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Work package 4.2 :

Small-scale tests on furniture products

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Abstract

The aim of the FIRESTARR project is to support CEN TC 256 WG1 and CENELEC TC9X WG3 in the drafting of part 2 (requirements for the fire behaviour of materials and components) of a seven part European standard pr EN 45545.

The first objective of this research is the selection of criteria for the fire behaviour performance levels of the materials used in this field of application, based on their reaction to fire measurements and related to the identified risks (existence of a fire hazard).
Moreover, once the choice of relevant test methods to measure them is taken, the obtained results from testing on representative railway materials will be compared with known national values and the proposals of classification criteria will be validated by real scale tests using parts of vehicles.
A specific fire risk assessment of railway vehicles has been elaborated taking into account the different designs existing in reality and the ways where they usually are operating.
It requires the adoption of tests and calculation methods which are able to connect the fire safety objectives with specific design and fire scenario.
The fire reaction parameters considered are measured by fire tests on representative railway materials, composites and parts of them under conditions simulating the risks and as similar as possible to those found in end-use.
Three main composites and components are considered: structural, furniture and electrotechnical.

The critical part of the vehicle to simulate, the conditions to reproduce and the definition of most relevant scenario to consider are defined by WP1 of this research (ref. 1).

The selection of representative railways materials or products from all countries having different levels of performance and the collection of their national results in terms of fire behaviour for all three “families” of considered materials (structural, furniture and electrotechnical) is given by the WP2 study (ref. 2).

The choice of methods for small and large scale tests representing the scenario defined by WP1 which are able to measure the reaction to fire parameters for each type of material in end-use conditions has been made taking into account the other European research programmes about the reaction to fire in other fields (building, upholstered furniture, cables, etc.).
The selected methods are chosen in consideration of their already validated acceptable levels of repeatability and reproducibility with particular attention to economic aspects.
Four specific WP3s were created for this objective: WP3.1 (Choice of small and large scale test methods for structural products), WP3.2 (Choice of small and large scale test methods for furniture products), WP3.3 (Choice of small and large scale test methods for electrotechnical products), WP3.4 (Choice of small and large scale test methods for toxicity evaluation).

The work done in WP3 for different type of products has defined the basis for the work of WP4 (Small scale tests), WP7 (Large scale tests) and WP8 (Real scale tests).

The present WP 4.2 report describes the data obtained by small scale tests carried out on materials, composites and components of Furniture products.

I Objectives of WP 4.2

The objective of this work package is to obtain data on the following reaction to fire parameters for furniture products or materials tested:

- ignitability
- spread of flame
- heat release
- smoke opacity
- toxic gases species generation

They can be collected into the following 4 different “families” of results :

- Ease of ignition (Ignitability)
- Fire growth (spread of flame and heat release)
- Loss of visibility (smoke opacity)
- Toxicity of smoke (toxic gas species generation)

All of these types of results can give determinant information to define and to cause the following Fire Critical Effects (FCE) which give human death:

- Irritation and narcosis (toxic gases)
- Loss of visibility to find the way-out (smoke opacity)
- Hyperthermia, burned skin, damage to respiratory tract (Heat)

The task of this specific sub-package is to carry out small scale tests on a representative series of Furniture materials and products or assemblies which include foams and fabrics used as components of seats and mattresses, pillow and curtains.
The data related to the first four reaction to fire parameters listed above are described and shown in this report. A different and separate part of the project was specifically dedicated to toxicity testing (WP4.4 - Toxicity evaluation of small scale test).
The main reasons for selection of these products and the complete list of them were explained in WP2 report.
The selection of test methods adopted was well described and defined by the work of WP3.2 with special attention on the accuracy of their measurements and the correlation level between laboratory test results and real scale test results. They were chosen from standardised and international methods.
Each one, with some additional changes in test conditions, was used to simulate the Fire scenario proposed by WP1 including all stages and sub-stages present in developing fire (primary and secondary ignition sources) (see figure 1).

All data obtained will be used to establish the selection criteria for the fire behaviour performance levels after the validation firstly with large scale test (WP7) and secondly with real scale test (WP8).
The results, after this comparison, should be significant enough to classify the constituent products of railway vehicles taking into account the acceptable risks for users, the vehicle design, the shape and the use of the products, the functional equipment, the ventilation system and all relevant combinations of these items.

This classification system will be technically defined by WP6 and will represent a methodology to establish that all effects and parameters related to fire behaviour should be understood as part of the complex system.
The final proposal will be evaluated by the European standardisation committees.

II Participants

LSF Italy is the leader of WP 4.2 : Small-scale tests on furniture products.

The other partners involved in this WP are :

LNE	FRANCE
SNCF	FRANCE
BAYER	GERMANY
ISSEP	BELGIUM
BASF	GERMANY
WFRC	UNITED KINGDOM
DBI	DENMARK
FS	ITALY

III Description of the products tested

In the field of furniture products actually or often used in new European railway vehicles, it is important to have different fire behaviour materials and a different country to provide them. The national fire behaviour classifications of these materials and components are known.
A pre-selection of materials was made to take into account different families and the defined fire scenarios in the WP1 report (ref. 1).
When only one country uses one of these materials, it provided this material.
Due to indications from the railway companies of different European countries involved in the research and the requirements of the scientific and technical project objectives, the selection of furniture products was inclusive of materials, assemblies with foam, fabrics and interlayer as components of seats, mattresses, pillows, curtain.
Consequently, they were divided in three different groups which depend on their respective applications area:

- Wall or curtains
- Bedding
- Seats

The Tables 1, 2 and 3 of this document show all information about each of them which include: PF number as product reference code, general description, application area, country of providing, thickness, mass per surface area and density.
The total number of furniture products tested was 32.

Concerning the seat application area, the materials were then subdivided in two separate parts due to a different evaluation as single components of seats and as combination of them, related to the type of fire reaction parameter measured:

- Fabrics
- Assemblies

III1. **Combinations**

For seats, which are the most sensible part of the vehicle, it was decided to determine some combinations or assemblies for each country to be tested in small scale.
For assembly, a combination of a block of foam covered first with a piece of an interlayer and second with a piece of fabric covering was planned.
Under the direction of different railway companies the components of a seat were supplied for each: one foam, one or two interlayers, several coverings.
In all or most cases, the combinations for each country were equal to the number of coverings because the foam and interlayer were the same.
So, this system to combine all materials and components of seats has permitted to determine 13 different combinations or assemblies, which are described in Table 4.
Every assembly is intended to simulate or represent the full seat article used in real compartment but having a smaller size to be able for bench scale testing.
For each country providing components the following combinations were defined:

- France: C01 – C02 – C03
- Italy: C04 – C05 – C06 – C07
- Germany: C08 – C09
- United Kingdom: C10 – C11 – C12 – C13

III2. **Special furniture products for seat application area**

The products identified as PF09 and PF25 were tested in single component configuration but considered as a complete seat and so evaluated in the same group of assemblies.
This particular application came from their end-use configuration indicated by respective railway companies.

IV Description of test methods and conditions used

The choice of test methods and conditions used for furniture products to represent the characteristics of the different sub-stages of Fire Scenario of WP1 are precisely defined in WP3.2 Part 1 report.
The summaries of them are shown in tables 5 and 6.

IV1. Generalities

The parameters (FIRST) have been identified earlier in the FIRESTARR project as indicated below:
F for Flame Spread
I for Ignitability
R for Rate of Heat release
S for Smoke Opacity
T for Smoke Toxicity

Each one of these reaction to fire parameters may be realistically related to a practical Fire Critical Effect which is explained as the point in time at which a person, as result of exposure to the products of fire within a defined passenger area, would be unable to leave the defined passenger area unaided.

Consequently, FIRST parameters are able to represent the following realistic critical phenomena:
(a) Ease of ignition and Flammability of railway products (FI).
(b) Uncontrolled fire developing within railway compartment characterised by a substantial increase of heat release and area burning (FIR).
(c) Reduction of visibility as assessed by inability of passengers to find an escape route in a railway compartment (S).
(d) Lethality of passengers within a railway compartment due to a toxic effluents (T)

In small scale methods chosen for WP4.2 testing, each parameter was measured to identify one or more of the above FCE.

IV2. Methods and conditions for application areas

For furniture products the test methods are established taking into account the application area and the FIRST parameter to measure. Toxicity measurements will not be treated in this document because they are described in a specific and separate report of the project.

IV2.1. ***Wall or Curtains***

The ignitability for wall and curtain products is measured according to:
- Pr EN ISO 11925-2 Standard (ref. 4) with only edge impinging and application time of 15 and 30s: 3 replicates for each application.
- ISO 5660 part 1(ref. 9) with two irradiance levels : 3 replicates at 25 kW/m^2 and 35 kW/m^2.

The fire growth for wall and curtain products is measured according to:
- ISO 5658 part 2 Standard (ref. 13) using the fixing frame: 3 replicates.
- ISO 5660 part 1 (ref. 9) with two irradiance levels: 3 replicates at 25 and 35 kW/m^2.

The smoke opacity for wall and curtain products is measured according to:

- ISO 5660 part 2 (ref. 14) with two irradiance levels: 3 replicates at 25 and 35 kW/m^2.
- ISO 5659 part 2 (ref. 15) with 3 different levels of ignition source as specified in the standard: 3 replicates for each level.

IV2.2. ***Bedding***

The ignitability for bedding products is measured according to:

- EN 597 part 1, 2 (ref. 3,4) for mattresses: 1 replicate.
- Pr EN 32952 part 2, 4 (ref. 7,8) for items which may normally be placed on a mattress : 1 replicate test.
- ISO 5660 part 1 (ref. 9) with two irradiance levels : 3 replicates at 25 kW/m^2 and 35 kW/m^2.

The fire growth for bedding products is measured according to:

- ISO 5660 part 1 (ref. 9) with two irradiance levels: 3 replicates at 25 and 35 kW/m^2.

The smoke opacity for bedding products is measured according to:

- ISO 5660 part 2 (ref. 14) with two irradiance levels: 3 replicates at 25 and 35 kW/m^2.
- ISO 5659 part 2 (ref. 15) with 3 different levels of ignition source as specified in the standard: 3 replicates for each level.

IV2.3. ***Fabrics of seats***

The ignitability for fabric coverings of seat products is measured according to:

- Pr EN ISO 11925-2 Standard (ref. 5) with only edge impinging and application time of 15 and 30s: 3 replicates for each application.
- UIC 564 part 2 annex 5 (ref. 6) : 6 replicates.

IV2.4. ***Assemblies or combinations***

The ignitability and fire growth for assemblies is measured according to:

- ISO 5660 part 1(ref. 9) with only one irradiance level : 3 replicates at 25 kW/m^2.
- Pr EN 1021 part 3, 4 (ref. 11, 12): 3 replicates.
- UIC 564 part 2 annex 13 (ref. 10) using 400x 400x 75mm specimen size for seat and back sides mounted on the specific mock-up similar to BS 5852 but with modified test specimen dimensions.

The smoke opacity for assemblies is measured according to:

- ISO 5660 part 2 (ref. 14) with two irradiance levels: 3 replicates at 25 and 35 kW/m^2.
- ISO 5659 part 2 (ref. 15) with 3 different levels of ignition source as specified in the standard: 3 replicates for each level.

IV2.5. ***Specimen preparation for assemblies in ISO 5660-1, 2 and ISO 5659.2 testing***

Concerning the test on combinations, the experience of the CBUF research programme will be used; in detail the “Protocol for specimen preparation in Cone Calorimeter testing’ of Section A6 in CBUF Rreport (ref. 16) has been directly adopted for ISO 5660 part 1, 2 test procedure and has been adapted to the smaller size of specimens for ISO 5659 part 2 testing.

IV3. Reference material tests

In order to assume the validity of all tests performed in WP 4.2, a series of calibration trials was carried out between the involved laboratories in each of the selected fire test methods. The results of these tests are stored in the FIRESTARR data base.

IV3.1. ***prEN ISO 11925-2 Small Burner Test***

Laboratories participated: LNE, LSF, BASF, WFRC, FS.
LDF was test specimen.
The flame was applied for 30s to the bottom edge of the specimen. Flame time to 150mm was taken as the key parameter. Test results were satisfactory in terms of reproducibility.

IV3.2. ***ISO 5660 cone calorimeter test method (CBUF protocol):***

Laboratories participated: LNE and SP
An assembly composed by a polyurethane foam and polypropylene fabric was the test specimen.
The assemblies were prepared according to the CBUF protocol. The key parameters for comparison were tig, RHR, THR, Mass loss, SEA. The results showed acceptable differences between laboratories and it was recommended that care be taken in particular in the preparation of specimens before testing.

IV3.3. ***UIC 564-2-annex 13 paper cushion test, pr EN 1021.3 and pr EN 1021.4 :***

Laboratories participated: FS, LSF, LNE, BASF and BAYER
An assembly composed by a polyurethane foam and backcoated acrylic fabric was the test specimen.
Following parameters are considered key ones to obtain in this test:

- Mass loss
- Duration of flaming
- Time to reach the extremities

The results obtained for all four laboratories were homogeneous and so it was satisfactory to introduce an additional measurement: mass loss against time.

IV3.4. ***ISO 5659-2 Single Chamber Smoke (CBUF protocol) :***

Laboratories participated: LNE and BASF
An assembly composed by a polyurethane foam and polypropylene fabric was the test specimen. The assembly was prepared according to the CBUF protocol.
The following parameters were considered key ones to obtain in this test:

- Ds10

- Dmax
- VOF4 (obscuring value during the first four minutes)
- percentage of light transmission versus time
- optical density versus time

Tests have been carried out under 3 different conditions (25kW/m2 with pilot flame, 25 kW/m2 without pilot flame and 50Kw/m2 without pilot flame).
Test results were acceptable for all conditions but particular attention was needed to the position of pilot flame and it was recommended to check this before each test.

V Test results

The test results are reported in the annexes.
Table 7 shows the selection of measured data which identify the family of data for each adopted method.
The annexes will be 3 and represent the different investigated application area: wall/curtains, bedding, seats (see table 5).
The seats annex will be sub-divided in two sections: fabrics and assemblies (table 5).
Each application area and consequently each annex will contain some data tables grouped in three families of results: ease of ignition, fire growth and loss of visibility (table 7).
Single tables report the data results on products tested for the same application area, the same family of data, the same method and same test condition.

V1. Annex 1: Test results for "Wall/curtains" application area

This contains tables on "ease of ignition" results for wall/curtains products tested according to:
Pr EN ISO 11925-2 edge flame applications of 15 and 30s (Table 1A),
ISO 5660 p.1 at 25 kW/m^2 and 35 kW/m^2 of irradiance level (Table 1B).

"Fire growth" results are according to:
ISO 5658 p.2 (Table 1C),
ISO 5660 p.1 at 25 (Table 1D) and 35 kW/m^2 (Table 1E) irradiance levels.

"Loss of visibility" results are according to:
ISO 5660 p.2 at 25 and 35 kW/m^2 (Table 1F) irradiance levels,
ISO 5659 p.2 at 25 kW/m^2 no pilot flame (Table 1G), at 25 kW/m^2 with pilot flame (Table 1H) and 50 kW/m^2 no pilot flame (Table 1I).

V2. Annex 2: Test results for "Bedding" application area

This contains tables on "ease of ignition" results for bedding products tested according to:
EN 597 p.1 (Table 2A) and p.2 (Table 2B)
Pr EN 39952 part 2 (Table 2C) and p. 4 (Table 2D)
ISO 5660 p.1 at 25 kW/m^2 of irradiance level (Table 2E).

"Fire growth" results are according to:
ISO 5660 p.1 at 25 (Table 2F) and 35 kW/m^2 (Table 2G) irradiance levels,

"Loss of visibility" results are according to:
ISO 5660 p.2 at 25 and 35 kW/m^2 (Table 2H) irradiance levels,

ISO 5659 p.2 at 25 kW/m^2 no pilot flame (Table 2I), at 25 kW/m^2 with pilot flame (Table 2J) and 50 kW/m^2 no pilot flame (Table 2K).

V3. Annex 3: Test results for "Seat" application area

There are 2 series of tables: Fabrics and Assemblies.

V3.1. Results on fabrics

It contains tables on "ease of ignition" results for covering fabric products tested according to:
Pr EN ISO 11925-2 edge flame applications of 15 and 30s (Table 3A1),
UIC 564 p.2 annex 5 (Table 3B1).

V3.2. Results on assemblies

It contains tables on "ease of ignition" results for assemblies products tested according to:
ISO 5660 p.1 at 25 kW/m^2 of irradiance level (Table 3A2),
Pr EN 1021 p.3 (Table 3B2) and p.4 (Table 3C),
UIC 564 p.2 annex 13 (Table 3D).

"Fire growth" results are according to:
ISO 5660 p.1 at 25 (Table 3E) and 35 kW/m^2 (Table 3F) irradiance levels,
Pr EN 1021 p.3 (Table 3G) and p.4 (Table 3H),
UIC 564 p.2 annex 13 (Table 3I).

"Loss of visibility" results are according to:
ISO 5660 p.2 at 25 and 35 kW/m^2 (Table 3J) irradiance levels,
ISO 5659 p.2 at 25 kW/m^2 no pilot flame (Table 3K), at 25 kW/m^2 with pilot flame (Table 3L) and 50 kW/m^2 no pilot flame (Table 3M).

VI Discussion of test results by application area

VI1. Wall / Curtain products

Generally, the small number of products tested does not allow a significant range of results to be obtained for assessing different reaction to fire performance levels.
However, the small flame test is less discriminating than cone calorimeter method in terms of ignitability and especially at 35 kW/m^2 irradiance.
In "Fire Growth" results, all products show a similar good spread of flame performance in ISO 5658-2 testing and only the q_{max} parameter discriminates little in the Cone calorimeter method; anyway they are not in accordance between 25 and 35 kW/m^2 irradiance levels (not same ranking).
Concerning the smoke opacity performance under dynamic conditions, the ISO 5660-2 method defines 3 potential different levels for S" data at 25 kW/m^2, while a small difference between products was detected in the measurements from single chamber smoke test for cumulative system only at lower irradiance level.
At 50 kW/m^2 the values much increase but don't produce a better stratification of data.

VI2. **Bedding products**

As curtain products, in the bedding application area only 4 different materials were tested and these do not give reliable results for use in their classification.
The only significant aspect in terms of ignitability comes from Pr EN 32952 part 4 results where for Damaged area values it is possible to rank the products evaluated.
For assessing of fire growth performance levels, the Cone calorimeter test results show a sensible difference in THR values at 35 kW/m^2 . Also using this method for measuring the smoke opacity in well-ventilated conditions, S" at 25 kW/m^2 appears to be a more discriminating parameter than the others.
Under cumulative conditions, the ISO 5659-2 test gives the same ranking of performance between 25 kW/m^2 with pilot flame and 25 kW/m^2 without pilot flame with D_{10min} data.

VI3. **Seat products: fabric and assemblies**

The analysis of results concerning the covering fabrics of seats shows that the damaged area data is not useful for a determination of Ignitability performance levels because of the particular difficulty to obtain an accurate measurement.
Other parameters do not show several categories of behaviour even for PF28, 29 and 30 where the worst results have been obtained by both methods used:
"time to reach the 150 mm mark" according to ISO 11925-2
"afterflame time" according to UIC 564.2 Annex 5.

The ignitability of assemblies gives more significant results only in ISO 5660 at 25 kW/m^2 because they permit to have a wider ranking of different behaviour: the range of data starts from 10 s for PF25 till 131 s for PF09.
The range decreases from 1 s to 73 s for the same products for tests carried out at 35 kW/m^2.
Concerning the other test methods (pr EN 1021 Parts 3 and 4, UIC 564.2 Annex 13) for evaluation of "ease of ignition", the results are affected by an imprecise determination of the "ignition times" for seats and backs because the measurement is extremely dependant on the operator and the difficulty to appreciate ignition with the burner in place.

The cone calorimeter results for "fire growth" highlights that q_{max} and THR data better summarise the peak of combustion and total heat contribution from a single product burning.
The q_{max} values are more stratified at 35 kW/m^2 than 25 kW/m^2 while for THR the results seem to be the same in both the irradiance levels.
The "fire growth" was studied also by the pr EN 1021.4 and UIC 564.2 annex 13 methods.
For "flaming time" parameter, both tests are discriminating but do not show exactly the same ranking of performance (look at the best product and worst one).
Referring to "Damaged volume" for seat and back data and "total mass loss", it may be pointed out that the paper cushion test appears to be more severe and gives a very large range of results; at the same time the pr EN 1021 Part 4 method can be used for the same purpose but gives a smaller range of absolute values for consideration.

In the analysis of "smoke opacity" under well-ventilated conditions as summarised by cone calorimeter results, S" and k_{max} allow a good stratification of data, especially for the first parameter.
A larger range of data is obtained at the 35 kW/m^2 irradiance level: k_{max} in the range [0.49-10.32], S" in the range [49.2-1881.7].

Under cumulative conditions, smoke opacity is determined by the ISO 5659-2 test method, where the most representative key parameters are D_{max} and V0F4.
A stratification of these results may be pointed out particularly at 25 kW/m^2 (with and without pilot flame) and their ranges are respectively: D_{max} 40-625, V0F4 22-1168 for flaming condition and D_{max} in the range [125-633], V0F4 in the range [76-1404] for smouldering condition.
At 50 kW/m2 the results are less stratified and higher; hence, they are less useful for classification purposes.

VII Conclusion

Based on the experience of testing laboratories and according to the principles of ISO/TR11696 Part 2 (ref.17), performance criteria for assessment of ignitability, fire growth and smoke opacity parameters were identified by key measurements. The objective was to propose performance categories and ranking between the products for each of their area of application.

For “wall/curtain” products was obtained:

Performance Criteria for Assessment of Ignitability

Test	Parameter	Performance Zone		
		I Non-ignitable	II Difficult to Ignite	III Easy to Ignite
PrEN ISO 11925-2 (15s & 30s flame applications to edge or face of specimen)	Time to reach 150mm (s)	NR	>60	<60
ISO 5660-1 (a) 25kW/m^2 (b) 35kW/m^2	 Ignition Time (s) Ignition Time (s)	 NI NI	 $\geq$60 $\geq$20	 <60 <20

Performance Criteria for Assessment of Fire Growth

Test	Parameter	Performance Zone		
		I Limited Contribution	II Moderate Contribution	III High Contribution
ISO 5660 – 1				
(a) 25kW/m^2	qmax (kW/m^2)	<50	50 - 150	>100
(b) 35kW/m^2	qmax (kW/m^2)	<75	75 – 150	>150
ISO 5658-2	CFE (kW/m^2)	>36	20 – 36	<20
	Qsb (MJ/m^2)	>2.5	1.5 – 2.5	<1.5

Performance Criteria for Assessment of Smoke Opacity

Test	Parameter	Performance Zone		
		I Low Opacity	II Medium Opacity	III High Opacity
ISO 5660 – 2 Dynamic Method				
(a) 25kW/m^2	kmax (l/m)	<1	1 – 5	>5
	SEA (m^2/m^2)	<100	100 – 300	>300
(b) 35kW/m^2	kmax (l/m)	<1.5	1.5 – 6	>6
	SEA (m^2/m^2)	<100	100 – 300	>300
ISO 5659-2 Cumulative Method				
(a) 25kW/m^2 (+pf)	Dmax VOF4	<100 <100	100 – 400 100 – 600	>400 >600
(b) 25kW/m^2 (-pf)	Dmax VOF4	<100 <100	100 – 400 100 – 200	>400 >200
(c) 50kW/m^2 (-pf)	Dmax VOF4	<100 <100	100 – 400 100 – 600	>400 >600

Performance of Wall/Curtains Products based on ISO/TR11696-2 quantitative analysis

Product Reference	Performance Category		
	Ease of Ignition	Fire Growth	Smoke Opacity
PF01	III	II	III
PF02	II	II	III
PF03	III	I	II
PF04	I	II	III

This proposal can be take into consideration by WP6 for Firestarr classification purpose because permit to obtain a discrimination of products for each reaction to fire parameter evaluated.

For Bedding products was obtained:

Performance Criteria for Assessment of Ignitability

Test	Parameter	Performance Zone		
		I Non-ignitable	II Difficult to Ignite	III Easy to Ignite
prEN 32952-4	Time to reach the edges (s)	NR	≥120	<120
ISO 5660-1				
(c) 25kW/m^2	Ignition Time (s)	NI	≥60	<60
(d) 35kW/m^2	Ignition Time (s)	NI	≥20	<20

Performance Criteria for Assessment of Fire Growth

Test	Parameter	Performance Zone		
		I Limited Contribution	II Moderate Contribution	III High Contribution
ISO 5660 – 1				
(c) 25kW/m^2	qmax (kW/m^2)	<50	50 - 150	>100
	THR (MJ)	<50	50 - 100	>100
(d) 35kW/m^2	qmax (kW/m^2)	<75	75 – 150	>150
	THR (MJ)	<70	70 - 120	>120

Performance Criteria for Assessment of Smoke Opacity

Test	Parameter	Performance Zone		
		I Low Opacity	II Medium Opacity	III High Opacity
ISO 5660 – 2 Dynamic Method				
(a) 25kW/m^2	kmax (l/m)	<1	1 – 5	>5
	SEA (m^2/m^2)	<200	200 – 1000	>1000
(b) 35kW/m^2	kmax (l/m)	<1.5	1.5 – 7	>7
	SEA (m^2/m^2)	<200	200 – 1000	>1000
ISO 5659-2 Cumulative Method				
(d) 25kW/m^2 (+pf)	Dmax VOF4 Ds10	<100 <100 <100	100 – 400 100 – 1000 100 - 400	>400 >1000 >400
(e) 25kW/m^2 (-pf)	Dmax VOF4 Ds10	<100 <100 <100	100 – 400 100 – 200 100 – 400	>400 >200 >400
(f) 50kW/m^2 (-pf)	Dmax VOF4 Ds10	<100 <100 <100	100 – 400 100 – 1000 100 - 400	>400 >1000 >400

Table 8: Performance of Bedding Products based on ISO/TR11696-2 quantitative analysis

Product Reference	Performance Category		
	Ease of Ignition	Fire Growth	Smoke Opacity
PF05	III	III	II
PF06	III	II	II
PF07	III	III	III
PF08	II	III	II

For Seat products was obtained:

Performance Criteria for Assessment of Ignitability

Test	Parameter	Performance Zone		
		I Non-ignitable	II Difficult to Ignite	III Easy to Ignite
ISO 5660-1				
(e) 25kW/m^2	Ignition Time (s)	NI	≥60	<60
(f) 35kW/m^2	Ignition Time (s)	NI	≥20	<20

Table 10: Performance Criteria for Assessment of Fire Growth

Test	Parameter	Performance Zone		
		I Limited Contribution	II Moderate Contribution	III High Contribution
ISO 5660 – 1				
(e) 25kW/m^2	qmax (kW/m^2)	<50	50 - 150	>150
	THR	<50	50 - 100	>100
(f) 35kW/m^2	qmax (kW/m^2)	<75	75 – 200	>200
	THR	<70	70 - 200	>200
UIC 564-2 Annex 13	Flaming time (s)	<300	300 – 600	>600
	TML (g)	<30	30 – 500	>500
Pr EN 1021-4	Afterflame time (s)	<120	120 – 300	>300
	TML (g)	<20	20 – 50	>50

Performance Criteria for Assessment of Smoke Opacity

Test	Parameter	Performance Zone		
		I Low Opacity	II Medium Opacity	III High Opacity
ISO 5660 – 2 Dynamic Method				
(a) 25kW/m^2	kmax (l/m)	<1	1 – 5	>5
	SEA (m^2/m^2)	<100	100 – 300	>300
(b) 35kW/m^2	kmax (l/m)	<1.5	1.5 – 6	>6
	SEA (m^2/m^2)	<100	100 – 300	>300
ISO 5659-2 Cumulative Method				
(g) 25kW/m^2 (+pf)	Dmax VOF4	<100 <100	100 – 400 100 – 600	>400 >600
(h) 25kW/m^2 (-pf)	Dmax VOF4	<100 <100	100 – 400 100 – 200	>400 >200
(i) 50kW/m^2 (-pf)	Dmax VOF4	<100 <100	100 – 400 100 – 600	>400 >600

Performance of Seats based on ISO/TR11696-2 quantitative analysis

Product Reference	Performance Category		
	Ease of Ignition	Fire Growth	Smoke Opacity
PF09	II	II	III
PF25	III	III	II
C01	III	II	III
C02	III	III	III
C03	II	II	III
C04	III	III	II
C05	III	III	III
C06	III	III	III
C07	III	II	III
C08	III	III	III
C09			
C10	III	III	II
C11	III	III	II
C12	III	III	III
C13	III	III	II

For Bedding and Seat products the performance categories defined are not enough to demonstrate or establish a discriminating ranking and levels between the different products evaluated in each fire reaction parameter.
Anyway, all data need to be subjected at statistical analysis by WP5 study that will or not identify a possible correlation between them and fire critical effects reached during the real scale tests series (WP8.2).
It is necessary to define a new large scale test method which take into account all realistic conditions of air ventilation, dimension of seat, and ignition source for better simulating the same thermal attack of 100g paper cushion.
For this purpose a new modified Belfagor burner have to be designed for the large scale tests because the old one used according to Pr EN 1021.4 was resulted less severe of the paper cushion by UIC 564 Annex 13 method.
The results obtained by a new large scale test method will be validated by Real scale test series.

VIII References

1. FIRESTARR WP1 Final Report

2. FIRESTARR WP2 Report. WP2/SNCF/98004. Selection of products for small-scale tests.

3. EN 597 – 1.Furniture. Assessment of the ignitability of mattresses and bed bases – Part 1: Ignition source: smouldering cigarettes.

4. EN 597 – 2.Furniture. Assessment of the ignitability of mattresses and bed bases – Part 2: Ignition source: Match flame equivalent.

5. PrEN ISO 11925-2.Reaction to fire for building products – Part 2: Ignitability when subject to direct impingement of flame.

6. UIC 564 - 2 Appendix 5.Regulation relating to the fire protection and fire-fighting measures in passanger-carrying railway vehicles or assimilated vehicles used on international services, Appendix 5. Test method for determining the fire resistance of coverings (textile or not).

7. PrEN 32952 - 2.Burning behaviour of bedding items – Part 2: Ignitability by a smouldering cigarette.

8. PrEN 32952 - 4. Burning behaviour of bedding items – Part 4: Ignitability by a small open flame.

9. ISO DIS 5660 - 1.Fire Safety – Reaction to Fire. Part 1: Heat release (Cone calorimeter method).

10. UIC 564 - 2 Appendix 13. Regulation relating to the fire protection and fire-fighting measures in passanger-carrying railway vehicles or assimilated vehicles used on international services, Appendix 13. Test method for determining the fire resistance of passenger seats.

11. PrEN 1021 - 3.Furniture. Assessment of the ignitability of upholstered furniture – Part 3: Ignition source: Flame equivalent to the flame from 20g of newspaper.

12. PrEN 1021 - 4.Furniture. Assessment of the ignitability of upholstered furniture – Part 4: Ignition source: Flame equivalent to the flame from 100g of newspaper.

13. ISO 5658 - 2 (1996) Reaction to fire test – Spread of flame – Part 2: Lateral spread on building products in vertical configuration.

14. ISO DIS 5660 - 2.Fire Safety – Reaction to fire – Smoke production rate (dynamic measurement).

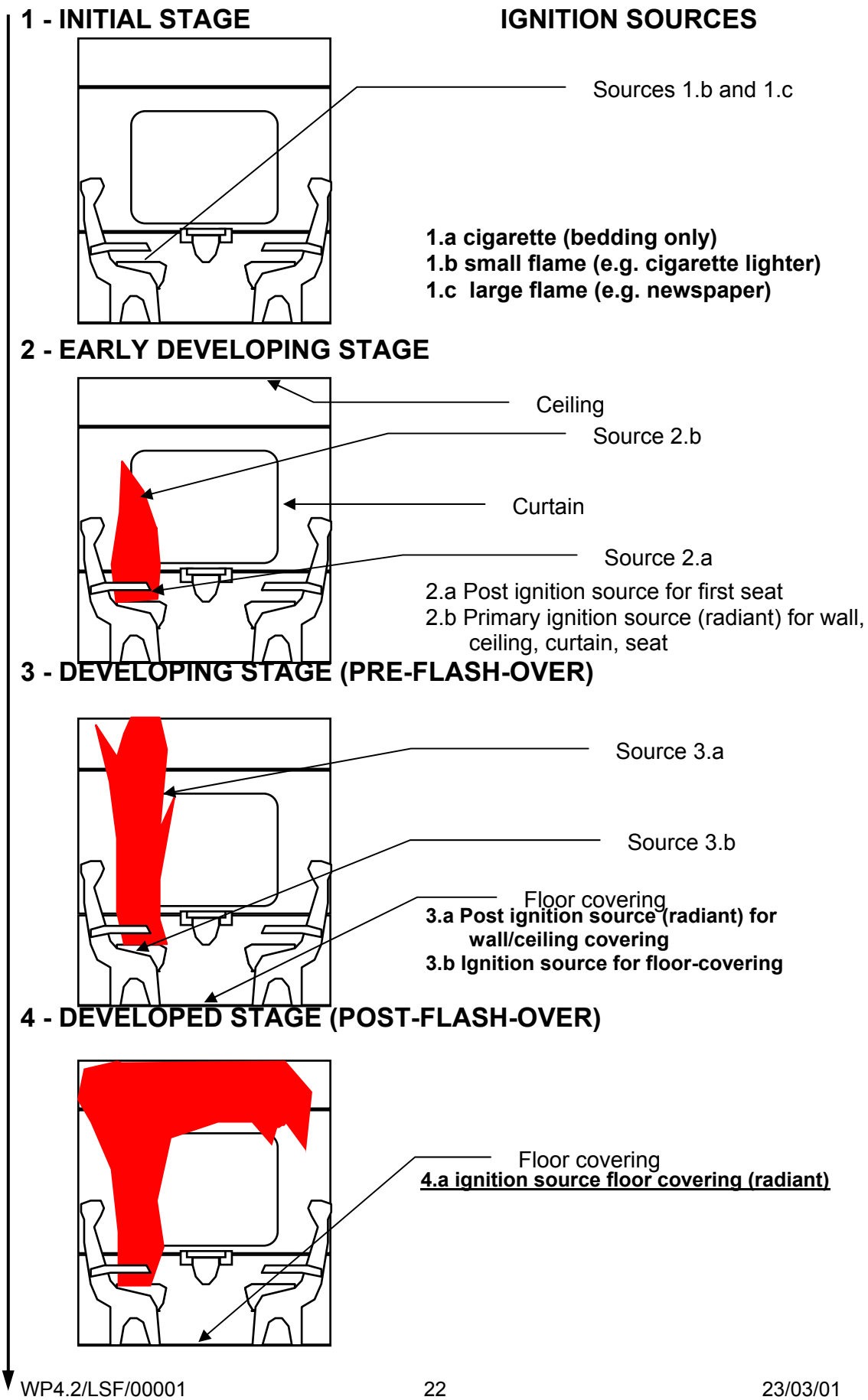
15. ISO 5659 Part 2. Plastics – Smoke generation – Determination of optical density by a single chamber test.

16. CBUF Fire Safety of Upholstered Furniture – Final report on the CBUF research programme (Edited by Bjorn Sundstrom) – European Commission Measurements and Testing Report EUR 16477 EN.

17. ISO/TR11696 Uses of reaction to fire test results Part 2: Fire hazard assessment of construction products (1999).

IX Figures and Tables:

IX1. **Figure 1: Stages of Fire Scenario 1**



IX2. **Table 1 : Furniture products tested in WP 4.2 for WALL application area**

PRODUCT REFERENCE	DESCRIPTION OF PRODUCT	APPLICATION AREA	COUNTRY	Thickness (mm)	Mass per surface area (g/m^2)	Density (kg/m^3)
PF01	Sunblind in glass and PVC	Wall	France	0.6	530	
PF02	Curtains in PVC fibre	Wall	France	1.3	600	
PF03	Curtains in preoxydate fibre	Wall	Italy	0.5	200	
PF04	Curtains in Polyester	Wall	Germany	0.5	300	

IX3. **Table 2 : Furniture products tested in WP 4.2 for BEDDING application area**

PRODUCT REFERENCE	DESCRIPTION OF PRODUCT	APPLICATION AREA	COUNTRY	Thickness (mm)	Mass per surface area (g/m^2)	Density (kg/m^3)
PF05	Mattress foam Mattress covering	Bedding	U.K. France	12.0		170
PF06	Sheet	Bedding	France	0.2	130	
PF07	Blanket	Bedding	France	4.0	600	
PF08	Pillow	Bedding	France		18	

IX4. **Table 3 : Furniture products tested in WP 4.2 for SEATS application area**

PRODUCT REFERENCE	DESCRIPTION OF PRODUCT	APPLICATION AREA	COUNTRY	Thickness (mm)	Mass per surface area (g/m^2)	Density (kg/m^3)
PF09	Silicone unlacerable fabric	Seat	France	7.0 /9.0	6000	
PF10	Polyurethane foam	Seat	France			50
PF11	Seat covering knitted velvet	Seat	France		500	
PF12	Seat covering "en drap"	Seat	France		800	
PF13	Seat covering in simulated leather	Seat	France		250	
PF14	Seat inter-layer polyacrylate-aramide fibre	Seat	France		250	
PF15	Polyurethane foam	Seat	Italy			70
PF16	Seat covering wool / synthetic fibre	Seat	Italy		1000	
PF17	Seat covering synthetic fibre	Seat	Italy		550	
PF18	Seat covering wool / acrylic fibre	Seat	Italy		600	
PF19	Seat covering texoid	Seat	Italy		900	
PF20	Seat interlayer polyacrylate-aramide fibre	Seat	Italy	4.0	550	
PF21	Polyurethane foam	Seat	Germany			85
PF22	Seat covering polyester fibre	Seat	Germany		600	
PF23	Seat covering wool/polyester fibre	Seat	Germany		400	
PF24	Seat Inter-Layers skin polyester	Seat	Germany	1.0	280	
PF25	Integral skin polyurethane foam	Seat	U.K.			100
PF26	Polyurethane foam	Seat	U.K.			70

PF27	Seat covering woollen spun cloth	Seat	U.K.		400	
PF28	Seat covering double plush seating moquette, untreated	Seat	U.K.		800	
PF29	Seat covering double plush seating moquette, Zirpro treated	Seat	U.K.		850	
PF30	Seat covering cut and uncut seating moquette, untreated	Seat	U.K.		850	
PF31	Seat inter-layer fibrous glass substrate with polymeric treatment and special coating	Seat	U.K.	0.5	170	
PF32	Seat inter-layer polyacrylate – aramide fibre	Seat	U.K.	2.0	450	

IX5. **Table 4 : Combinations tested in WP 4.2 for SEAT application area**

List of Assemblies

COMBINATION / ASSEMBLY REFERENCE	COVERING PRODUCT REFERENCE	INTERLAYER PRODUCT REFERENCE	FOAM PRODUCT REFERENCE
C01	PF11	PF14	PF10
C02	PF12	PF14	PF10
C03	PF13	PF14	PF10
C04	PF16	PF20	PF15
C05	PF17	PF20	PF15
C06	PF18	PF20	PF15
C07	PF19	PF20	PF15
C08	PF22	-	PF21
C09	PF23	-	PF21
C10	PF27	PF32	PF26
C11	PF29	PF32	PF26
C12	PF30	PF32	PF26
C13	PF28	PF31	PF26

IX6. **Table 5 : Test methods**

APPLICATION AREAS		FIRST PARAMETERS		
		IGNITABILITY	**FIRE GROWTH**	**SMOKE OPACITY**
WALL / CURTAINS		Pr EN ISO 11925.2 ISO 5660 part 1	ISO 5658 part 2 ISO 5660 part 1	ISO 5660 part 2 ISO 5659 part 2
BEDDING		EN 597 part 1, 2 Pr EN 32952 part 2, 4 ISO 5660 part 1	ISO 5660 part 1	ISO 5660 part 2 ISO 5659 part 2
SEATS	FABRICS	Pr EN ISO 11925.2 UIC 564.2 Annex 5		
	ASSEMBLIES	ISO 5660 part 1 Pr EN 1021 part 3, 4 UIC 564.2 Annex 13	ISO 5660 part 1 Pr EN 1021 part 3, 4 UIC 564.2 Annex 13	ISO 5660 part 2 ISO 5659 part 2

IX7. **Table 6 : Test conditions**

TEST METHODS	FIRST PARAMETER	TEST CONDITIONS	SIMULATING STAGES OF WP1 FIRE SCENARIO
Pr EN ISO 11925.2	IGNITABILITY	- Edge application. - Application time of 15s and 30s. - 3 replicate tests for each application.	A casual or arson application of a match or lighter flame to the edge of a lining or covered textiles (ignition sources 1.a and 1.b of fig. 1).
EN 597 part 1, 2	IGNITABILITY	- According to the Standard. - 1 replicate test.	An accidental application of a small thermal energy source onto the surface of mattress (ignition sources 1.a and 1.b of fig. 1).
Pr EN 32952 part 2, 4	IGNITABILITY	- According to the Standard. - 1 replicate test.	Smouldering and flaming small accidental ignition sources on bedding sheets and blanket (ignition sources 1.a and 1.b of fig. 1).
UIC 564.2 Annex 5	IGNITABILITY	- According to the Standard. - 6 replicate tests.	A casual or arson application of a match or lighter flame to the edge of a lining or covered textiles (ignition sources 1.a and 1.b of fig. 1).
ISO 5660 Part 1, 2	IGNITABILITY	- According to Part 1 of Standard. - Irradiance level at 25 kw/m^2. - CBUF protocol for specimen preparation (*) has followed for assemblies testing. - 3 replicate tests.	Effect of the heat flux produced by an existing external fire of limited size (ignition source 2.a of fig. 1). One incident heat flux was fixed.
	FIRE GROWTH	- According to Part 1 of Standard. - Irradiance level at 25 and 35 kw/m^2. - CBUF protocol for specimen preparation (*) has followed for assemblies testing. - 3 replicate tests for each irradiance level.	Effect of the heat flux produced by a bigger fire already in developing stage near the upholstered furniture (seat). Two incident heat fluxes to represent two different developing levels of the early fire (ignition source 2.b of fig. 1).
	SMOKE OPACITY	- According to Part 2 of Standard. - Irradiance level at 25 and 35 kw/m^2. - CBUF protocol for specimen preparation (*) has followed for assemblies testing. - 3 replicate tests for each irradiance level.	Smoke emission measured using two levels of incident heat flux to represent the different levels of thermal attack produced by existing fire. The conditions are characterised by a high availability of fresh air within a small compartment.

UIC 564.2 Annex 13	IGNITABILITY	- According to the Standard. - 3 replicate tests.	Simulating the presence of a large flame caused by a fire at the early developing stage (ignition source 1.c of fig. 1).
	FIRE GROWTH	- According to the Standard. - 3 replicate tests.	Simulating the presence of a large flame caused by a fire at the early developing stage (ignition source 1.c of fig. 1).
Pr EN 1021 part 3, 4	IGNITABILITY	- According to the Standard. - 3 replicate tests.	Taking into account the low level of reliability of the paper cushion test ignition source, parallel tests with two levels of thermal attack simulating the effects produced by 20g and 100g of burning newspaper were carried out.
	FIRE GROWTH	- According to the Standard. - 3 replicate tests.	Taking into account the low level of reliability of the paper cushion test ignition source, parallel tests with two levels of thermal attack simulating the effects produced by 20g and 100g of burning newspaper were carried out.
ISO 5658 part 2	FIRE GROWTH	- According to the Standard. - Use of fixing frame. - 3 replicate tests.	Spread of flame measurement of ignited curtains (ignition source 2.b of fig. 1).
ISO 5659 part 2	SMOKE OPACITY	- According to the Standard. - CBUF protocol for specimen preparation (*) adapted to the smaller sizes of sample has followed for assemblies testing. - 3 replicate tests for each thermal attacks required by the Standard.	Smoke emission measured using two extreme levels of incident heat flux. The conditions are characterised by a low availability of fresh air within a small compartment.

(*) = Doc. “Protocol for specimen preparation in Cone Calorimeter testing” (Section A6 of CBUF Final Report).

IX8. **Table 7.1 : TEST RESULTS on WALL/CURTAINS PRODUCTS**

APPLICATION AREA	FAMILIES OF RESULTS	TEST METHODS	PARAMETERS EVALUATED IN TEST RESULTS
WALL / CURTAINS	EASY OF IGNITION	ISO 5660 Part 1 at 25 kW/m^2	- Time to ignition (ti).
		Pr EN ISO 11925.2	- Time to reach 150mm. - Flaming debris (yes/no). - Demaged area.
	FIRE GROWTH	ISO 5658 part 2	- Heat for sustained burning (QSB). - Critical Flux at extinction (CFE). - Maximum lateral stop reached by the flame (X_{max}).
		ISO 5660 p.1 at 25 and 35 kW/m^2	- Averaged heat release rate over the period starting at ti and ending 180s later (q_{180}). - Averaged heat release rate over the period starting at ti and ending 300s later (q_{300}). - Maximum value fo heat release rate (q_{max}). - Total Heat Released (THR).
	LOSS OF VISIBILITY	ISO 5660 p.2 at 25 and 35 kW/m^2	- Specific Extinction Area (SEA or S"). - Maximum value of Smoke extinction coefficent (k_{max}).
		ISO 5659 part 2	- Maximum level of smoke Density produced (D_{max}). - Smoke density value reached after 10min from starting of test (D_{10}). - Index of smoke growth for the first 4 minutes of test (V0F4).

IX9. **Table 7.2 : TEST RESULTS on BEDDING PRODUCTS**

APPLICATION AREA	FAMILIES OF RESULTS	TEST METHODS	PARAMETERS EVALUATED IN TEST RESULTS
BEDDING	EASY OF IGNITION	EN 597 part 1, 2	- Progressive smouldering ignition (yes/no). - Flaming Ignition (yes/no) - Time to reach the edges. - Demaged lenght.
		Pr EN 32952 part 2, 4	- Progressive smouldering ignition (yes/no). - Flaming Ignition (yes/no) - Time to reach the edges. - Demaged area.
		ISO 5660 Part 1 at 25 kW/m^2	- Time to ignition (ti).
	FIRE GROWTH	ISO 5660 p.1 at 25 and 35 kW/m^2	- Averaged heat release rate over the period starting at ti and ending 180s later (q_{180}). - Averaged heat release rate over the period starting at ti and ending 300s later (q_{300}). - Maximum value fo heat release rate (q_{max}). - Total Heat Released (THR).
	LOSS OF VISIBILITY	ISO 5660 p.2 at 25 and 35 kW/m^2	- Specific Extinction Area (SEA or S"). - Maximum value of Smoke extinction coefficent (k_{max}).
		ISO 5659 part 2	- Maximum level of smoke Density produced (D_{max}). - Smoke density value reached after 10min from starting of test (D_{10}). - Index of smoke growth for the first 4 minutes of test (V0F4).

IX10. **Table 7.3 : TEST RESULTS on SEAT PRODUCTS**

APPLICATION AREA		FAMILIES OF RESULTS	TEST METHODS	PARAMETERS EVALUATED IN TEST RESULTS
SEAT	FABRICS	EASY OF IGNITION	Pr EN ISO 11925.2	- Time to reach 150mm. - Flaming debris (yes/no). - Demaged area.
			UIC 564.2 Annex 5	- Afterflame time. - Flaming debris (yes/no) - Demaged area.
	ASSEMBLIES	EASY OF IGNITION	ISO 5660 Part 1 at 25 kW/m^2	- Time to ignition (ti).
			Pr EN 1021 part 3, 4	- Time to ignition for seat (ti_{seat}). - Time ti ignition for back (ti_{back}).
			UIC 564.2 Annex 13	- Time to ignition for seat (ti_{seat}). - Time ti ignition for back (ti_{back}).
		FIRE GROWTH	ISO 5660 p.1 at 25 and 35 kW/m^2	- Averaged heat release rate over the period starting at ti and ending 180s later (q_{180}). - Averaged heat release rate over the period starting at ti and ending 300s later (q_{300}). - Maximum value fo heat release rate (q_{max}). - Total Heat Released (THR).
			Pr EN 1021 part 3, 4	- Afterflame time ($t_{afterflame}$). - Smouldering time ($t_{smouldering}$). - Demaged volume for seat (A). - Demaged volume for back. (B). - Total mass loss (M_{loss}).
			UIC 564.2 Annex 13	- Flaming time ($t_{flaming}$). - Smouldering time ($t_{smouldering}$). - Demaged volume for seat (A). - Demaged volume for back. (B). - Total mass loss (M_{loss}).
		LOSS OF VISIBILITY	ISO 5660 p.2 at 25 and 35 kW/m^2	- Specific Extinction Area (SEA or S"). - Maximum value of Smoke extinction coefficent (k_{max}).
			ISO 5659 part 2	- Maximum level of smoke Density produced (D_{max}). - Smoke density value reached after 10min from starting of test (D_{10}). - Index of smoke growth for the first 4 minutes of test (V0F4).

ANNEX 1: Test results for “Wall/Curtains” application area

TABLE 1A:
"Ease of ignition" results for wall/curtain products tested according to Pr EN ISO 11925.2 flame edge application

	Flame application time: 15 s			Flame application time: 30 s		
Products	**Time to reach 150 mm (s)**	**Flaming debris (yes/no)**	**Demaged area (cm^2)**	**Time to reach 150 mm (s)**	**Flaming debris (yes/no)**	**Demaged area (cm^2)**
PF 01	n.r.	no	6.3	n.r.	no	7.8
PF 02	n.r.	no	18.7	n.r.	no	32.2
PF 03	10	no	20.0	11	no	18.7
PF 04	n.r.	no	16.3	n.r.	no	19.6

Remarks: **n.r. =** **Not reached**
n.d. = **No data available**

TABLE 1B:
"Ease of ignition" results for wall/curtain products tested according to ISO 5660 part1 at 25 and 35 kw/m^2

	Irradiance:	
	25 kW/m^2	**35 kW/m^2**
Products	**Time To Ignition (s)**	**Time to ignition (s)**
PF 01	23	19
PF 02	98	97
PF 03	n.d.	23
PF 04	n.d.	n.d.

n.d. = **No data available**

TABLE 1C:
"Fire growth" results for wall/curtain products tested according to ISO 5658.2

Products	**Heat for Sustained Burning QSB (MJ/m^2)**	**Critical flux at extinction CFE (kW/m^2)**	**Maximum lateral stop reached by the flame Xmax (mm)**
PF 01	n.d.	> 50	0
PF 02	n.d.	> 50	0
PF 03	n.d.	> 50	0
PF 04	n.d.	> 50	0

Remarks: **n.d. =** **No data available**

TABLE 1D:
"Fire growth" results for wall/curtain products tested according to ISO 5660.1 at 25 kW/m^2

Products	q_{180} (kW/m^2)	q_{300} (kW/m^2)	q_{max} (kW/m^2)	THR (MJ/m^2)
PF 01	11.6	6.1	66.2	2.0
PF 02	9.0	5.2	50.1	2.1
PF 03	n.d.	n.d.	6.3	1.4
PF 04	n.d.	n.d.	1.5	n.d.

Remarks: **n.d. =** **No data available**

TABLE 1E:
"Fire growth" results for wall/curtain products tested according to ISO 5660.1 at 35 kW/m^2

Products	q_{180} (kW/m^2)	q_{300} (kW/m^2)	q_{max} (kW/m^2)	THR (MJ/m^2)
PF 01	13.1	6.5	101.1	2.1
PF 02	12.9	8.2	52.4	2.8
PF 03	15.5	8.1	58.7	2.6
PF 04	n.d.	n.d.	148.2	n.d.

Remarks: **n.d. =** **No data available**

TABLE 1F:
"Loss of visibility" results for wall/curtain products tested according to ISO 5660.2 at 25 and 35 kW/m^2

	Irradiance:			
	25 kW/m^2		35 kW/m^2	
Products	**S"** (m^2/m^2)	**k_{max}** (m^{-1})	**S"** (m^2/m^2)	**k_{max}** (m^{-1})
PF 01	126.6	3.24	164.7	4.42
PF 02	274.5	3.83	318.4	3.93
PF 03	25.5	0.53	63.3	2.04
PF 04	8.3	1.03	358.2	4.03

TABLE 1G:
"Loss of visibility" results for wall/curtain products tested according to ISO 5659.2 at 25 kW/m^2 no pilot flame

Products	Maximum level of smoke density (Dmax)	Smoke density value at 10 min (D_{10})	Index of smoke growth for the first 4 min. (V0F4)
PF 01	164	145	277
PF 02	104	96	93
PF 03	45	44	110
PF 04	82	20	6

Remarks: **n.d. =** **No data available**

TABLE 1H:
"Loss of visibility" results for wall/curtain products tested according to ISO 5659.2 at 25 kW/m^2 with pilot flame

Products	Maximum level of smoke density (Dmax)	Smoke density value at 10 min (D_{10})	Index of smoke growth for the first 4 min. (V0F4)
PF 01	107	100	221
PF 02	120	118	124
PF 03	39	34	113
PF 04	n.d.	n.d.	n.d.

TABLE 1I:
"Loss of visibility" results for wall/curtain products tested according to ISO 5659.2 at 50 kW/m^2 No pilot flame

Products	Maximum level of smoke density (Dmax)	Smoke density value at 10 min (D_{10})	Index of smoke growth for the first 4 min. (V0F4)
PF 01	238	186	663
PF 02	214	162	531
PF 03	93	70	307
PF 04	239	233	413

Remarks: **n.d. =** **No data available**

ANNEX 2 : Test results for “Bedding” application area

TABLE 2A:
"Ease of ignition" results for bedding products tested according to EN 597 part 1

Product	Progressive smouldering ignition (yes/no)	Flaming ignition (yes/no)	Time to reach the edges (s)	Demaged lenght (mm)
PF 05	no	no	n.r.	60 *

Remarks: **n.r. =** **Not reached**
* = **Lenght of burned cigarette**

TABLE 2B:
"Ease of ignition" results for bedding products tested according to EN 597 part 2

Product	Progressive smouldering ignition (yes/no)	Flaming ignition (yes/no)	Time to reach the edges (s)	Demaged maximum lenght (mm)
PF 05	no	no	n.r.	15

Remarks: **n.r. =** **Not reached**

TABLE 2C:
"Ease of ignition" results for bedding products tested according to Pr EN 39952 part 2

Products	Progressive smouldering ignition (yes/no)	Flaming ignition (yes/no)	Time to reach the edges (s)	Demaged area (cm^2)
PF 06	no	no	n.r.	7.7
PF 07	no	no	n.r.	13.6
PF 08	no	no	n.r.	14.0

Remarks: **n.r. =** **Not reached**

TABLE 2D:
"Ease of ignition" results for bedding products tested according to Pr EN 39952 part 4

Products	Progressive smouldering ignition (yes/no)	Flaming ignition (yes/no)	Time to reach the edges (s)	Demaged area (cm^2)
PF 06	no	yes	n.r.	64.0
PF 07	no	yes	n.r.	9.0
PF 08	yes	yes	n.r.	110.0

Remarks: **n.r. =** **Not reached**

TABLE 2E:
"Ease of ignition" results for bedding products tested according to ISO 5660.1 at 25 and 35 kW/m^2

	Irradiance:	
	25 kW/m^2	35 kW/m^2
Products	**Time to ignition (s)**	**Time to ignition (s)**
PF 05	34	21
PF 06	n.d.	17
PF 07	48	17
PF 08	198	42

TABLE 2F:
"Fire growth" results for bedding products tested according to ISO 5660.1 at 25 kW/m^2

Products	**q_{180} (kW/m^2)**	**q_{300} (kW/m^2)**	**q_{max} (kW/m^2)**	**THR (MJ/m^2)**
PF 05	21.3	15.8	111.3	4.1
PF 06	n.d.	n.d.	3.7	n.d.
PF 07	116.3	79.7	174.7	360.3
PF 08	84.9	55.6	172.0	16.2

Remarks: **n.d. =** **No data available**

TABLE 2G:
"Fire growth" results for bedding products tested according to ISO 5660.1 at 35 kW/m^2

Products	**q_{180} (kW/m^2)**	**q_{300} (kW/m^2)**	**q_{max} (kW/m^2)**	**THR (MJ/m^2)**
PF 05	44.5	32.4	163.0	8.7
PF 06	16.2	9.8	91.3	10.2
PF 07	123.7	81.7	271.3	186.7
PF 08	107.0	69.0	181.7	20.4

Remarks: **n.d. =** **No data available**

TABLE 2H:
"Loss of visibility" results for bedding products tested according to ISO 5660.2 at 25 and 35 kW/m^2

	Irradiance:			
	25 kW/m^2		35 kW/m^2	
Products	**S" (m^2/m^2)**	**k_{max} (m^{-1})**	**S" (m^2/m^2)**	**k_{max} (m^{-1})**
PF 05	164.3	4.08	227.2	5.51
PF 06	132.0	0.73	69.0	1.87
PF 07	358.7	1.47	441.7	2.43
PF 08	629.5	2.03	437.0	2.87

TABLE 2I:
"Loss of visibility" results for bedding products tested according to ISO 5659.2 at 25 kW/m^2 no pilot flame

Products	Maximum level of smoke density (Dmax)	Smoke density value at 10 min (D_{10})	Index of smoke growth for the first 4 min. (V0F4)
PF 05	69	69	141
PF 06	86	75	105
PF 07	357	308	274
PF 08	119	73	82

TABLE 2J:
"Loss of visibility" results for bedding products tested according to ISO 5659.2 at 25 kW/m^2 with pilot flame

Products	Maximum level of smoke density (Dmax)	Smoke density value at 10 min (D_{10})	Index of smoke growth for the first 4 min. (V0F4)
PF 05	16	16	21
PF 06	84	83	137
PF 07	129	104	345
PF 08	57	43	119

TABLE 2K:
"Loss of visibility" results for bedding products tested according to ISO 5659.2 at 50 kW/m^2 no pilot flame

Products	Maximum level of smoke density (Dmax)	Smoke density value at 10 min (D_{10})	Index of smoke growth for the first 4 min. (V0F4)
PF 05	44	42	144
PF 06	37	35	114
PF 07	422	349	1184
PF 08	212	205	469

ANNEX 3 : Test results for “Seat” application area
Fabric and Assemblies

TABLE 3A1:
"Ease of ignition" results for covering fabric products tested according to ISO 11925.2 edge flame application

	Flame application time: 15 s			Flame application time: 30 s		
Products	**Time to reach 150 mm (s)**	**Flaming Debris (yes/no)**	**Demaged area (cm^2)**	**Time to reach 150 mm (s)**	**Flaming debris (yes/no)**	**Demaged area (cm^2)**
PF 11	n.r.	no	10.9	n.r.	no	15.5
PF 12	n.r.	no	10.0	19	no	19.4
PF 13	n.r.	no	13.0	25	no	26.8
PF 16	n.r.	no	4.3	n.r.	no	7.7
PF 17	n.r.	yes	12.3	n.r.	yes	10.2
PF 18	n.r.	no	8.3	n.r.	no	11.7
PF 19	n.r.	no	12.3	n.r.	no	14.3
PF 22	n.r.	no	18.8	n.r.	no	23.5
PF 23	n.r.	no	16.0	n.r.	no	29.2
PF 27	n.r.	no	19.3	n.r.	no	20.6
PF 28	31	no	n.d.	26	no	n.d.
PF 29	n.r.	no	n.d.	50	no	n.d.
PF 30	20	no	n.d.	22	no	n.d.

Remarks: **n.r. = Not reached** **n.d. = No data available**

TABLE 3B1:
"Ease of ignition" results for covering fabric products tested according to UIC 564.2 annex 5

Products	**After flame (s)**	**Flaming debris (yes/no)**	**Demaged area (cm^2)**
PF 11	0	no	61.7
PF 12	0	no	51.3
PF 13	5	no	72.1
PF 16	6	no	48.5
PF 17	0	yes	33.7
PF 18	5	no	43.9
PF 19	5	no	92.4
PF 22	0	yes	29.5
PF 23	23	yes	73.0
PF 27	10	no	131.9
PF 28	275	no	310.6
PF 29	73	no	132.2
PF 30	151	no	397.4

TABLE 3A2:
"Ease of ignition" results for assemblies products tested according to ISO 5660.1 at 25 and 35 kW/m^2

	Irradiance:	
	25 kW/m^2	35 kW/m^2
Products	**Time to ignition (s)**	**Time to ignition (s)**
PF 09	131	73
PF 25	10	1
C 01	50	88
C 02	37	23
C 03	79	21
C 04	52	28
C 05	53	23
C 06	35	20
C 07	45	34
C 08	35	15
C 09	n.d.	n.d.
C 10	24	17
C 11	71	16
C 12	57	14
C 13	83	16

TABLE 3B2:
"Ease of ignition" results for assemblies products tested according to Pr EN 1021.3

Products	**Time to ignition for seat (s)**	**Time to ignition for back (s)**
PF 09	50	62
PF 25	10	7
C 01	n.d.	n.d.
C 02	45	24
C 03	13	14
C 04	37	32
C 05	9	27
C 06	9	9
C 07	5	5
C 08	n.d.	n.d.
C 09	n.d.	n.d.
C 10	18	18
C 11	63	63
C 12	23	23
C 13	27	24

Remarks: **n.d. = no data available**

TABLE 3C:
"Easy of ignition" results for assemblies products tested according to Pr EN 1021.4

Products	Time to ignition for seat (s)	Time to Ignition for back (s)
PF 09	15	19
PF 25	10	1
C 01	11	13
C 02	17	14
C 03	14	14
C 04	5	5
C 05	3	3
C 06	9	9
C 07	6	6
C 08	25	n.d.
C 09	12	25
C 10	2	1
C 11	1	1
C 12	1	1
C 13	15	18

TABLE 3D:
"Ease of ignition" results for assemblies products tested according to UIC 564.2 Annex 13

Products	Time to ignition for seat (s)	Time to ignition for back (s)
PF 09	80	60
PF 25	27	28
C 01	58	38
C 02	45	55
C 03	30	23
C 04	50	49
C 05	28	35
C 06	47	45
C 07	40	32
C 08	32	30
C 09	12	25
C 10	70	68
C 11	64	87
C 12	52	61
C 13	90	92

Remarks: n.d. = no data available

TABLE 3E:
"Fire growth" results for assemblies products tested according to ISO 5660.1 at 25 kw/m^2

Products	q_{180} (kW/m^2)	q_{300} (kW/m^2)	q_{max} (kW/m^2)	THR (MJ/m^2)
PF 09	24.2	20.8	117.3	48.3
PF 25	51.4	38.0	117.0	10.7
C 01	15.9	12.7	130.3	53.3
C 02	16.2	11.5	114.7	17.4
C 03	42.8	31.1	98.3	43.5
C 04	35.7	22.9	159.6	8.0
C 05	49.6	51.9	165.7	83.1
C 06	30.2	20.8	204.7	33.3
C 07	28.5	17.1	128.0	4.3
C 08	98.0	59.2	226.6	17.7
C 09	n.d.	n.d.	n.d.	n.d.
C 10	35.9	29.5	213.9	8.76
C 11	79.9	63.1	206.2	74.4
C 12	129.1	98.7	439.0	77.0
C 13	118.5	87.4	321.8	37.0

Remarks: **n.d. =** **No data available**

TABLE 3F:
"Fire growth" results for assemblies products tested according to ISO 5660.1 at 35 kw/m^2

Products	q_{180} (kW/m^2)	q_{300} (kW/m^2)	q_{max} (kW/m^2)	THR (MJ/m^2)
PF 09	52.5	58.1	137.0	48.1
PF 25	63.5	49.1	125.2	16.1
C 01	31.3	38.7	159.7	62.9
C 02	79.3	61.6	170.0	88.2
C 03	62.8	47.7	132.3	82.2
C 04	81.9	66.4	283.3	80.1
C 05	75.9	68.2	182.0	88.9
C 06	67.3	52.1	279.0	86.7
C 07	91.2	62.5	167.1	15.9
C 08	111.0	72.2	265.6	64.6
C 09	n.d.	n.d.	n.d.	n.d.
C 10	56.0	46.0	246.9	15.3
C 11	104.0	93.2	281.4	87.0
C 12	173.4	147.8	524.8	92.1
C 13	133.2	110.4	328.8	53.9

Remarks: **n.d. =** **No data available**

TABLE 3G:
"Fire growth" results for assemblies products tested according to Pr EN 1021.3

Products	Flaming time (s)	Smouldering time (s)	Demaged volume for seat (cm^3)	Demaged volume for back (cm^3)	Total mass loss (g)
PF 09	4	n.d.	11.0	27.2	3.1
PF 25	35	n.d.	179.8	270.3	45.0
C 01	0	6	59.0	67.3	4.1
C 02	6	n.d.	34.8	44.1	7.1
C 03	17	n.d.	58.6	77.9	7.6
C 04	n.d.	n.d.	45.0	71.2	7.7
C 05	230	n.d.	559.5	690.0	10.0
C 06	n.d.	n.d.	108.8	126.3	11.3
C 07	n.d.	n.d.	191.8	304.5	11.3
C 08	n.d.	n.d.	n.d.	n.d.	n.d.
C 09	n.d.	n.d.	n.d.	n.d.	n.d.
C 10	128	n.d.	109.2	246.2	4.0
C 11	130	n.d.	74.0	134.0	4.3
C 12	184	n.d.	84.8	290.3	17
C 13	29	n.d.	39.2	46.8	8.6

Remarks: **n.d. =** **No data available**

TABLE 3H:
"Fire growth" results for assemblies products tested according to Pr EN 1021.4

Products	Flaming time (s)	Smouldering time (s)	Demaged volume for seat (cm^3)	Demaged volume for back (cm^3)	Total mass loss (g)
PF 09	8	n.d.	25.8	123.4	8.8
PF 25	30	n.d.	538.3	2304.7	54.7
C 01	1	16	165.8	524.4	18.5
C 02	6	n.d.	63.6	233.3	17.0
C 03	22	n.d.	149.3	286.7	22.1
C 04	20	n.d.	258.0	591.3	31.5
C 05	177	n.d.	1532.5	3723.8	36.5
C 06	10	n.d.	531.0	1598.3	21.5
C 07	n.d.	n.d.	620.0	2042.5	39.0
C 08	125	0	1865.0	7025.0	34.0
C 09	239	0	2799.0	6.0	68.7
C 10	125	n.d.	368.1	1213.0	21.0
C 11	154	n.d.	198.7	456.4	12.3
C 12	152	n.d.	234.6	796.4	19.7
C 13	70	n.d.	33.4	233.3	24.6

Remarks: **n.d. =** **No data available**

TABLE 3I:
"Fire growth" results for assemblies products tested according to UIC 564.2 Annex 13

Products	Flaming time (s)	Smouldering time (s)	Demaged volume for seat (cm^3)	Demaged volume for back (cm^3)	Total Mass Loss (g)
PF 09	166.7	97	52.8	56.9	6
PF 25	1273	203	3754.0	6666.7	2090.0
C 01	260	235	1673.0	2050.0	36.5
C 02	1335	n.d.	4963.5	5762.5	112.5
C 03	280	375	2380.0	1752	47.0
C 04	448	n.d.	4249.0	4393.3	127.0
C 05	860	n.d.	6711.0	8600.0	201.7
C 06	225	n.d.	3149.0	2424.3	127.0
C 07	498	n.d.	3415.0	6000.0	147.0
C 08	270	0	5635.0	9511.0	44.0
C 09	239	0	2799.0	11616.0	68.7
C 10	327	760	86.6	299.1	23.2
C 11	663	850	350.6	482.3	69.5
C 12	830	n.d.	206.0	622.0	116.8
C 13	295	0	752.0	932.3	2483.3

Remarks: **n.d. =** **No data available**

TABLE 3J:
"Loss of visibility" results for assemblies products tested according to ISO 5660.2 at 25 and 35 kW/m^2

	Irradiance:			
	25 kW/m^2		35 kW/m^2	
Products	**S" (m^2/m^2)**	**k_{max} (m^{-1})**	**S" (m^2/m^2)**	**k_{max} (m^{-1})**
PF 09	930.7	1.40	729.7	1.76
PF 25	56.6	0.79	79.5	0.49
C 01	1505.3	5.71	1655.7	7.15
C 02	413.3	4.85	822.7	6.37
C 03	1443.7	5.81	1881.7	10.32
C 04	162.7	1.06	214.3	1.32
C 05	685	3.25	953.0	1.81
C 06	370.8	0.64	533.7	1.18
C 07	893.8	4.71	768.5	6.68
C 08	656.3	4.9	1150.5	5.80
C 09	n.d.	n.d.	n.d.	n.d.
C 10	72.0	0.41	49.2	0.96
C 11	199.4	0.61	175.4	0.86
C 12	231.4	1.21	320.4	1.52
C 13	212.3	1.40	186.3	1.40

TABLE 3K:
"Loss of visibility" results for assemblies products tested according to ISO 5659.2 at 25 kW/m^2 no pilot flame

Products	Maximum level of smoke density (Dmax)	Smoke density value at 10 min (D_{10})	Index of smoke growth for the first 4 min. (V0F4)
PF 09	197	135	76
PF 25	174	162	463
C 01	221	216	378
C 02	n.d.	n.d.	n.d.
C 03	404	397	947
C 04	173	167	319
C 05	227	224	468
C 06	125	122	236
C 07	633	625	1404
C 08	458	435	234
C 09	n.d.	n.d.	n.d.
C 10	201	198	295
C 11	265	254	207
C 12	271	254	326
C 13	313	312	381

Remarks : n.d. = no data available

TABLE 3L:
"Loss of visibility" results for assemblies products tested according to ISO 5659.2 at 25 kW/m^2 with pilot flame

Products	Maximum level of smoke density (Dmax)	Smoke density value at 10 min (D_{10})	Index of smoke growth for the first 4 min. (V0F4)
PF 09	86	52	22
PF 25	48	48	31
C 01	169	151	440
C 02	75	75	211
C 03	257	175	751
C 04	40	38	75
C 05	114	92	73
C 06	n.d.	n.d.	n.d.
C 07	413	317	1168
C 08	625	493	1076
C 09	n.d.	n.d.	n.d.
C 10	108	106	75
C 11	150	140	82
C 12	180	169	239
C 13	205	196	293

Remarks: n.d. = No data available

TABLE 3M:
"Loss of visibility" results for assemblies products tested according to ISO 5659.2 at 50 kW/m^2 no pilot flame

Products	Maximum level of smoke density (Dmax)	Smoke density value at 10 min (D_{10})	Index of smoke growth for the first 4 min. (V0F4)
PF 09	368	353	448
PF 25	68	65	176
C 01	419	359	800
C 02	442	412	1066
C 03	435	352	1370
C 04	99	91	244
C 05	343	268	672
C 06	201	113	275
C 07	687	665	2135
C 08	719	660	1809
C 09	n.d.	n.d.	n.d.
C 10	95	89	219
C 11	182	125	583
C 12	173	119	509
C 13	174	147	487