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Work package 3.2 Part 2: Selection of large and real scale test methods for furniture products for Work Package 7.2 and 8.2.

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1 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 programme includes a series of tests to evaluate in large and real scale the fire behaviour of a representative range of furniture products used on European trains.
As indicated by statistical research on fires in trains and the description of the best fire scenario in railway vehicle determinated by Work Package 1, the seat represents the most dangerous part of the compartment; it is the only furniture product which will be evaluated in WP7.2 and WP8.2.
This report describes the reaction to fire test methods which have been selected. The detailed test procedures are reported in Annex A and Annex B.

2 OBJECTIVES OF WP 3.2 PART 2

The objective of the WP 3.2 part 2 are essentially two:

I) To define a large scale test method for seats used in railway vehicles. The method will be used in WP 7.2 and could be selected as a supporting test to small-scale tests chosen for classification purposes.
II) To define a real scale test method for seats used in railway vehicles which will be adopted in WP 8.2 as the validation test for small scale tests performed in WP4.2 and large scale tests carried out in WP7.2.

The methods have to represent as close as possible the conditions described by the reference scenario of WP 1.
They will reproduce the end-use conditions of the railway products selected in WP 2 and should be able to measure the main five reaction to fire parameters : ignitability, spread of flame, rate of heat release, smoke generation and the toxic gas species produced during the combustion.

Amongst the different categories and application areas of selected products, referenced as furniture products, the main ones include seats, curtains and bedding; only seats will be tested in large and real scale as the most dangerous part of the compartment and representing the probable primary ignited item in the interior of a railway vehicle.

In carrying out small scale tests, some assemblies were defined which were simply a combination of a block of foam covered first with a piece of an interlayer and second with a piece of fabric covering.
As requested by various railway companies, the FIRESTARR consortium should test full-scale seats as they actually exist on European trains.

These full size seat products will be selected and evaluated in both large and real scale tests.

3 PARTICIPANTS

The following 9 partners of working group 3.2 part 2 made the selection of large and real reaction to fire test methods for seats of furniture products :

LSF (leader)
BASF
BAYER
DBI
FS
ISSEP
LNE
SNCF
WFRC

4 SELECTION OF LARGE-SCALE TEST METHOD

The definition of the main characteristics of fire behaviour related to products used in railway vehicle is correlated with measurements of five reaction to fire parameters: ignitability, spread of flame, heat release, smoke opacity and toxic potency.
In the small scale tests the choice of method hadto take into account also the representativity of the reference scenario, sampling of product, the standardised and international methods and the economic aspects.
Where small scale samples are not representative enough,it is necessary to test these products on the final shaped product or a test specimen of large dimension.

Concerning the furniture products (ref. 2) and in particular for seats only, one method was selected for use in Working Programme 7.2 that is, the Furniture calorimeter Test.

4.1 Furniture calorimeter test

This method has the advantage of being already an International Standard and permits to perform the test directly on the full real product.
It comes from NT FIRE 032 Standard (ref. 7) which intended the method to be used for the evaluation of fire behaviour of upholstered furniture products and generally describes a tecnhical procedure for ignition of a seat by a specified flame source. During free combustion under well ventilated conditions, data describing the fire behaviour from ignition to complete burn out is obtained and recorded.

The selection of this method was derived also from its use in a previous big European research project on fire safety of upholstered furniture named CBUF where a well defined and full detailed test protocol was adopted to test several type of chairs; it is specially useful for the measurement of toxic gases produced during the combustion.

Another reason for adopting this Standard to carry out the tests on railway vehicle seats is the possibility to choice and use an appropriate ignition source which better reproduces the realistic thermal attack.

In the objectives of the FIRESTARR project, the scope of the method is to simulate the best fire scenario defined by WP1 which means to reproduce an arson attack by a primary ignition source on a seat. This event represents the probable primary ignited item in the interior of railway vehicles.

The method is intended to evaluate the contribution to fire growth and smoke generation from a seat which is forcing ignited using a square burner applied on 3 different levels of vendalised seat.

Starting from NT FIRE 032 Standard (ref. 7) as reference document, a new “ad hoc” protocol was developed for FIRESTARR project requirements and so for WP 7.2 testing.
It is detailed in ANNEX A.

4.2 Ignition source : “FIRESTARR A” burner.

The ignition source that will be used in WP 7.2 testing programme was studied and designed by the leader of this WP. It originally comes from pr EN 1021 part 4 Standard (ref. 6) as Belfagor burner and then modified to simulate the same thermal attack given by 100gr of burning paper cushion.
The choice to use a square burner was made to improve the ignition source in terms of repeatability and reproducibility.
The primary version of Belfagor burner used in Pr EN 1021.4 Standard (ref. 6) was shown in small scale test series to be less severe than the 100g paper cushion, in particular when applied to a seat part.
LSF has carried out several comparison tests and attempts on TGV seats to identify the right changes to make on the original Belfagor burner and the new ignition source has been named “FIRESTARR A”.
This new burnerhas been shown experimentally to have the following properties:-

Flow rate of propane gas: 5 l/min
Correspondant thermal attack on seat: 7 kW
Application time: 180s

The burner is described and shown in the Annexes.

5 SELECTION OF REAL-SCALE TEST METHOD

This test should demonstrate the fire behaviour of some critical furniture parts of a coach.
Moreover, it has to take into account the defined most probable and realistic scenario coming out from the WP1 study and will serve as a main validation procedure in verifying the predictions and proposals of the classification system criteria using the information from WP10 when comparing the results with small and large scale data.

The end use conditions of materials or products in a carriage have to be taken in consideration and the following 5 reaction to fire parameters have to be measured: ignitability, spread of flame, rate of heat release, smoke generation and toxic gas species generation.

The choice of the real scale method has to take into account also some other parameters related to the fire hazard such as the time to flash-over and tenability limits.
Tenability is determined on the basis of fire effects on passengers, including both direct effects, such as heat, toxic gases or oxygen deprivation, and indirect effects, such as reduced visibility due to smoke obscuration.

For furniture products (particularly seats), as for structural materials, only one method and procedure was selected for use in Working Programme 8.2, that is the Train Compartment test.

5.1 Train Compartment test

Looking to the WP1 (ref.1) conclusion, a railway carriage Voiture VU78 with 11 compartments served by a side corridor was identified by SNCF.
Each compartment contained eight seats, a 1200mm x 950mm window and a 1930mm high x 600mm wide door opening to the corridor. The compartment was 2300mm high, 1900mm wide and 2040mm long (see figures in annex B). The ceiling of the compartment was curved from a height of 1940mm above floor level. This compartment may be assumed to have a volume of approximately $9m^3$ and so comparable to the small compartment size of $<10m^3$, which CEN/TC 256 JWG specified in their materials requirements document prEN 45545 Part 2 (ref. 4).

The ventilation conditions into the Voiture VU78 compartment were precisely defined by SNCF and are shown in FigureB.2of Annex B. Since SNCF were able to supply the exact ventilation grids used in their compartment to the FIRESTARR laboratories, this was a critical requirement in the selection of this compartment for the WP8.2 and WP8.1 tests.

It was relevant to note that similar designs of railway vehicles are common on Italian Railways. FS provided details of their smallest T25 sleeping compartment with dimensions of 1975mm x 1223mm x 2190mm (i.e. $5.3m^3$). This compartment has a maximum airflow of about $100m^3/h$ with a similar circulation pattern to the Voiture VU78 compartment.

ISO 9705 Part 2 (ref. 3) extends the scope of the ISO 9705 small room test methodology since non-lining products may be evaluated inside the room, or other products may be evaluated under the 3m x 3m hood. This means that the same measurement system for fire effluents may be applied to these other test conditions. It was concluded that a real-scale Voiture VU78 compartment could be sited underneath the standard ISO 9705 hood/duct system. The apparatus for this compartment test is shown in Figures B.1 and B.3of Annex B.

5.1.1 Principle

Two seats were placed edge to edge inside the compartment and positioned in the right wall on the corner with window side; a third seat was placed on the other side and then facing and in the same orientation of the ignited seat for the verification of the effect developed by the first item fire source respectively exposed in front of another seat and on its back side from behind.
According to the fire scenario, the real and worst fire source, represented by 100g of paper cushion, is reproduced by FIRESTARR Burner “A”.
This source is applied on first seats in the corner for three minutes with the door closed and after that at same time the burner is removed and the door opened.
For simulating the different and probable real situations which may occur with different positions of seats in a compartment, 3 different stages/tests were determined:

Stage1: The seat that will be ignited is not vandalised. The objective is to observe if there is a flame spread to the adjacent seat and facing seat measuring all reaction to fire parameters which may be related to the identified risks.
Stage2: The seat that will be ignited is vandalised. The objective is the same of the first stage.
Stage3: The seat that will be ignited is vandalised. The objective is to observe if there is a flame spread to the adjacent seat and the effect to the back side of a third seat placed before the first one with the same sense of direction. All reaction to fire parameters which may be related to the identified risks were measured.

An additional Stage 4 was included in this procedure only for testing some combinations which have their structural frame that permitts only one configuration of mounted seats and

differently from the others. In this case the seats were placed as a sofà in the centre of the compartment and oriented in the opposite direction with the same frame to apply their seat-backs which are in contact.

Stage 1, stage 2, stage 3 and stage 4 are described in the scheme 1, 2, 3 and 4.

The procedure is intended to assess the ignitability, heat release, spread of flame and toxic gases when the door is initially closed and subsequently (after 3 minutes) opened for simulating as soon as possible the two main stages of real fire scenario (limited and full ventilation).

For the determination of toxic gas species, one sampling probe is positioned inside the compartment at the door level and a second one along the exhaust duct; in this way is possible to determine the toxicity hazard generated by fire smoke and so compare the results on qualitative/quantitative analysis of effluents coming from the different sampling points.

A detailed description of technical aspects about toxicity measurements is given in the WP3.4 Part 2 Report.

A new “ad hoc” protocol was developed for FIRESTARR project requirements and so for WP 8.2 testing It is detailed in Annex B.

6 REFERENCES

1. FIRESTARR WP1 Report. WP1/FS/98002
   Statistical analysis of fires which have occurred in European Railways

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

3. ISO 9705 : 1993 Fire Tests – Full-scale room test for surface products

4. prEN 45545 Part 2 Draft document WGS 2006 : 2000
   Material requirements : Classification for Fire Protection

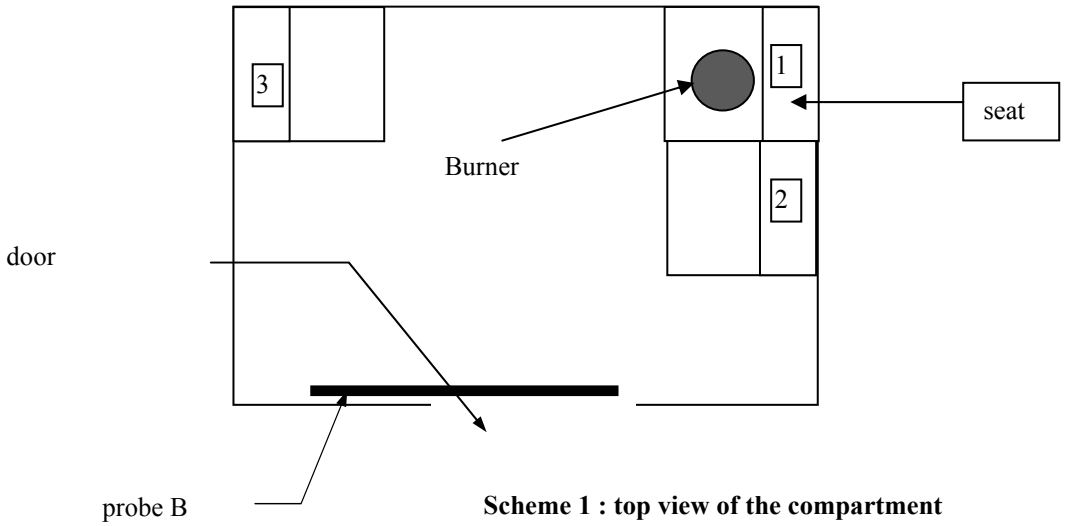
5. ISO 9705 Fire Tests – Reaction to Fire – Full-Scale Room Test for Surface Products
   Part 2 : Guidance Document

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

7. FURNITURE CALORIMETER TESTS - NT FIRE 032. Upholstered furniture: Burning behaviour – Full scale test

↳ stage 1 (see scheme 1) :

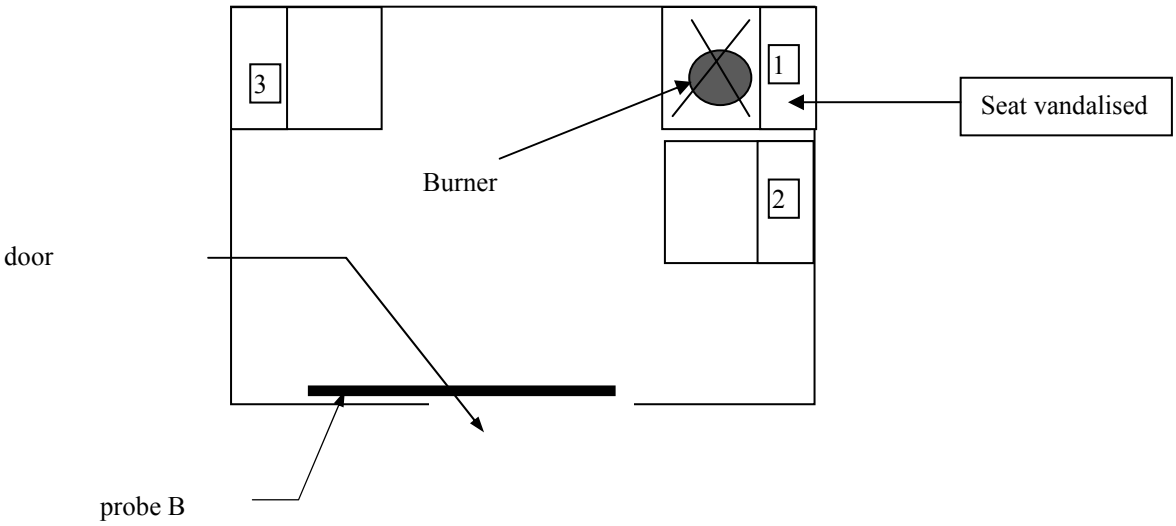
→ 3 seats not vandalised in the compartment, (see scheme 1)
→ toxic gas analysis in the exhaust duct : probe A
→ Toxic gas analysis at nose level in the door opening : Probe B
→ measurements and observation during the test



Scheme 1 : top view of the compartment

↳ stage 2 : (see scheme 2)

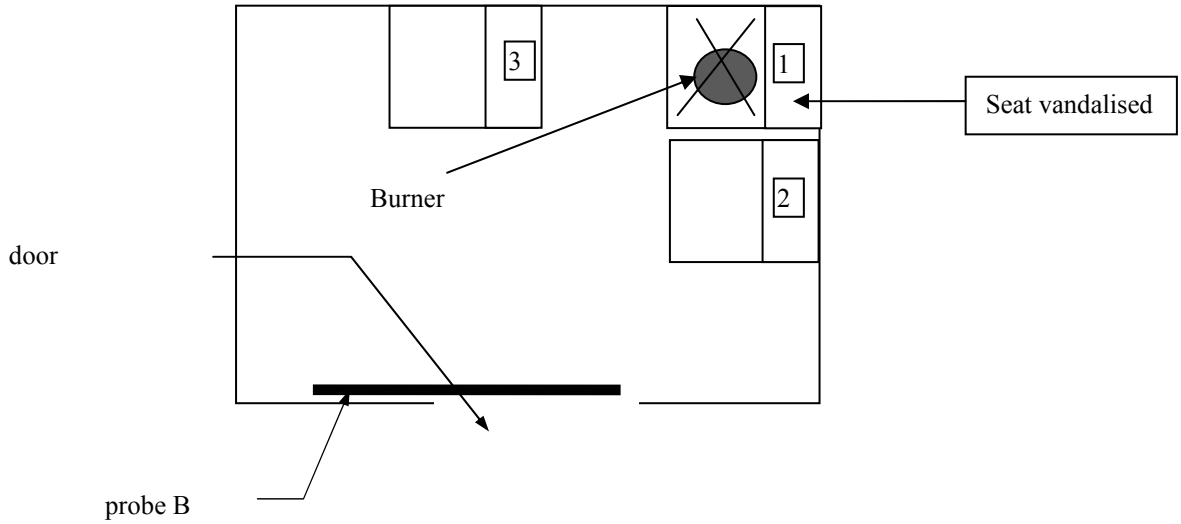
→ 3 seats with one vandalised (n°1) in the compartment
→ toxic gas analysis in the exhaust duct : probe A
→ Toxic gas analysis at nose level in the door opening : Probe B
→ measurements and observation during the test



Scheme 2 : top view of the compartment

↳ stage 3 : (see scheme 3)

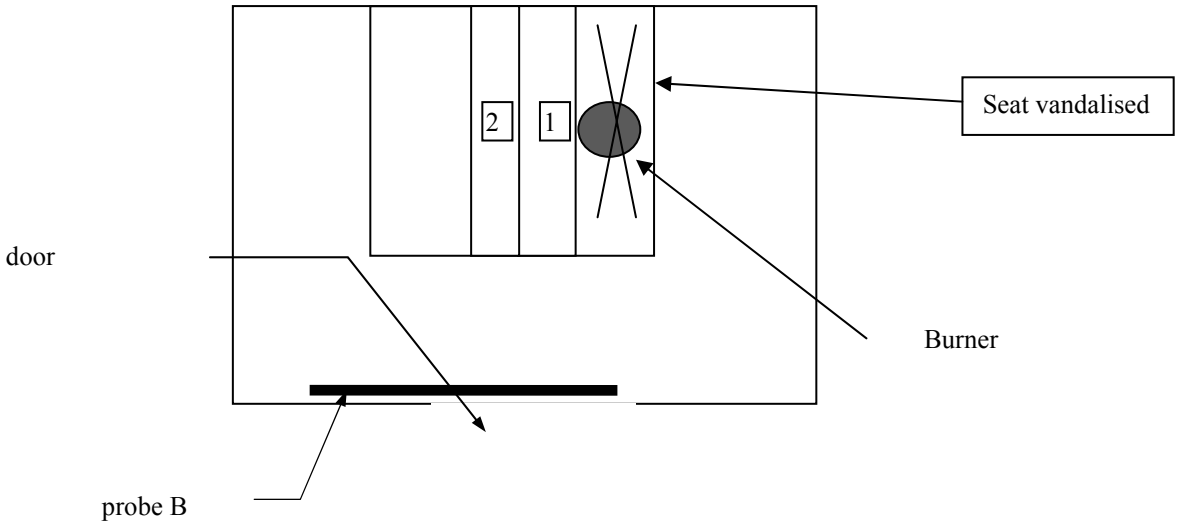
→ 3 seats with one vandalised (n°1) in the compartment
→ toxic gas analysis in the exhaust duct : probe A
→ Toxic gas analysis at nose level in the door opening : Probe B
→ measurements and observation during the test



Scheme 3 : top view of the compartment

↳ stage 4 : (see scheme 4)

→ 2 seats as sofa configuration with one vandalised (n°1) in the compartment
→ toxic gas analysis in the exhaust duct : probe A
→ Toxic gas analysis at nose level in the door opening : Probe B
→ measurements and observation during the test



Scheme 4 : top view of the compartment

ANNEX A: Large scale Furniture Calorimeter test. Method for seats used in railway vehicles

1. SCOPE

This Laboratory procedure specifies a test method that simulates an arson attack by a primary ignition source on a seat that represents the probable primary ignited item in the interior of railway vehicles (ref. 2.6).

The method is intended to evaluate the contribution to fire growth and smoke generation from a seat which is deliberately ignited using a square burner applied to 3 different levels of vandalised seat.

This test is performed essentially in accordance with the principles and methods specified in NT FIRE 032 Standard.

2. REFERENCES

The specifications given in the following reference documents have to be taken into account for performing this test according to FIRESTARR WP7.2 procedure:

2.1 ISO 9705: 1993 Full-scale room test for surface products – Room corner test.

2.2 NT FIRE 032: 1991 Upholstered furniture – Burning behaviour on full scale test.

2.3 SAFIR Final report : 1999 Smoke gas analysis by Fourier transform infrared spectroscopy.

2.4 Draft ISO standard/Technical report proposal: 1999 Toxicity testing of fire effluents – Analysis of gases and vapours in fire effluents using FTIR technology.

2.5 CBUF Final report EUR n. 16477 EN – Fire Safety of Upholstered furniture (edited by B. Sundstrom) Appendix 7 and 8.

2.6 FIRESTARR WP1/FS/98002: Report of Work Package 1.

2.7 FIRESTARR WP2/SNCF/98004: Report of Work Package 2 – Selection of products for small scale tests.

2.8 FIRESTARR WP5/LNE/TYPE26: Analysis of small scale tests data for Assemblies

3. DEFINITIONS

3.1 seat: Furnishing seat which is generally recognised in railway vehicles

3.2 product: Assembly of seats about which information is required.

A product may contains 2 or 3 attached seats.

3.3 specimen: Representative piece of a product which has to be tested including the mounting frame but in single seat configuration.

3.4 Ignition of the seat: when the heat release peak reaches at least the value of 30 kW excluding the burner contribution.

4. PRINCIPLE

A railway seat is mounted on the upper part of a weighing platform and under the ISO 9705 (ref. 2.1) hood and duct measuring system.
The ignition source is a square burner which has been studied and designed to simulate the thermal attack given by a 100gr burning paper cushion.

The seat is ignited through 3 different growing levels of vandalisation:

- non vandalised seat
- 1st level vandalised seat
- 2nd level vandalised seat

The ventilation conditions essentially represent a well-ventilated railway compartment with door open.

5. TEST APPARATUS

5.1 HR measurement

The gas sample for oxygen measurement shall be taken in the exhaust duct at a position where the combustion products are uniformly mixed.
A multihole stainless steel probe tube with inner diameter of 10mm shall be horizontally fitted across the section of exhaust duct. It shall consist in two series of 10 holes of 2mm and 3mm diameter having a distance between them of 10mm and facing downstream.
The accuracy and calculation of the heat release measuring device should be in accordance to the specification given in NT FIRE 032 Standard (ref. 2.2) and time between two scans not exceed 5 s.

5.2 CO and CO_2 measurement

The gas species shall be measured from the same sampling line of oxygen measurement by NDIR analyser having an accuracy of $\pm$ 0.1 vol% for carbon monoxide and $\pm$ 0.02 vol% for carbon dioxide. The optimal output range is 0-1% for CO and 0-6% for CO2. The time between two scans shall not exceed 5s. All other specifications on calculations and measuring device are given in NT FIRE 032 Standard (ref. 2.2).

5.3 Smoke measurement

The optical density of the smoke is determined by measuring the light absorption with a system consisting of a lamp, lenses, an aperture and a photocell detector. It shall be placed so that this light beam crosses the exhaust duct along a diameter at point where the smoke is homogeneous.
All specifications about lamp, lenses, aperture and detector are given in the NT FIRE 032 Standard (ref. 2.2).
The smoke production rate should be calculated according to ISO 9705 Annex F (ref. 2.1).

5.4 Weighing platform

The weighing platform shall be used to continuously measure the mass loss of the burning test specimen and consists of a 2400 x 1200mm non-combustible slab (e.g. calcium silicate board) placed at 1750-2000mm below the lower edge of the hood and 500±200mm above the floor level on top of a weight measuring device.
It has to be centred under the smoke collection hood.
All other specifications are given in the NT FIRE 032 Standard (ref. 2.2).

5.5 The smoke collection hood

The hood shall be in accordance to NT FIRE 032 (ref. 2.2).

5.6 Ignition source, gas supply (FIRESTARR Burner A)

A gas burner named FIRESTARR Burner A should be used. It is the Belfagor square burner (see PR EN 1021 parts 3 and 4 Standard) which is modified with 6 additional holes of 1mm diameter all oriented directly to the seat surface and placed as shown in Appendix B.
Propane gas shall be used at a flow rate of 5l/min (this value corresponds to a thermal attack of 7 kW).

5.7 Application of the burner on seat

The burner should be positioned in the horizontal plane level following the Pr EN 1021 parts 3 and 4 Standard except for the weight of the burner on the seat,which shall be 100g.
It shall be placed midway between the two edges of the seat.
The application time of the burner shall be 180s ± 1s.

5.8 Smoke gas analysis performed by FTIR equipment

The composition of smoke gases shall be analysed by an FTIR instrument. The specifications and requirements of the analysis technique shall be according to the SAFIR Final Report (ref. 2.3) in section WP2 - Sampling in large scale.
An additional sampling probe shall be fitted into the exhaust duct for the analysis of the chemical composition of the smoke gases. It shall be constructed according to paragraph 9.2.1, oriented vertically in the duct and mounted not more than 300mm away from the existing duct flow temperature measurement (HRR) and near the bi-directional probe, downstream.
After the sampling probe a heated filter shall be fitted and heated as the rest of sampling line which shall be fabricated from Teflon tube. All parts of the sampling line must be heated to at least 150 °C.

5.9 Environment around the burning sample

The environment around the burning sample shall be a draught free area with no more than 2 walls closer than 2m from the outer edge of the smoke collection hood.

6. CALIBRATION

Before performing the tests the heat release measuring system shall be calibrated with a propane gas burner (the same ignition source recommended in ISO 9705 Standard – ref. 2.1). Three levels of heat output are used : 100, 300 and 700 kW. In addition, the system shall be checked every morning with a propane calibration at 300 kW of heat output level. The calibration procedure is in accordance with Nord test Fire 032 (ref. 2.2).

7 SPECIMEN

7.1 Size and test configuration

The product shall be tested as a single seat configuration and centred on the testing platform just before the test.
If the furniture item is originally a double or multi seats product, it shall be cut into separate single seats for testing.

7.2 Laceration of seats

7.2.1 Laceration representing the 1st level of vandalised seat

The covering and interlayer (if one exists) of only the seat (topside) of the specimen shall be cut along the diagonals beginning 5cm from the corners. The edges shall not be removed.

7.2.2 Laceration representing the 2nd level of vandalised seat

The covering and interlayer (if one exists) of the seat (topside) and back side of the specimen shall be cut along the diagonals beginning 5cm from the corners. The edges shall be removed so that the foam is uncovered and directly in contact with burner.

7.3 Number of replicates

A maximum of 2 tests shall be replicated following the testing sequence illustrated in Appendix A.

8. CONDITIONING

The specimen shall be conditioned for a least one week in an atmosphere having temperature of 23±5°C and a relative humidity of 50±5%.

The test procedure detailed in paragraph 10 shall be carried out within 1 hour after removal of the specimen from the conditioned environment.

9. FTIR PROCEDURE TECHNIQUES FOR FIRE GASES MEASUREMENT

9.1 General description of FTIR measurement technique

SAFIR final report (ref. 2.3) requirements which are summarised into ISO Draft Standard/Technical report proposal “Toxicity testing of fire effluents – Analysis of gases and vapours in fire effluents using FTIR technology”(ref. 2.4) shall be adopted.

The principle of this method is:

Smoke gas samples for FTIR analysis are taken from a sampling line connected to an exhaust duct and drawn continuously through a heated sampling line and IR absorption cell of a FTIR spectrometer.
The infrared beam is directed by a mirror system through the gas absorption cell and at chosen intervals interferograms are acquired and then converted to absorption spectra.
All parts of sampling line and IR absorption cell are heated at least 150°C to prevent the water from liquefying and dissolving gases like HCl and HBr.
FTIR technique measurement and device are based on the conversion of regular irradiance from an infrared source into interfered irradiance and transformation of an interferogram into a conventional wavelength spectrum with wide range. The spectrum is shown as absorbance (energy absorbed in the optical path) as function of frequency radiation expressed in wave number (number of cycles per cm).
Polyatomic and heteronuclear diatomic compounds having an infrared region of absorbance can be identified looking to their characteristic wavelengths and quantified on base of absorption intensities. Concentrations are calculated by the relationship between the areas-absorbance of unknown spectra and reference gas mixtures with known concentration of gases.

9.2 Sampling line description

9.2.1 Probe

A multihole stainless steel probe tube with inner diameter of 10mm is vertically fitted across the section of exhaust duct. It shall consist of two series of 10 holes with 2mm and 3mm diameters having a distance between them of 10mm and facing downstream.

9.2.2 Filter

Either planar membrane filters or cylindrical filters are recommended. The planar filters should optimally have a porosity of 5 micron and a diameter of 47mm, although other porosity and diameter may be used.

9.2.3 Sampling line

A gas sampling line of PTFE with an inner diameter of 3-4mm should be used. This line has to be kept at a constant temperature of at least 150°C. The length should be as short as possible but in any case shall not exceed 4m.

9.2.4 Flow rate

From 5 to 10 l/min, depending on the requirements of the response time.

9.2.5 Procedures and instrumental requirements

The recommended resolution is between 2 and 4 cm^{-1}. The response time of the analysis should be 30s or less.
The filter shall be taken out from the filter unit at the end of each test. It shall be rolled up and introduced into a calibrated flask of water for complete dissolution. After filtration, the solution shall be analysed by ion selective potentiometry for halogen compounds determination.

9.2.6 Toxic gases species

The gaseous species to be analysed are: CO, CO2, O_2, HCN, NOx, HCl, HBr, SO_2,Acrolein and Formaldehyde.
The objective of the analysis is compare the results obtained with real and small scale test data.

10. Test procedure

10.1 The temperature of the test area under the exhaust hood from the start of specimen placed onto the weighing platform until the start of the test shall be 20°C±10°C.

10.2 The volume flow rate shall be set to 2.5 m^3/s and kept constant during all testing time.

10.3 Record a baseline at least 2 minutes before the ignition of the burner for all type of measurements.

10.4 Ignition sequence and test performing

After the baseline recording, the burner which has previously been checked for position, shall be lit away from specimen and stabilised for 1minute.

The burner shall be carefully applied onto the seat and a clock shall be started.

After the specified application time the gas flow shall be stopped and the burner carefully moved out.

During the test the following events with their times shall be noted:

Ignition of seat
Melting and dripping
Fire under the seat
Flame reaching the front, bottom, top of back, edges of back and edges of seat.
Collapse of any part
Any other event of interest

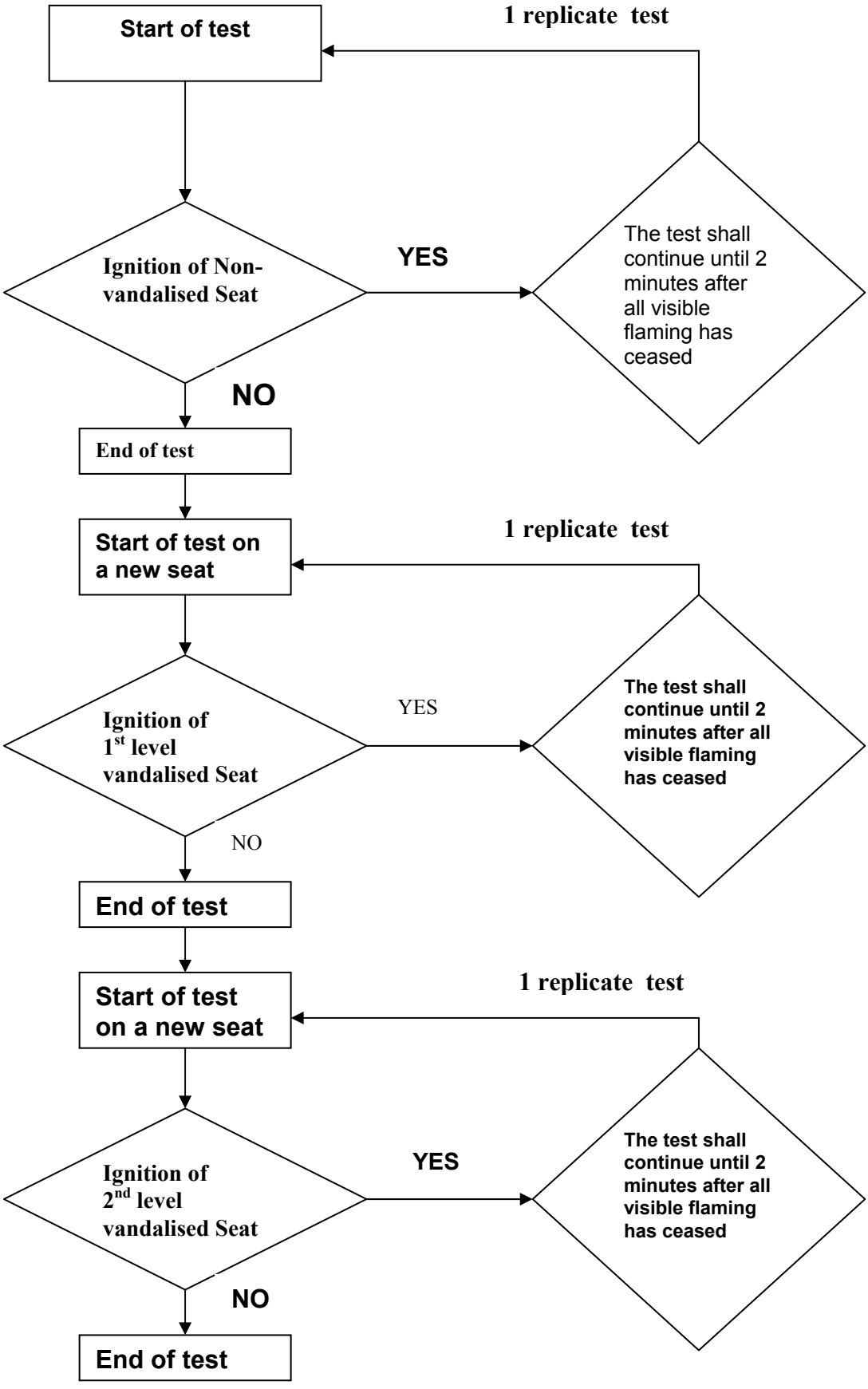
The test shall continue until 2 minutes after all visible flaming is stopped.

11. Test report

The test report shall include the following information:

Name of Testing Laboratory
Test method
Identification number and name of product
Description of the specimen
Conditioning
Date of test
Method of sampling for toxic gases analysis system
Test results : graphs of HRR, production of CO, production of CO2, production of smoke rate, mass flow rate on duct, production of all gaseous species detected by FTIR.
Deviations from the test method
Optionally equipment and instrument used.

<u>Appendix A</u>: FIRESTARR WP 7.2 Large scale test for railway seats – Testing sequence:

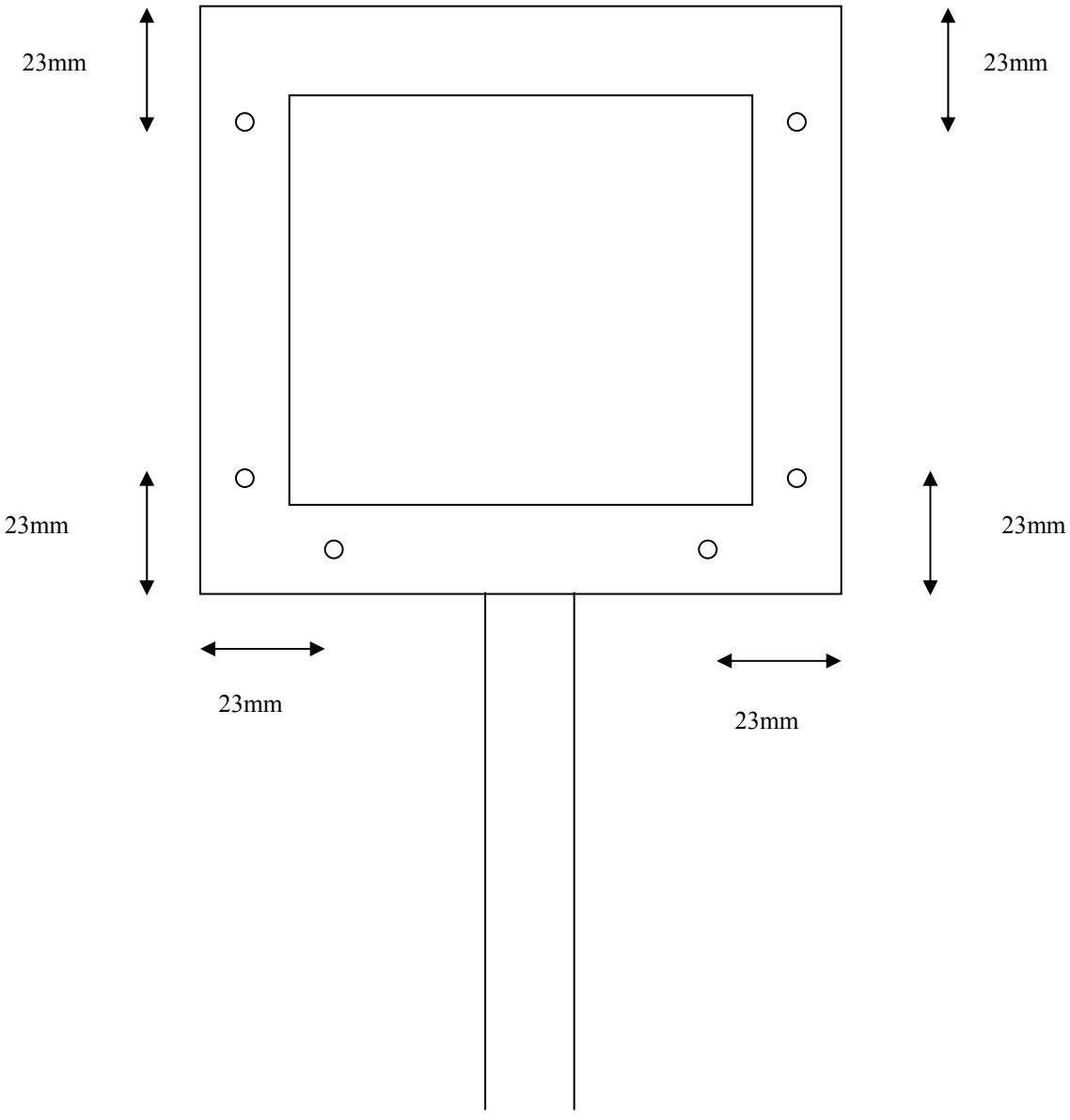


<u>Appendix B</u> : BURNER Firestarr "A"

Belfagor burner with additional holes as here shown.

Add these 6 (six) holes of 1mm diameter to the original Belfagor burner (described in Pr EN 1021.3/4 Standard), all oriented directly to the seat surface and placed as here shown:

LOWER VIEW



Annex B : Small compartment test. Real scale method for seats used in railway vehicles.

1. SCOPE

This Laboratory Procedure specifies a test method that simulates a burning seat within a small compartment under well-ventilated conditions with an open door.

The method is intended to evaluate the contribution to fire growth and smoke generation from a seat which is deliberately ignited using a square burner applied onto 2 different levels of vandalized seat(both seat and back damaged).

2. REFERENCES

2.1 ISO 9705: 1993 Fire Tests – Full scale room test for surface products

2.2 ISO 9705 Part 2 (to be published in 2000) Fire Tests – Reaction to Fire – Full scale room test for surface products: Guidance

2.3 WP7.1/LSF/0000X?? Designing fires for FIRESTARR – Determination of the thermal attack to be used to evaluate the reaction to fire performance of structural products (walls and ceilings).

2.4 NT FIRE 032: 1991 Upholstered furniture – Burning behaviour on full scale test.

2.5 SAFIR Final report: 1999 Smoke gas analysis by Fourier transform infrared spectroscopy.

2.6 Draft ISO standard/Technical report proposal: 1999 Toxicity testing of fire effluents – Analysis of gases and vapours in fire effluents using FTIR technology

3. DEFINITIONS

3.1 seat: furnishing seat, which is generally recognized in railway vehicles.

3.2 product: assembly of seat about which information is required.

A product may contain 2 or 3 attached seats.

3.3 specimen: representative piece of a product, which is to be tested including the mounting frame, but in single seat configuration.

3.4 Ignition if the seat: when the heat release peak reaches at least the value of 30 kW excluding the burner contribution.

4. PRINCIPLE

An enclosure, with the specimen incorporated into three walls and a ceiling, simulating a compartment within a railway carriage, is burnt under the ISO 9705 hood and duct measuring system. The enclosure is based on the dimensions of a typical compartment for a 'Voiture VU78' railway carriage, the specifications of which have been supplied by SNCF.

The test specimen is mounted on steel representing seat bases benches in the right corner near the window.

The fire source is a laboratory propane burner, which has been designed to simulate the heat output and heat flux on the compartment seat caused by 100gr of paper (burner 100 gr paper equivalent). This burner is called Firestarr "A" (Fig. B4) and is derived from the Belfagor burner with additional holes (6 holes). The ventilation conditions are the same as those used for the furniture calorimeter and essentially represent a well-ventilated compartment with the door open.

The method provides data for the specified ignition source for the early stages of a fire from ignition up to full involvement of the walls and ceiling. Measurements of heat release, smoke opacity and concentrations of toxic gases are made in the ISO 9705 ducting.

5. TEST APPARATUS

5.1 HR measurement

The gas sample for oxygen measurement shall be taken in the exhaust duct at a position where the combustion products are uniformly mixed.
A multihole stainless steel probe tube with inner diameter of 10mm shall be horizontally fitted across the section of exhaust duct. It shall consist in two series of 10 holes of 2mm and 3mm diameter having a distance between them of 10mm and facing downstream.
The accuracy and calculation of the heat release measuring device should be in accordance to the specification given in NT FIRE 032 Standard (ref. 2.2) and time between two scans not exceed 5s.

5.2 CO and CO_2 measurement

The gas species shall be measured from the same sampling line of oxygen measurement by NDIR analyser having an accuracy of $\pm$ 0.1 vol% for carbon monoxide and $\pm$ 0.02 vol% for carbon dioxide. The optimal output range is 0-1% for CO and 0-6% for CO2. The time between two scan not exceed 5s. All other specifications on calculations and measuring device are given in NT FIRE 032 Standard (ref. 2.2).

5.3 Smoke measurement

The optical density of the smoke is determined by measuring the light absorption with a system consisting of a lamp, lenses, an aperture and a photocell detector. It shall be placed so that his light beam shall cross the exhaust duct along a diameter at point where the smoke is homogeneous.
All specifications about lamp, lenses, aperture and detector are given in the NT FIRE 032 Standard (ref. 2.2).
The smoke production rate should be calculated according to ISO 9705 Annex F (ref. 2.1).

5.4 The smoke collection hood

The hood shall be in accordance to NT FIRE 032 (ref. 2.2).

5.5 Ignition source, gas supply (FIRESTARR Burner A)

A gas burner named FIRESTARR Burner A should be used. It is the Belfagor square burner (see PR EN 1021 parts 3 and 4 Standard) which is modified with additional 6 (six) holes of 1mm diameter all oriented directly to the seat surface and placed as shown in Figure B.4.
Propane gas shall be used at flow rate of 5l/min (this value corresponds to a thermal attack of 7 kW).

5.6 Application of the burner on seat

The burner should be placed in front of the seat that shall be ignited and positioned in the horizontal plane level following the Pr EN 1021 parts 3 and 4 Standard except for what concerns the weight of the burner on the seat that shall be 100g.
It shall be placed midway between the two edges of the seat.
The application time of the burner shall be 180s $\pm$ 1s.

5.7 Smoke gas analysis performed by FTIR equipment

The composition of smoke gases shall be analysed by an FTIR instrument. The specifications and requirements of analysis technique shall be according to SAFIR Final Report (ref. 2.3) in section WP2 - Sampling in large scale.
An additional sampling probe shall be fitted into exhaust duct for the analysis of the chemical composition of the smoke gases. It shall be constructed according to paragraph 9.2.1, oriented vertically in the duct and mounted not more than 300mm away from the existing duct flow temperature measurement (HRR) and near the bi-directional probe, downstream.
After the sampling probe a heated filter shall be fitted and heated as the rest of sampling line that shall beconstructed from Teflon tube. All parts of sampling line must be heated at least 150°C.

5.8 Environment around the burning sample

The environment around the burning sample shall be a draught free area with no more than 2 walls closer than 2m from the outer edge of smoke collection hood.

5.9 Test Specimen Framework

The test specimen is assembled on a steel framework representing a railway carriage compartment (Figure B.1). The lower parts of the walls are constructed of non-combustible boards or steel sheets backed with mineral wool insulation. The non-combustible boards shall be calcium silicate boards with a density of (800 $\pm$ 150) kg/m^3 and a thickness of (12 $\pm$ 3) mm.

A similar non-combustible board shall also be used to form the dummy window; however for durability the thickness may need to be increased.

Within the compartment, two steel benches measuring 2020mm $\times$ 600mm $\times$ 300mm high shall be positioned along the walls to simulate the seat bases.

5.10 Air Distribution System

The air distribution system was based on drawings supplied by SNCF of the system used within the Voiture VU78 railway carriage.

A schematic layout of the air distribution is shown in Figure B.2. The air entering the compartment initially passes through a 175mm × 200mm section of ducting at floor level that extends the full width of the enclosure. A proportion of the air exits from a 160mm × 80mm grille located at floor level beneath the opposite seat. The remaining air passes through a venturi, which draws additional air from within the compartment via a 900mm × 100mm intake grille, and exits through a 1000mm × 70mm grille positioned directly beneath the dummy window. The air leaves the compartment through both the open door and a 200mm × 90mm extract grille located beneath the seat adjacent to the door.

Air shall be supplied to the distribution system by a fan and suitable speed controller. The air input shall be adjusted to 261m^3/h by using an anemometer positioned centrally within the ducting at the point where it enters the side wall of the compartment.

5.11 Hood and exhaust duct

The system for collecting the combustion products shall have a capacity and be designed in such a way that all of the combustion products leaving the corner specimen assembly during a test are collected. The exhaust capacity shall be at least 3.5m^3/s at normal pressure and a temperature of 25°C. The design of the exhaust system is detailed in ISO 9705 Annex D (ref. 2.1).

5.12 Instrumentation in the test specimen assembly

12 type K thermocouples are positioned on the compartment wall. Four are in the wall behind the ignited seat: 3 at 100cm from the floor at 40, 89, 189cm from the corner of the dummy window, the last at 131cm from the floor at 40cm from the corner of the dummy window. Four are in the ceiling over the seat back position. Four are in the wall in front to ignited seat, in the same position of the other wall.
One more thermocouple of the same type is positioned over the door (see Figure B.1).

6. CALIBRATION

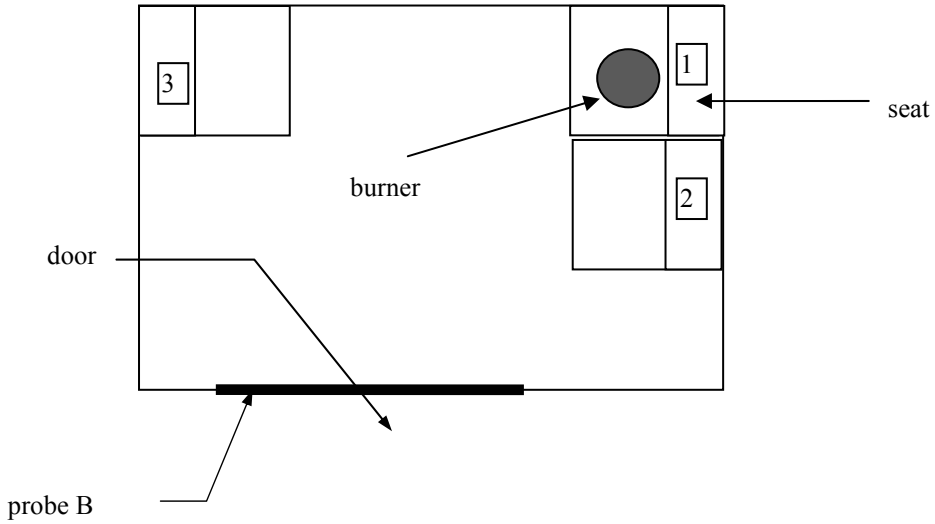
Before performing the tests the heat release measuring system shall be calibrated with a propane gas burner (the same ignition source recommended in ISO 9705 Standard – ref. 2.1). Three levels of heat output are used: 100, 300 and 700 kW. In addition, the system shall be checked every morning with a propane calibration at 300 kW of heat output level. The calibration procedure is in accordance with Nord test Fire 032 (ref. 2.2).

7. TEST SPECIMEN ASSEMBLY

Every seat is placed on steel bench or its original frame with arms and headrest, when they areavailable.

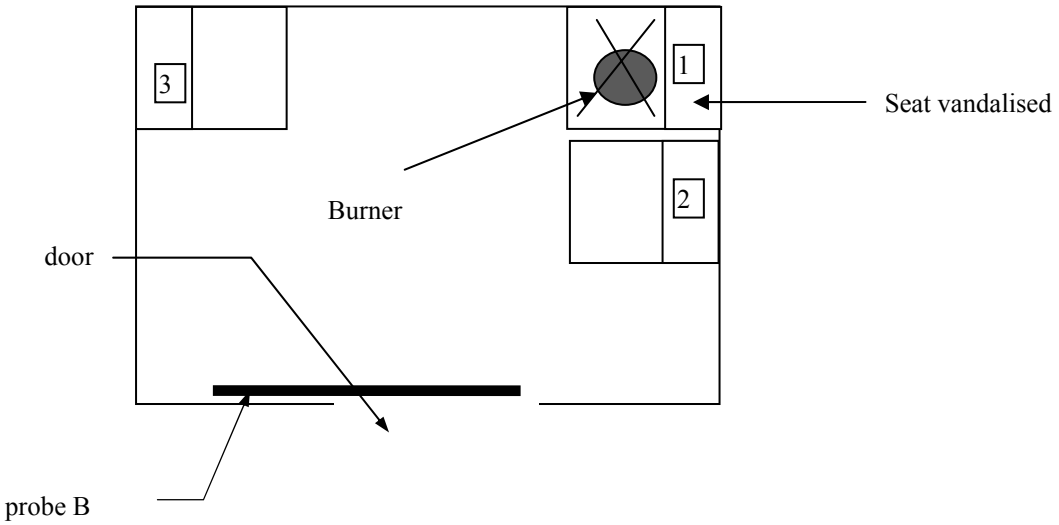
There are 4 possible configurations:

- stage 1 (see scheme 1):
  - → 3 seats not vandalised in the compartment
  - → toxic gas analysis in the exhaust duct: Probe A
  - → toxic gas analysis at nose level in the door opening: Probe B
  - → measurements and observation during the test



Scheme 1 : top view of the compartment

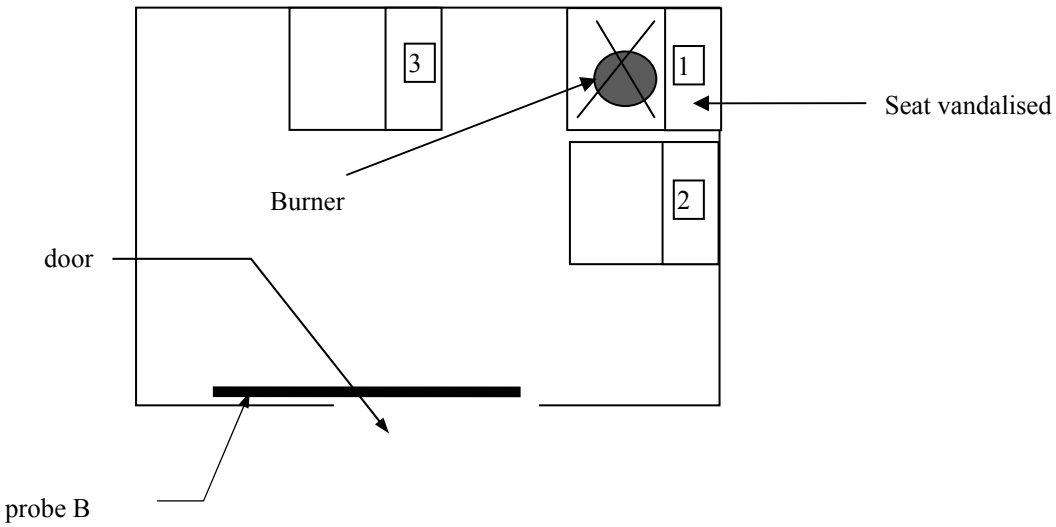
- stage 2 : (see scheme 2)
  - → 3 seats with one vandalised (n°1) in the compartment
  - → toxic gas analysis in the exhaust duct: Probe A
  - → toxic gas analysis at nose level in the door opening: Probe B
  - → measurements and observation during the test



Scheme 2 : top view of the compartment

↳ stage 3 : (see scheme 3)

→ 3 seats with one vandalised (n°1) in the compartment
→ toxic gas analysis in the exhaust duct: Probe A
→ toxic gas analysis at nose level in the door opening: Probe B
→ measurements and observation during the test

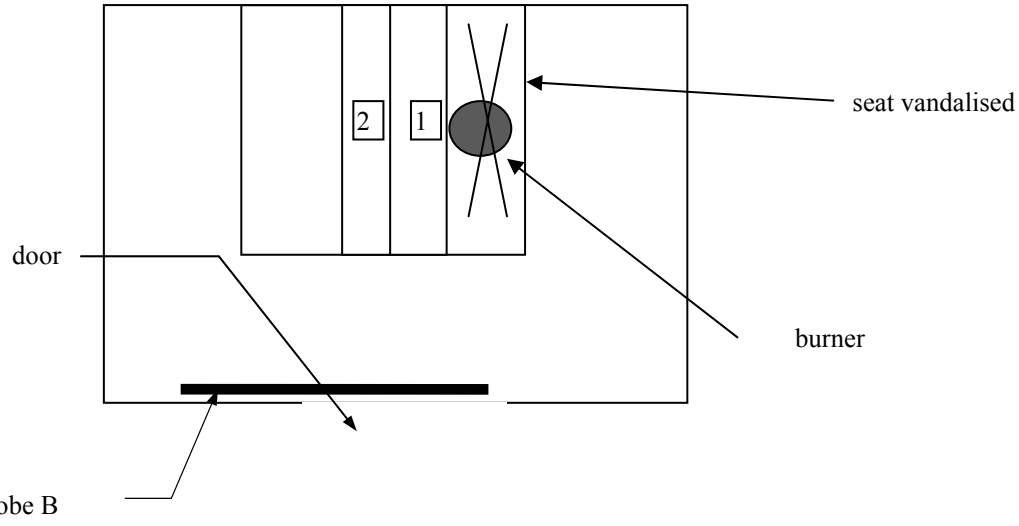


Scheme 3 : top view of the compartment

Note: this configuration is possible only when the seats have their original structure.

↳ stage 4 : (see scheme 4)

→ 2 seats as sofa configuration with one vandalised (n°1) in the compartment
→ toxic gas analysis in the exhaust duct: Probe A
→ toxic gas analysis at nose level in the door opening: Probe B
→ measurements and observation during the test



Scheme 4 : top view of the compartment

Note: this configuration is possible only when seats original structure allows it.

7.1 Laceration of seats representing the 2nd level of vandalised seat

The covering and interlayer (if exists) of the seat and back sides of specimen shall be cut along the diagonals beginning 5cm from the corners. The edges shall be removed so that the foam is uncovered and directly in contact with burner.

8. CONDITIONING

The specimen shall be conditioned for a least one week in an atmosphere having temperature of 23±5°C and a relative humidity of 50±5%.

The test procedure detailed in paragraph 10 shall be carried out within 1 hour after removal of the specimen from the conditioned environment.

9. FTIR PROCEDURE TECHNIQUE FOR FIRE GASES MEASUREMENT

9.1 General description of FTIR measurement technique

SAFIR final report (ref. 2.5) requirements which are summarised into ISO Draft Standard/Technical report proposal “Toxicity testing of fire effluents – Analysis of gases and vapours in fire effluents using FTIR technology” (ref. 2.6) shall be adopted.

The principle of this method is:

Smoke gas samples for FTIR analysis is taken from a sampling line connected to exhaust duct and drawn continuously through a heated sampling line and IR absorption cell of a FTIR spectrometer.
The infrared beam is directed by a mirrors system through the gas absorption cell and at chosen intervals interferograms are acquired and then converted to absorption spectra.
All part of sampling line and IR absorption cell are heated at least 150°C to prevent thewaterfrom liquefying and dissolving gases like HCl and HBr.
FTIR technique measurement and device are based to the conversion of regular irradiance from an infrared source into interfered irradiance and transformation of an interferogram into a conventional wavelength spectrum with wide range. The spectrum is shown as absorbance (energy absorbed in the optical path) as function of frequency radiation expressed in wave number (number of cycles per cm).
Polyatomic and heteronuclear diatomic compounds having an infrared region of absorbance can be identified looking to their characteristic wavelengths and quantified on base of absorption intensities. Concentrations are calculated by the relationship between the areas-absorbance of unknown spectra and reference gas mixtures with known concentration of gases.

9.2. Sampling line description

9.2.1 Probes

A first multihole stainless steel probe tube with inner diameter of 10mm and vertically fitted acrossing the section of exhaust duct. It shall consist in two series of 10 holes of 2mm and 3mm diameter having a distance between them of 10mm and facing downstream.
A second stainless Steel linear multihole, 800mm lenght having 8mm inner diameter placed diagonally inside the compartment. It starts at 100mm under high right corner of the door and finish at 200mm under high left corner of the door diagonally acrossing the section of it. It has 7 holes with 100mm between each and having the following diameter distribution: 1.5mm, 1.6mm, 1.8mm, 2.1mm, 2.5mm, 3.2mm and 5mm (closest to end). Downstream.

9.2.2 Filter

Either planar membrane filters or cylindrical filters are recommended. The planar filters should optimally have a porosity of 5micron and a diameter of 47mm, although other porosity and diameter may be used.

9.2.3 Sampling line

A gas sampling line of PTFE with an inner diameter of 3-4mm should be used. This line has to be kept at a constant temperature of at least 150°C. The length should be as short as possible but in any case not exceed 4m.

9.2.4 Flow rate

From 5 to 10 l/min, depending on the requirements of the response time.

9.3 Procedures and instrumental requirements

The recommended resolution is between 2 and 4 cm^{-1}. The response time of the analysis should be 30s or less.
The filter shall be taken out from the filter unit at the end of each test. It shall be rolled up and introduced into a calibrated flask of water for complete dissolution. After filtration, the solution shall be analysed by ionoselective potentiometry for halogen compounds determination.

9.4 Toxic gases species

The gases species to be analysed are: CO, CO2, O_2, HCN, NOx, HCl, HBr, SO_2, Acrolein and Formaldehyde.
The objective of the analysis is to compare the results obtained with real and small scale tests data.

10. TEST PROCEDURE

10.1 The temperature of the test area under the exhaust hood from the start of the specimen mounting until the start of the test shall be 20°C ± 10°C.

10.2 The volume flow rate shall be set to 2.5 m^3/s and kept constant during all testing time.

10.3 Start all recording and measuring devices and record data for at least 3 minutes prior to the burner being ignited.

10.4 Ignition sequence and test performing

After the baseline recording, the burner, which has previously checked for position, shall be lit away from specimen and stabilized for 1 minute.

The burner shall be carefully applied onto the seat and a clock shall be started.

After the specified application time the gas flow shall be stopped and the burner carefully moved out.

10.5 A photographic and video recording shall be made during the test.

10.6 At t=(180 ± 5) s, open the door of the compartment

10.7 During the test, record the following observations:

A. **Fire behaviour of the seat tested**

A.i. tig of the seat tested (s)

A.ii. t afterflame of the seat tested (s)

A.iii. Melting of the seat tested (yes/no)

A.iv. Dripping of the seat tested (yes/no)

A.v. Pool fire under the seat tested (yes/no)

Fire behaviour of the adjacent seat

A.vi. Ignition of the adjacent seat (yes/no)

A.vii. Ignition of the adjacent seat (yes/no)

A.viii. tig of the adjacent seat (s)

A.ix. t afterflame of the adjacent seat (s)

A.x. Melting of the adjacent seat (yes/no)

A.xi. Dripping of the adjacent seat (yes/no)

A.xii. Pool fire under the adjacent tested (yes/no)

B. **Fire behaviour of the facing seat**

B.i. Ignition of the facing seat (yes/no)

B.ii. tig of the facing seat (s)

B.iii. t afterflame of the facing seat (s)

B.iv. Melting of the facing seat (yes/no)

B.v. Dripping of the facing seat (yes/no)

B.vi. Pool fire under the facing seat (yes/no)

10.8 Record the extent of damage of the product after the test:

A. Fire behaviour of the seat tested for the seat

A.i. Damaged length of the seat tested (cm)

A.ii. Damaged width of the seat tested (cm)

A.iii. Damaged depth of the seat tested (cm)

B. Fire behaviour of the seat tested for the back of the seat

B.i. Damaged length of the back of the seat tested (cm)

B.ii. Damaged width of the back of the seat tested (cm)

B.iii. Damaged depth of the back of the seat tested (cm)

C. Fire behaviour of the adjacent seat for the seat

C.i. Damaged length of the adjacent seat (cm)

C.ii. Damaged width of the adjacent seat (cm)

C.iii. Damaged depth of the adjacent seat (cm)

D. Fire behaviour of the adjacent seat for the back of the seat

D.i. Damaged length of the back of the adjacent seat (cm)

D.ii. Damaged width of the back of the adjacent seat (cm)

D.iii. Damaged depth of the back of the adjacent seat (cm)

E. Fire behaviour of the facing seat for the seat

E.i. Damaged length of the facing seat (cm)

E.ii. Damaged width of the facing seat (cm)

E.iii. Damaged depth of the facing seat (cm)

F. Fire behaviour of the facing seat for the back of the seat

F.i. Damaged length of the back of the facing seat (cm)

F.ii. Damaged width of the back of the facing seat (cm)

F.iii. Damaged depth of the back of the facing seat (cm)

11. TEST REPORT

The test report shall include the following information:-

a) name and address of testing laboratory

b) date and identification number of the report

c) name and address of the client

d) reference that the test was carried out in accordance with this Laboratory Procedure

e) name of manufacturer or supplier of the product

f) name and other identification marks and description of the product

g) method of sampling

h) general description of the product tested including density, weight per unit area and thickness

i) description of substrate (if used) and fixing to the substrate

j) other relevant mounting details, such as air-gaps, joints, flashings, etc.

k) conditioning of the specimens

l) date of test

m) test results and observations in accordance with 9.6

n) the statement ‘The test results relate to the behaviour of the test specimens of a product under the particular conditions of the test; they are not intended to be the sole criterion for assessing the potential fire hazard of the product in use’.

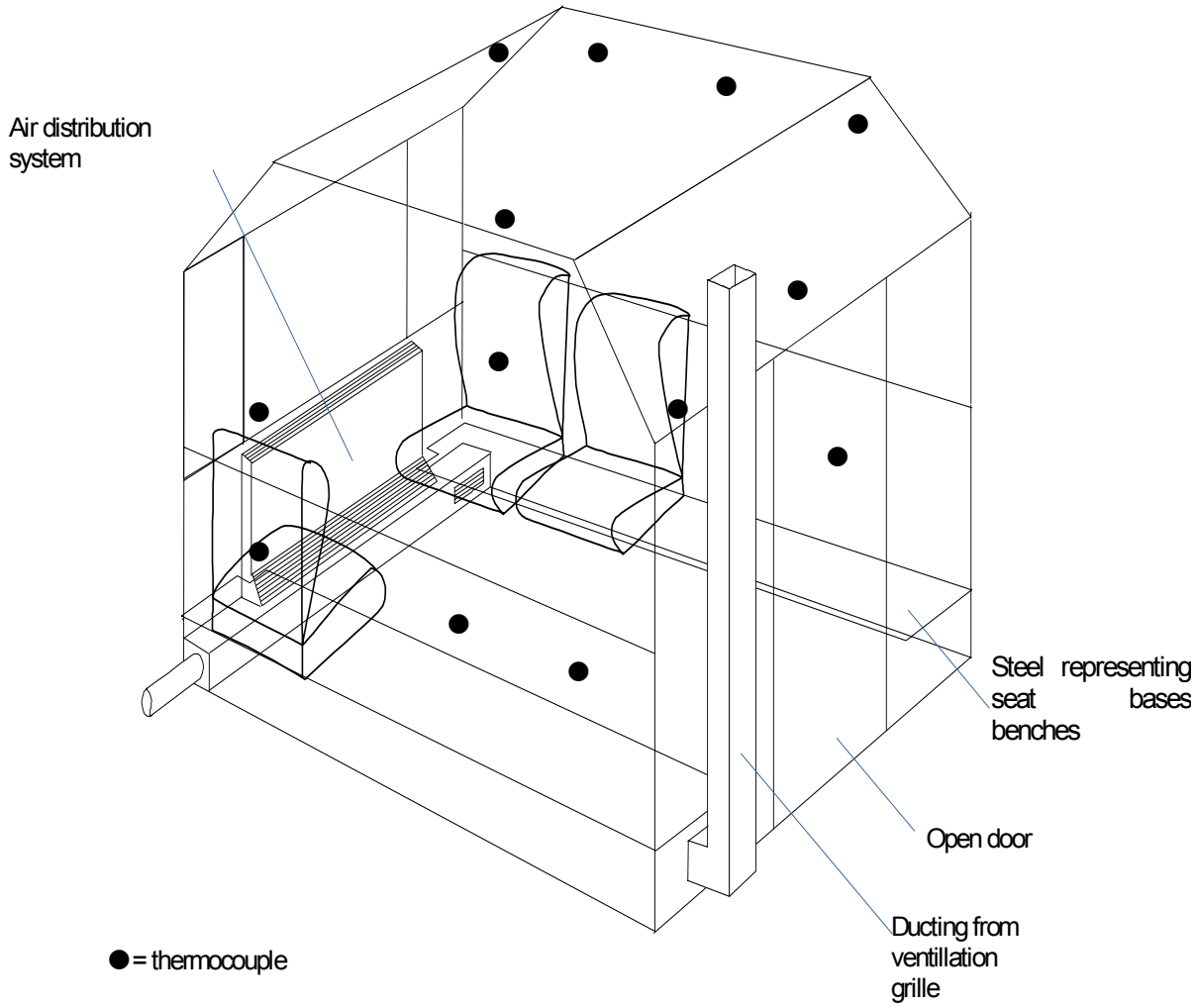
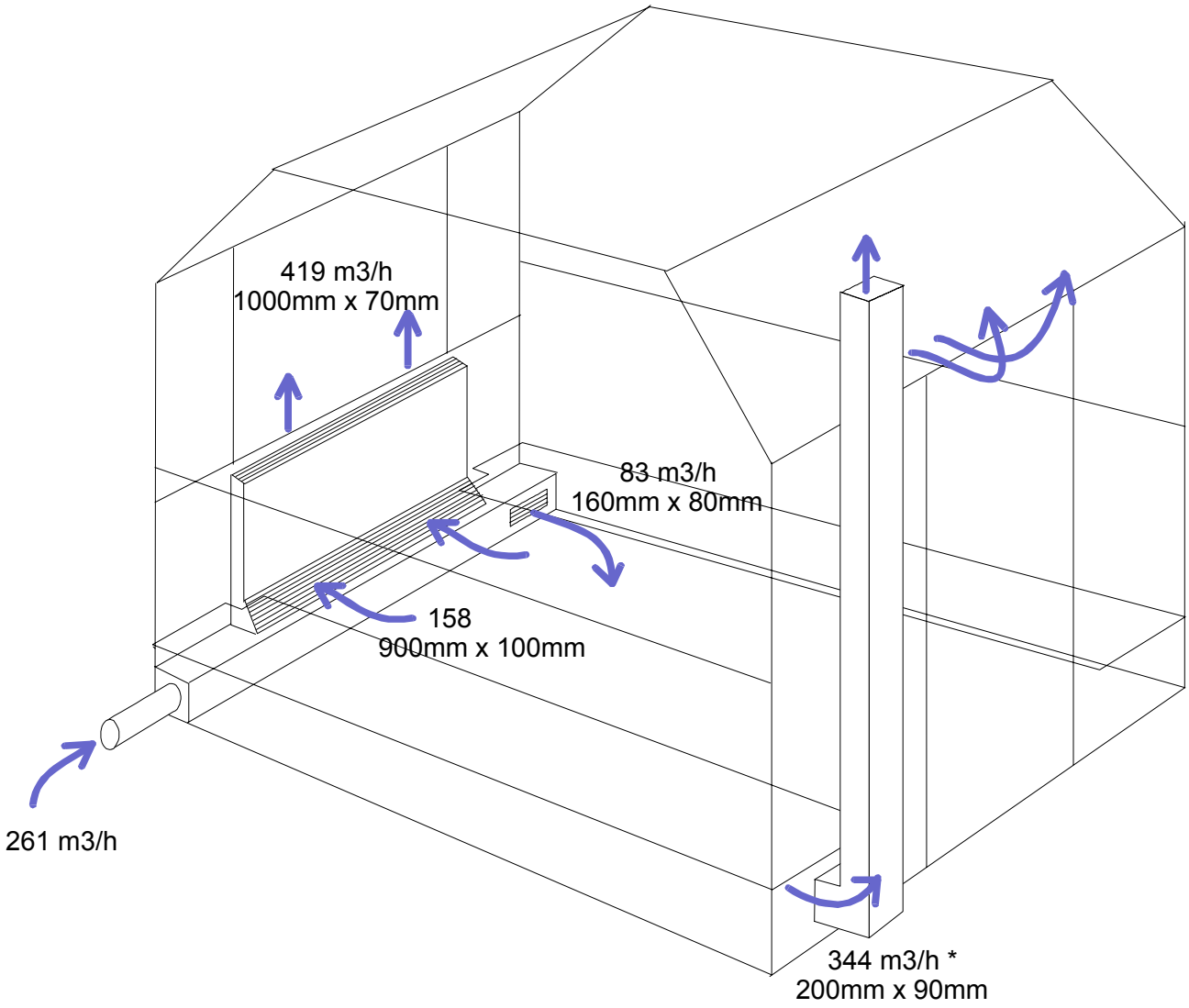


Figure B.1
Position of seats and thermocouples within compartment



* Value of volume flow with door closed

Figure B.2
Air distribution within compartment

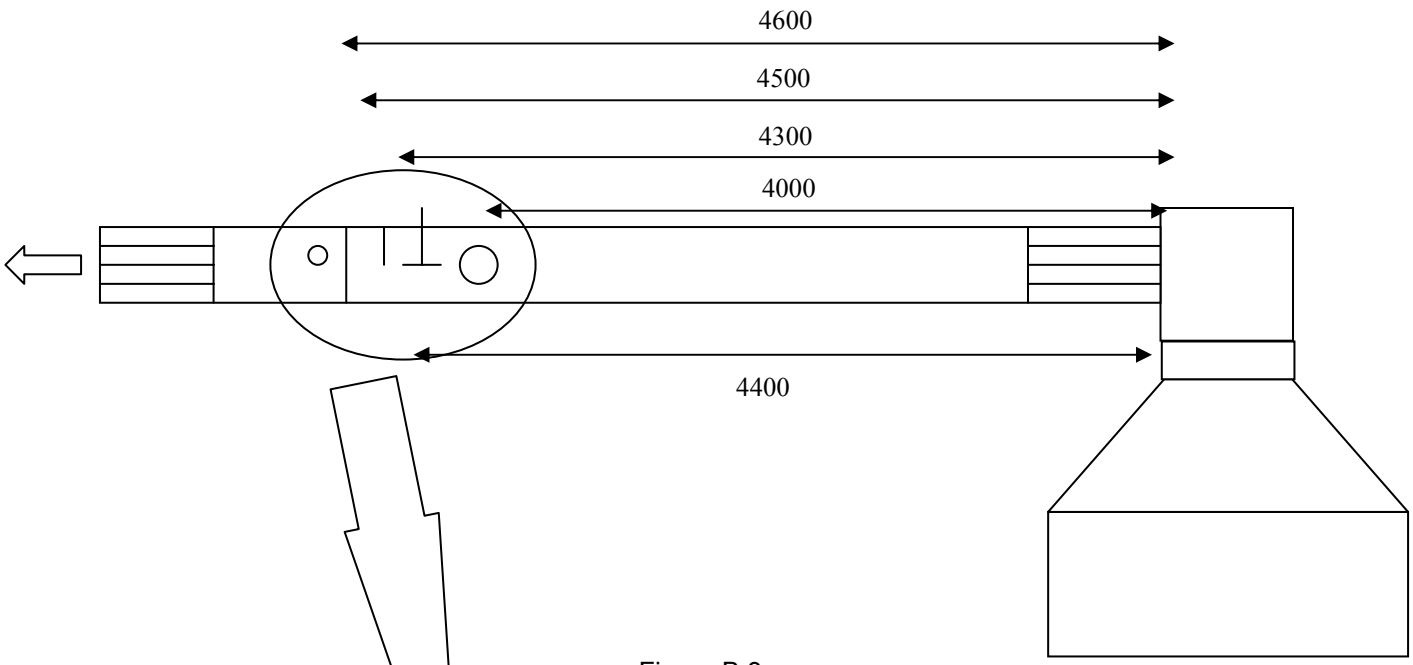


Figure B.3a
Set-up of measurement systems
in ISO 9705 exhaust duct

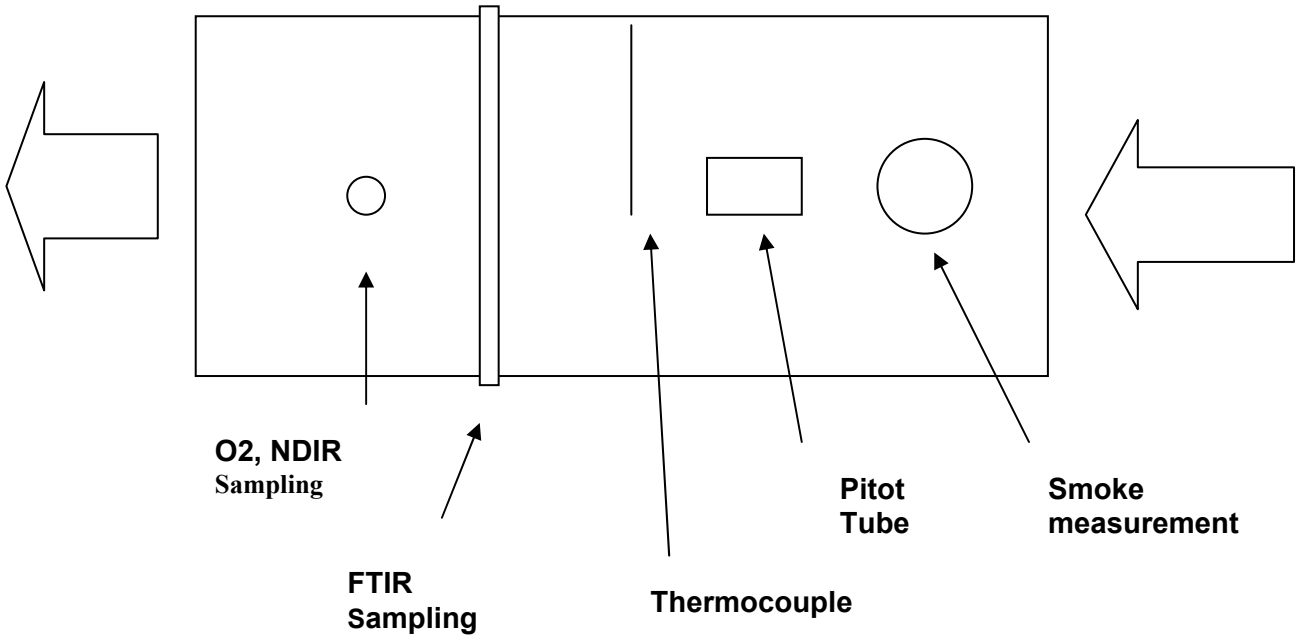


Figure B.3b
Particular of measurement systems

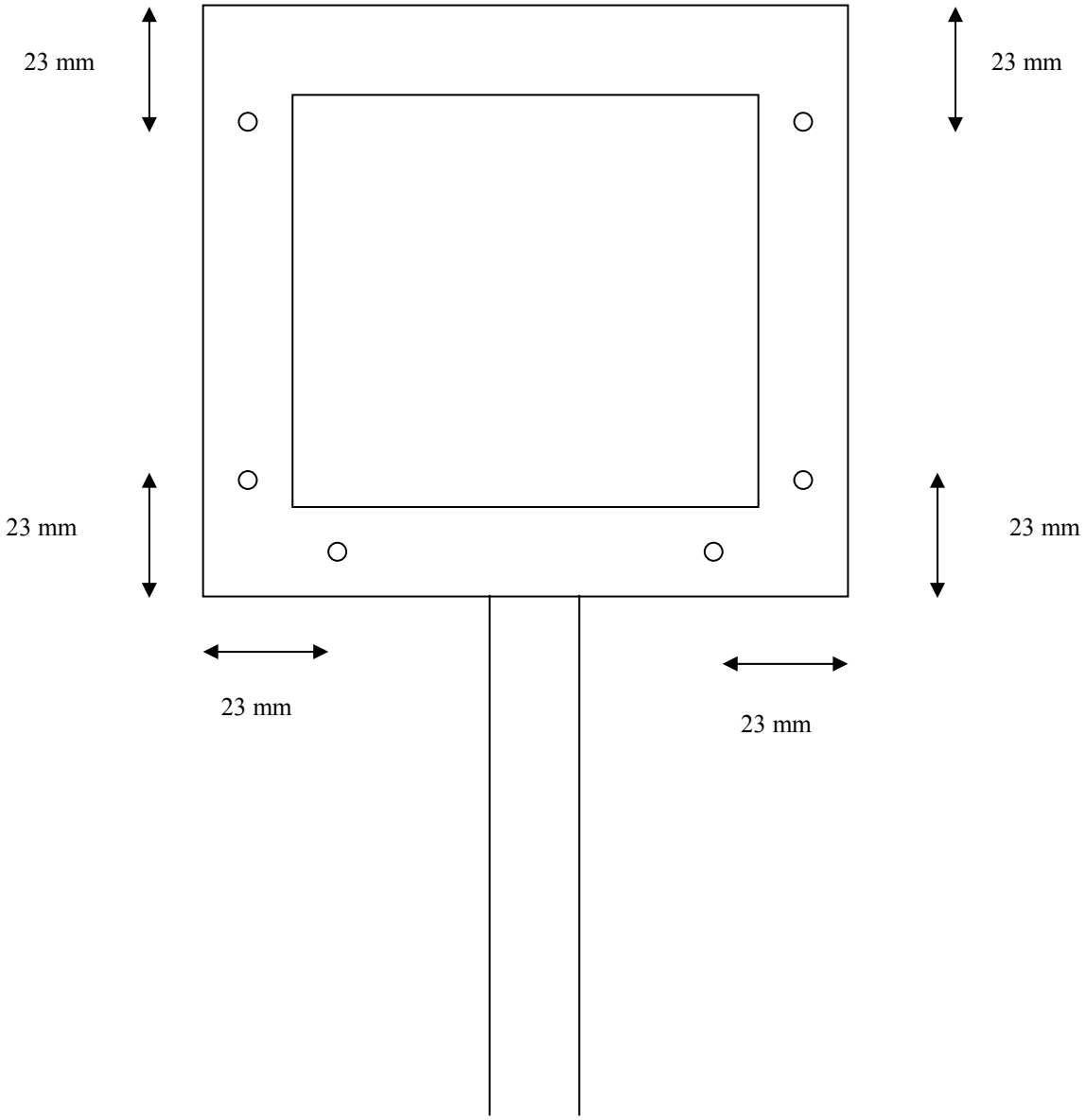


Figure B.4
Burner Firestarr “A” in lower view