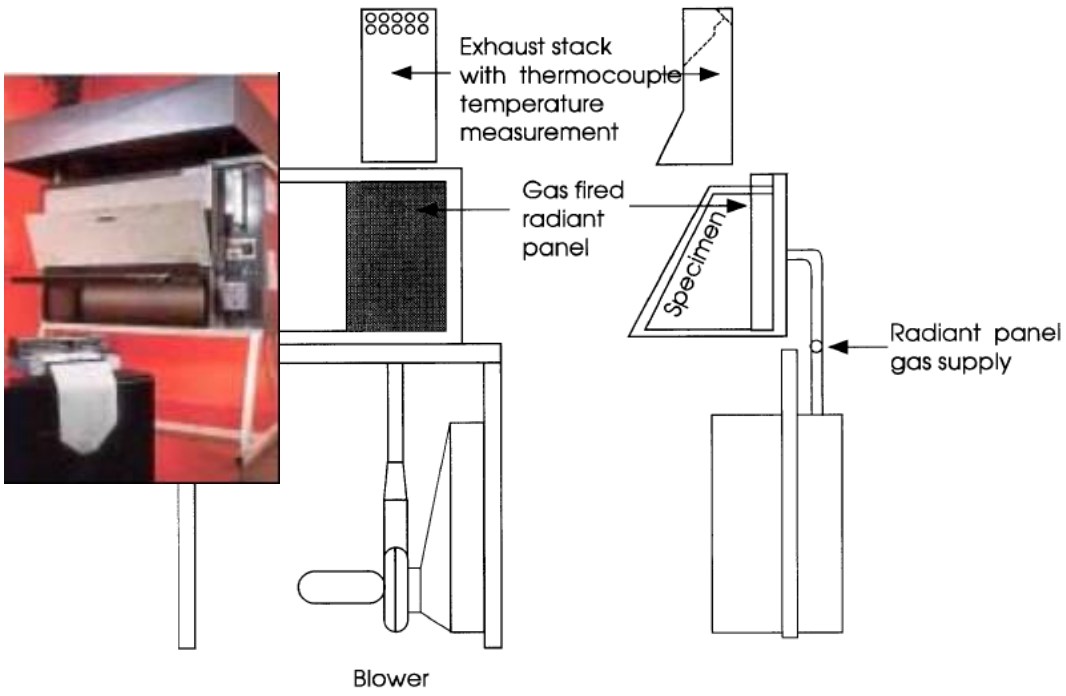
Table 22: Flame-spread classification

Class according to Uniform Building Code, section 204	Class according to Life Safety Code, NFPA 101	Flame Spread
I	A	0-25
II	B	26-75
III	C	76-200

-Radiant panel test according to ASTM E 162

This test method is measuring surface flammability of materials employing a radiant heat source and an inclined specimen disposed such that ignition is forced near the upper edge. The flame front progresses downward.

Figure 14: the ASTM E 162 radiant panel test method [32]



The ASTM E 162 illustrated in Figure 14, was developed by the National Bureau of Standards in 1955. An al-most identical method, ASTM D-3675 [33], is used for cellular materials such as seat cushioning. This method measures flame spread and rate of energy release under a varying radiant flux from about 40 to 3 kW/m^2.

The key measurement is a flame spread index I_s which is the product of the flame factor F_s and the heat Evolution factor Q:

$$I_s = F_s \times Q \qquad (2)$$

The higher the index, the greater the flammability.

REFERENCES

[1] Richard D. Peacock, Paul .A. Reneke, Walter W. Jones, Richard W. Bukowski, Building and Fire Research Laboratory, NIST. Gaithersburg MD 20899, USA, Vytenis Babrauskas, Fire Science and Technology, Inc USA, Concepts for Fire Protection of Passenger Rail, Transportation Vehicles Past, Present, and Future, Fire and materials, VOL 19,71-87 (1995)

[2] **HIFI, High Fire Performance Wood Products,** http://www.fireretard.com/

[3] CREPIM, Parc de La Porte Nord, Rue Christophe Colomb, 62700, Bruay La Buissière, France, Tel : 00 33 3 21 61 64 00, Fax: 00 33 3 21 61 64 01, crepim@wanadoo.fr

[4] Babrauskas, V. & Grayson, S.J. 1992. Heat release in fires. Elsevier science publishers Ltd. 644 p.

[5] Troitzsch, J.1990. International plastics flammability handbook. Principles –regulations - testing and approval. 2nd ed., Carl Hanser Verlag, Kolbergerstr. 22, D-8000 München 80, 517 p.

[6] Richard D. Peacock, Richard W. Bukowski, Walter W. Jones, Paul .A. Reneke, , James E. Brown, Building and Fire Research Laboratory, NIST. Gaithersburg MD 20899, USA, Vytenis Babrauskas, Fire Science and Technology, Inc USA, Fire Safety of Passengers Trains: a Review of current approaches and New Concepts, NISY technical Note 1406, January 1994.

[7] Fire Testing Technology, P.O. Box 116, Eadt Grinstead, West Sussex, RH19 4FP,UK

[8] ISO/CD 11925-2. 1994. Fire tests - Reaction to fire - Ignitability of building products under direct flame impingement - Part 2: Single flame source test. International Organization for Standardization. 36 p.

[9] ISO/CD 11925-3. 1994. Fire tests - Reaction to fire - Ignitability of building products under direct flame impingement - Part 3: Multisource test. International Organization for Standardization. 21 p.

[10] ISO/TC92/SC1/WG2 N268. August 1996. Guidance document on ignitability. 35 p.

[11] ISO/DIS 5657. 1996. Reaction to fire tests - Ignitability of building products using a radiant heat source. International Organization for Standardization. 42 p.

[12] ISO/DIS 5658-2. 1993. Fire tests - Reaction to fire - Lateral surface spread of flame on building products with specimen in vertical configuration. International Organization for Standardization. 34 p.

[13] ISO/DIS 9239-2. 1995. Fire tests - Reaction to fire - Horizontal surface spread of flame on floor coverings using a radiant heat ignition. International Organization for Standardization. 27 p.

[14] ISO CD 13785. Fire tests - Reaction to fire - Part 1- Intermediate-scale test for facades. 8 p.

[15] ISO WD 13785. Fire tests - Reaction to fire - Full-scale tests for facades. (Canada-Germany Joint Submission).11 p.

[16] ISO 5660. 1993. Fire tests - Reaction to fire - Part 1: Rate of heat release from building products (Cone calorimeter method). International Organization for Standardization. 31 p.

[17] ISO 9705. 1993. Fire tests - Full-scale room test for surface products. International Organization for Standardization. 31 p.

[18] ISO/CD 5660. 1996. Fire tests - Reaction to fire - Part 2: Smoke release rate from building products (dynamic measurement). International Organization for Standardization. 15 p.

[19] ISO/DIS 5659-2. 1993. Plastics - Smoke generation - Part 2: Determination of specific optical density by a single-chamber test. International Organization for Standardization. 46 p.

[20] prEN ISO 1716-Part 2. Fire test for building materials: Reaction to fire.Determination of gross calorific value.

[21] COMMISSION DECISION (2000/147/EC) of 8 February 2000 implementing Council Directive 89/106/EEC as regards the classification of the reaction to fire performance of construction products, Ref. OJ L 50, 23.2.2000, p.14)

[22] prEN ISO 11925-2. Reaction to fire tests - Ignitability of building products subjected to direct impingement of flame.

[23] prEN ISO.9239-1 Floor coverings - Determination of the burning behaviour using a radiant heat source.European Committee for Standardization. 19 p.

[24] IMO Resolution A.653(16) adopted on 19 October 1989. Recommendation on improved fire test procedures for surface flammability of bulkhead, ceiling and deck

[25] finish materials. International Maritime Organization. 42 p.

[26] IMO Resolution A.687(17) adopted on 6 November 1991. Fire test procedures for ignitability of primary deck coverings. International Maritime Organization. 2 p.

[27] IMO Resolution MSC.41(64) adopted on 5 December 1994. Interim standard for measuring smoke and toxic products of combustion. International Maritime Organization. 4 p.

[28] IMO Resolution MSC.61(67) Adoption of the International Code for Application of Fire Test Procedures. December 1996.

[29] Fire and Flammability Bulletin. April 1995. IMO to allow more polymers to be used in high speed craft. p. 2-3.

[30] ISO/TC93/SC3/WG1/N509. 1996. Assessment of fire smoke toxicity tests. 21 p.

[31] Eurocode ENV 1995-1-2:1994.

[32] ASTM E-162, Standard Teat Method for Surface Flammability of Materials Using a Radiant Heat Energy Source, Annual Book of ASTM Standards, Volume 04.07. American Society for Testing and Materiais (1 988).

[33] ASTM D 3675, Standard Test Method for Surface Flammability of Cellular Materials Using a Radiant Heat Energy Source, Annual Book of ASTM Standards, Volume 09.02, American Society for Testing and Materials (1990).

[34] ASTM E-662, Standard Teat Method for Specific Opticai Density of Smoke Generated by Soiid Materials,. Annual 8ook of ASTM Standards, Volume 04.07, American Society for Testing and Materials (1983).

[35] ASTM E-1354, Standard Test Method for Heat and Visible Smoke Release Rate for Materials and Products Using an Oxygen Consumption Calorimeter, Annual Hook of ASTM Standards, Volume 04.07, American Society for Testing and Materials, (1 990).

[36] ASTM E-648, Standard Teat Method for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source, Annual Book of ASTM Standards, Volume 04.07, American Society for Testing and Materials (1988).

[37] ASTM E-84, Standard Teat Method for surface burning characteristics of building material, Annual Book of ASTM Standards, Volume 04.07, American Society for Testing and Materials (1999).

[38] UL Standard for Safety for Test for Flammability of Plastic Materials for Parts in Devices and Appliances, Underwriters Laboratories Inc. (UL), 333 Pfingsten Road, Northbrook, IL 60062-2096, Fifth Edition, Dated October 29, 1996, revisions through and including May 22, 2001.

[39] Federal Motor Vehicle Standard safety, 49 CFR Ch. V (10–1–99 Edition), § 571.302 Standard No. 302; Flammability of interior materials.

[40] ISO 3795: road vehicles, and tractors and machinery for agriculture and forestry – Determination of the burning behaviour of material.

[41] Department of transportation Federal Aviation Administration 14 CFR Parts 25, 91, 121, 125, and 135 [Docket No. FAA–2000–7909; Notice No. 00–09], RIN 2120–AG91, Improved Flammability Standards for Thermal/Acoustic Insulation Materials Used in Transport Category Airplanes, Federal Register / Vol. 65, No. 183 / Wednesday, September 20, 2000.

[42] JAR Part 25, Appendix F, Part l, para. (a) (1) (i), Change 14

[43] FAR Part 25, Appendix F, Part l, para. (a) (1) (i), Amdt. 25-83

[44] Airbus Directives (ABD) and Procedures, Fireworthiness Requirements, ABD 0031, Pressurized Section of Fuselage, Airbus Industrie 1997, Airbus Industrie, Programmes and Processes Directorate, 31707 Blagnac CEDEX, France

[45] American Society for Testing and Materials (ASTM). Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products. ASTM E 906. Annual Book of ASTM Standards, Volume 04.07, 1997.

[46] Babrauskas, V. “Comparative Rates of Heat Release from Five Different Types of Test Apparatuses.” Journal of Fire Sciences 4 (1986

[47] Babrauskas, V. “Development of the Cone Calorimeter, A Bench-scale Heat Release Rate Apparatus Based on Oxygen Consumption.” Fire and Materials 8 (1984).

[48] Babrauskas, V., and W.J. Parker. “Ignitability Measurements with the Cone Calorimeter.” Fire and Materials 11 (1987).

[49] Babrauskas, V., and G. Mulholland. “Smoke and Soot Data Determinations in the Cone Calorimeter,” in Mathematical Modeling of Fires, 83-104, (ASTM STP 983). ASTM, 1987.

[50] Babrauskas, V. “The Cone Calorimeter , Fire Properties,” in New Technology to Reduce Fire Losses & Costs, 78-87, S.J. Grayson and D.A. Smith, eds. London: Elsevier Applied Science Publishers, 1986.

[51] Messerschmidt B. (Danish Institute of Fire Technology), Wickström U., Van Hees P. (SP Swedish National Testing and Research Institute), Prediction of SBI test results by means of cone calorimeter test results; Interflam’ 99, conference Proceedings volume 1, pp 11-22

[52] Wickstrom U., Goransson U., Fire and Materials, Vol 1, 15-22 (1992), Full-scale/bench-scale correlations of wall and ceiling lining.

[53] Wickstrom U., Goransson U., Journal of Testing evaluation, Vol. 15, N°6, (Nov) 1987, 364-370, Prediction of heat release rates of surface material in large-scale fire tests based on cone calorimeter results.

[54] S.J. Grayson, A.M. Green and S. Gregory, Fire Testing Technology Limited UK, Predicting the fire performance of products from bench scale fire tests; Flame Retardants’ 2000, Conference Proceedings, pp 15-26

[55] Alain Sainrat, Chritian Moulinier, Laboratoire National d’Essai, France, A new small scale test apparatus for the control and the development of products in relation with the Euroclasses; Flame Retardants’ 2000, Conference Proceedings, pp 27-40

[56] prEN 45-545 : Railway applications - Fire safety on railway vehicles.

[57] ISO TR 9122-4 : Toxicity testing of Fire effluents – part 4 – The Fire model (furnace and combustion apparatus used in small-scale testing).

[58] ISO TR 13344 : Determination of the lethal toxic potency of fire effluents.

[59] Federal Railways Administration 2000 requirements, 49 CFR, Transportation, Subtitle B, Other Regulations Relating To Transportation CHAPTER II , FEDERAL RAILROAD ADMINISTRATION, DEPARTMENT OF TRANSPORTATION, PART 238, PASSENGER EQUIPMENT SAFETY STANDARDS, October 1, 2000.

[60] pr EN ISO 11925-2 : Reaction to fire tests for building products – part 2 : Ignitability when subjected to direct impingement of flame.

[61] UIC 546-2 Appendix 11 : Regulations relating to fire protection and fire-fighting measures in passenger-carrying railway vehicles or assimilated vehicles used on international services. Appendix 11. Test method for determining the fire-resistance of rigid thermoplastic materials.

[62] ISO 5660-1 : Fire tests – Reaction to fire. Part 1: Heat release (cone calorimeter method).

[63] IEC 60695-2-2 : Fire hazard testing for electro technical products. Part 2 : Test methods. section 2.2 : Needle-flame test.

[64] ISO 5658-2 : Reaction to fire tests – Spread of flame – Part 2 : Lateral spread on building products in vertical configuration.

[65] pr EN ISO 9239-1 : Reaction to fire tests for floorings – Part 1 : Determination of the burning behaviour using a radiant heat source.

[66] ISO DIS 5660-2 : Fire tests – Reaction to fire. Part 2 : Smoke production rate (dynamic measurement).

[67] ISO 5659–2 : Plastics – Smoke generation – Determination of optical density by a single chamber test.

[68] NF X 70-100 : Fire tests – Analysis of pyrolysis and combustion gases – Tube furnace method.

[69] DIN 53436 : Producing thermal decomposition products from materials in an air stream and their toxicological testing.

[70] ISO 9705 : Fire tests – Full scale room test for surface products.

[71] pr EN 13823 : Reaction to fire tests for building products – Building products excluding floorings exposed to the thermal attack by a single burning item (SBI test).

[72] EN 597-1 : Furniture – Assessment of the ignitability of mattresses and upholstered bed bases – Part 1 : Ignition source – Smouldering cigarette

[73] EN 597-2 : Furniture – Assessment of the ignitability of mattresses and upholstered bed bases – Part 2 : Ignition source – Match flame equivalent.

[74] pr EN 32952 - Parts 1 and 2 : Textiles – Burning behaviour of bedding items – Parts 1 and 2 – Ignitability by smouldering cigarette.

[75] pr EN 32952 – Parts 3 and 4 : Textiles – Burning behaviour of bedding items. Parts 3 and 4 – Ignitability by a small open flame.

[76] UIC 564-2 Annex 5 : Regulations relating to fire protection and fire-fighting measures in passenger-carrying railway vehicles or assimilated vehicles used on international services. Appendix 5 : Test method to measure the reaction to fire of covered textiles.

[77] UIC 564-2 Annex 13 : Regulations relating to fire protection and fire-fighting measures in passenger-carrying railway vehicles or assimilated vehicles used on international services. Appendix 13 : Test method to measure the ignitability of seats.

[78] pr EN 1021 Part 3: Furniture – Assessment of the ignitability of upholstered furniture – Part 3 : Ignition source : Flame equivalent to the flame from 20 g of newspaper.

[79] pr EN 1021 Part 4 : : Furniture – Assessment of the ignitability of upholstered furniture – Part 3 : Ignition source : Flame equivalent to the flame from 100 g of newspaper.

[80] NT FIRE 032 – Furniture calorimeter tests : Upholstered furniture : burning behaviour – Full scale.

[81] IEC 60695-2-10 : Fire hazard testing – Glow-wire flammability test method for materials.

[82] IEC 60695-2-4/2 : Fire hazard testing – Part 2 Test Methods – Section 4 sheet 2 : 500 W nominal pre-mixed test flame and guidance.

[83] IEC 60695-2-4/1 : Fire hazard testing – Part 2 Test Methods – Section 4 sheet 1 : 1 kW nominal pre-mixed test flame and guidance.

[84] pr EN 50264 : Railway applications – Railway rolling stock cables having special fire performance – Standard wall.

[85] pr EN 50266-2-4 : Cable calorimeter tests.

[86] FIPEC book : Fire Performance of Electric Cables – new test methods and measurement techniques – Final Report.

[87] NF F 16-101 : Rolling stock – Fire behaviour – Materials selection.

[88] NF F 16-102 : Rolling stock – Fire behaviour – Materials selection – Application for electrical equipment.

[89] NF 16-201 : Railxay Rolling stock – Fire resistance test for seats

[90] NF P 92-501 : Safety against fire – Building materials – Reaction to fire tests – Radiation test used for rigid materials, or for materials on rigid substrates (flooring and finishes) of all thicknesses, and for flexible materials thicker that 5 mm.

[91] NF P 92-503 : Safety against fire – Building materials – Reaction to fire tests – Electrical burner test used for flexible materials.

[92] NF P 92-504 : Safety against fire – Building materials – Reaction to fire tests – Flame persistence test and speed of flame spread.

[93] NF P 92-505 : Safety against fire – Building materials – Reaction to fire tests – Test used for thermoplastic materials – Dripping test.

[94] NF P 92-506 : Safety against fire – Building materials – Reaction to fire tests – Radiant panel test for flooring.

[95] NF P 92-510 : Safety against fire – Building materials – Reaction to fire tests – Determination of upper calorific value.

[96] NF EN ISO 4589-2 : Plastics – Determination of burning behaviour by oxygen index – Part 2 : Ambient-temperature test.

[97] NF X 10-702 : Fire test methods – Determination of the opacity of the fumes in an atmosphere without air renewal.

[98] DIN 5510 : Preventive Fire Protection in railway vehicles. Part 1: Levels of protection, fire preventive measures and certification, Part 2: Fire behaviour and fire side effects of materials and parts; Classifications, Demands and test methods, Part 4: Vehicle design;

Safety requirements, Part 5: Electrical equipment; Safety requirements, Part 6: Auxiliary measures, emergency brake operation function; Information systems, fire alarms, fire fighting equipment; Safety requirements

[99] DIN 53438 : Testing of combustible materials; reaction against a flame of burner, Part 1: General remarks, Part 2: Edgeing flame action, Part 3:Surface flame action.

[100] DIN 54837 : Testing of materials, small components and component sections for rail vehicles; Determination of burning behaviour using a gas burner.

[101] DIN 4102 : Behaviour of building materials and components in fire – Part 1: Building materials, terminology, requirements and tests - Part 14: Floor coverings and floor coatings; determination of rate of flame spread using a radiant heat source.

[102] DIN 54431 : Testing of seats in railways for public traffic; determination of burning behaviour with a paper pillow ignition source.

[103] TL 918433 : Technical specifications for delivery; material combinations, passenger seats; particular demands against burning behaviour.

[104] BS 6853 : Code of practice for fire precautions in the design and construction of passenger carrying trains.

[105] BS 476-7 : Fire tests on building materials and structures – Part 7 : Method of test to determine the classification of the surface spread of flame of products.

[106] pr EN 2825 : Aerospace series – Burning behaviour, determination of smoke density and gas components in the smoke of materials under the influence of radiating heat and flames – Determination of smoke density.

[107] pr EN 2826 : Aerospace series – Burning behaviour, determination of smoke density and gas components in the smoke of materials under the influence of radiating heat and flames – Determination of gas components in the smoke.

[108] UNI 8456 : Combustible materials which can be hit by flame on both surfaces. Reaction to fire by applying a small flame.

[109] UNI 9174 : Reaction to fire of material which can be hit by flame with radiant heating.

[110] UNI 8457 : Combustible materials which can be hit by flame on one surface. Reaction to fire by applying a small flame.

[111] UNI 9175 : Reaction to fire of upholstered furnitures by applying a small flame.

[112] IEC EN 50267 : Common test methods for cables under fire conditions – Test on gases evolved during combustion of materials from cables

[113] IEC EN 50267 : Common test methods for cables under fire conditions – Test on gases evolved during combustion of materials from cables

[114] British Standard 5852, part 2, Fire tests for furniture, Methods of test for the ignitability of upholstered composites for seating by flaming sources, British standard institution, Maylands Avenue, Hemel Hempstead, Herts HP24SQ, UK, 1982.

[115] Furniture and Furnishings Fire Safety Regulations 1988, Statutory Instrument 1988 No. 1324, PART I: Ignitability test for polyurethane foam in slab or cushion form.

[116] TECHNICAL BULLETIN 117, Requirements, Test Procedure and Apparatus for Testing the Flame Retardance of Resilient Filling Materials Used in Upholstered Furniture, STATE OF CALIFORNIA, DEPARTMENT OF CONSUMER AFFAIRS, BUREAU OF HOME FURNISHINGS AND THERMAL INSULATION, 3485 ORANGE GROVE AVENUE, NORTH HIGHLANDS, CA 95660-5595, MARCH 2000.

[117] TECHNICAL BULLETIN 133, Flammability Test Procedure for Seating Furniture for Use in Public Occupancies, STATE OF CALIFORNIA, DEPARTMENT OF CONSUMER AFFAIRS, BUREAU OF HOME FURNISHINGS AND THERMAL INSULATION, 3485 ORANGE GROVE AVENUE, NORTH HIGHLANDS, CA 95660-5595, JANUARY 1991.

[118] European Directive 95/28/CE from European Parliament and Council from the 24 october th of 1995, OJ of EC, N) L 281, 23/11/95.

[119] NF C 32-070, Insulated cables and flexible cords for installations- Classification tests on cables and cords with respect to their behaviour to fire.

[120] Shinichi Sugahara, Department of Architecture, Graduate School of Engineering, University of Tokyo; Masashi Yoshida, Building Department, National Institute for Land and Infrastructure; Kazuo Ueda, Toyo Seiki Seisaku-Sho Ltd; A study on the structure of cone calorimeter as the authorized apparatus, Interflam'2001, Conference Proceedings Volume 1, pp 543-554

[121] Tuula Hakkarainen, VTT Buiding and Transport, Espoo, Finland, Correlation studies of SBI and cone calorimeter test results; Interflam'2001, Conference Proceedings Volume 1, pp 519-530

[122] Peter Briggs, Warrington Fire Research Centre, UK; Yannick Le Tallec & Alain Sainrat, Laboratoire National d'Essais, France; Serge Metral, SNCF, France; Silvio Messa, LSF, Italy; Hervé Breulet, ISSEP, Belgium; The Firestarr Research project on the reaction-to-fire performance of products in European trains, Interflam'2001, Conference Proceedings Volume 2, pp 519-530

[123] British Standard 6807, Methods of test for Ignitability of mattresses with primary and secondary sources of ignition, British standard institution, Maylands Avenue, Hemel Hempstead, Herts HP24SQ, UK, 1982.

[124] http://www.gtfi.org/

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