TENABILITY ASSESSMENT OF FIRE

This presentation is based on the study

"Real-scale fire tests of one bedroom apartments with regard to tenability assessment"

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Introduction : objective

This study was conducted in September and October 2011 by LNE and LCPP;

- The main objective of the study is to determine which fire effect occurs first in a few simple scenarios using ISO13571 [1] and to ISO 19706 [2] recommendations as a tool to carry out tenability assessment.
- Tenability is defined as the ability of humans to perform cognitive and motor-skill functions at an acceptable level when exposed to a fire environment. If exposed individuals are able to perform cognitive and motor-skill functions at an acceptable level, the exposure is said to be tenable. If not, the exposure is said to result in compromised tenability.

[1] ISO 13571 : Life-threatening components of fire – Guidelines for the estimation of time to compromised tenability in fires.

[2] ISO 19706 : Guidelines for assessing the fire threat to people.

Introduction : general

According to the ISO 13571 standard, the tenability can be affected by the following factors :

- **Effects related to the toxicity of fire effluents**. This mechanism may be due to effects of asphyxiating or irritant effects.
  - Asphyxiating (or narcotic) effects: these effects are cumulative and related to the absorbed dose.
    - The carbon monoxide gas (CO) and hydrogen cyanide (HCN) are the only asphyxiant gases included in ISO13571 standard.
    - Their effect may be increased by the presence of carbon dioxide (CO_2).
    - The corresponding evaluation criterion is $\mathbf{FED_{tox}}$ (Fractional Effective Dose due to toxicity);
  - Irritating effects: these effects are immediate and related to the concentration of irritating gases.
    - Hydrogen chloride (HCl), nitric oxide (NO), Hydrogen bromide (HBr), Hydrogen fluoride (HF), Sulphur dioxide (SO_2), ammonia (NH_3), are the most common irritating gases.
    - The corresponding evaluation criterion is **FEC** (Fractional Effective Concentration),
    - Interpretation of effects due to oxygen decay is also included in the analysis.

- **Thermal Effects.** These effects may be due to the temperature of the air (convective effect) or to the received radiation (radiative effect).
  - These two effects are cumulative and dose-related..
  - The corresponding evaluation criterion that combines these two effects is $\mathbf{FED_{therm}}$ (Fractional Effective Dose due to thermal effects).

- **Effects related to visibility**. they are considered as worsening the ability of people to move.
  - Interpretation is performed by the measurement of **OD** (optical density).

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Experimental procedure : scenarios

Two series of tests have been performed :

- The first series ("Tests 1") consists in a night dwelling scenario in a closed room.
  - Ignition sequence is performed on the mattress equipped with its bedding components.
  - Different ignition source are used : a standard cigarette, a standard small flame equivalent to a match and a crib.
  - Room door and window remains closed during all tests of this series.
  - The exposure scenario corresponds to a person sleeping.

- The second series ("Tests 2") is the situation of a ventilated fire in a small living space.
  - Ignition sequence consists in a scenario of an accidental fire in the wastepaper basket, at the foot of the office desk.
  - Two sequences of ignition were carried out with wastepaper baskets.
  - The window remains closed, but the door is opened 2 min 30 s after ignition.

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Experimental procedure : scenarios

Two series of tests have been performed :

- For tests series 1, the exposure scenario corresponds to a person sleeping. Fire starts on mattress, for example because of a non-extinguished cigarette. The person don’t wake up, door and window remain closed during the entire scenario.

- For tests series 2, the scenario is an accidental fire, starting from a wastepaper basket. Two exposure scenarios are considered.
  - In the first one (2A), it is assumed that the occupant leaves the room quickly, about 2 min 30 s after fire ignition. He opens the door, which remains opened during all the remaining duration of the scenario.
  - In the second one (2B), the studied hypothesis corresponds to another occupant, who remains standing in the middle of the room during the entire scenario, while the first one has left.

Test denomination	Door status	Ignition source	Ignition target	Deviation from standard configuration
1A	Closed	Cigarette	Bed quilt	Floor covering $B_{fl}s1$
1B		Match		
1C		Crib		
2A	Initially closed. Open after 2 min	Cigarette on waste paper basket	One paper basket filled with 500g of creased paper balls	Floor covering $C_{fl}s1$
2B		Match on waste paper basket	Two paper baskets, each filled with 500g of creased paper balls	

Summary of the tests performed

Experimental procedure : description of the tested room

- The test room is a realistic 9m² bedroom apartment (3m x 3m) with a ceiling height of 2.5m.
- To imitate real life conditions, the test room is decorated, furnished and equipped with objects encountered in everyday life :

Item	Mass (kg)	Proportion
Wood and wooden products	130,3	54%
Paper, chipboard	7,3	3%
PVC-based materials	82,5	34%
PU foams	4,3	2%
Other plastics	9,7	4%
Miscelleanous (cotton, wool, etc.)	7,1	3%
Total	**241,2**	**-**

Table 1: Fuel mass load on the tested room

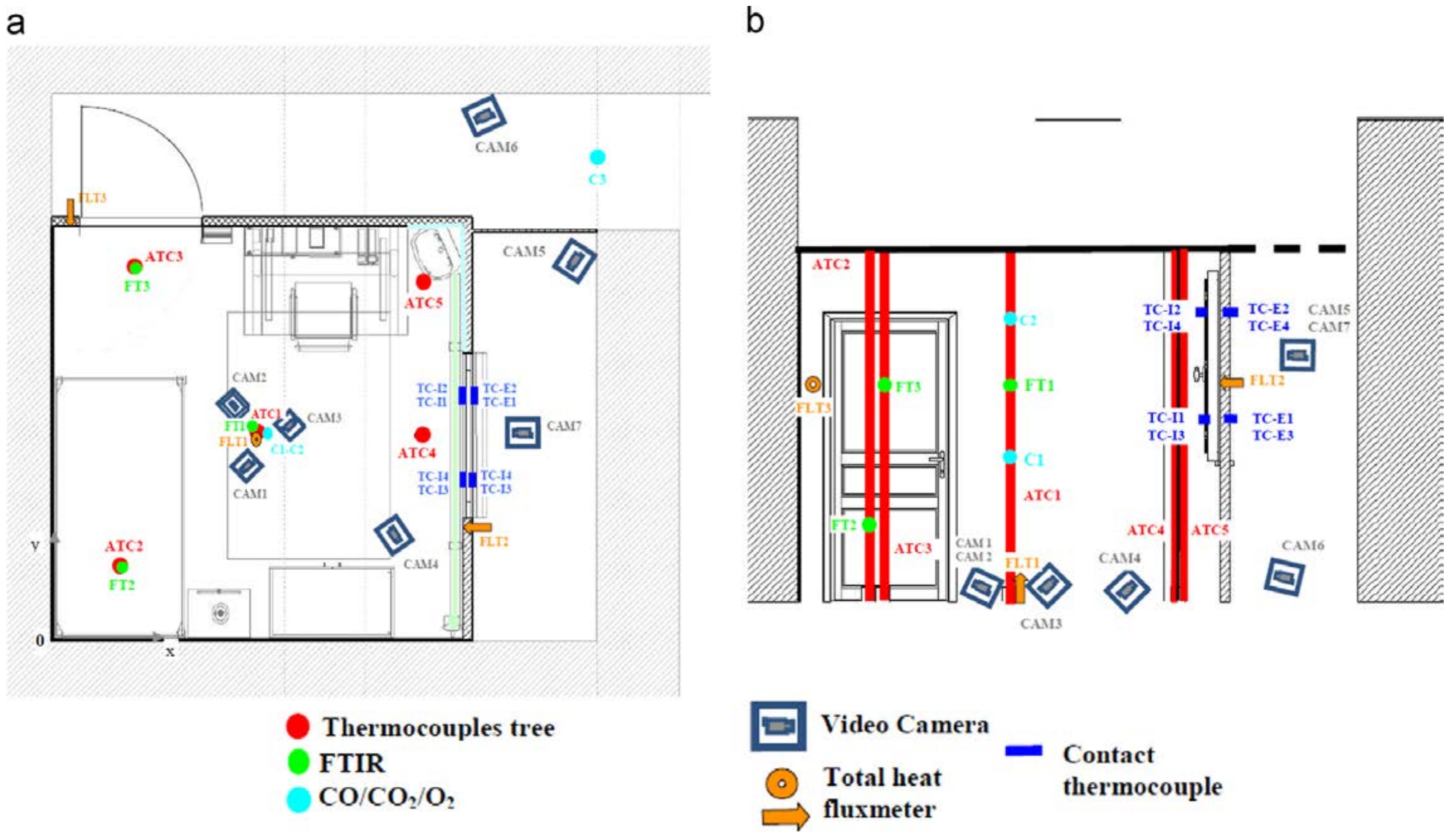
Experimental procedure : description of the tested room

Experimental procedure : instrumentation

- The instrumentation of the test room and the adjacent corridor is designed to collect data necessary for estimating tenability conditions and their evolution overtime.

  - Measurement of temperature by 5 thermocouples trees,
  - Measurement of heat fluxes by 3 water-cooled tangential gradient heat fluxmeters
  - Measurement means for the estimation of effluent toxicity effects by
    - 3 Fourier transform infrared analyzers (FTIR) and
    - 3 CO and CO_2 non-dispersive infrared (NDIR) analyzers and O_2 paramagnetic analyzers,
  - Measurement means for the estimation of visibility loss by 5 specific white light opacimeters,
  - Additional instruments : 2 high definition cameras and 4 webcams.

Experimental procedure : instrumentation



Instrumentation description : (a) top view and (b) side view.

Results

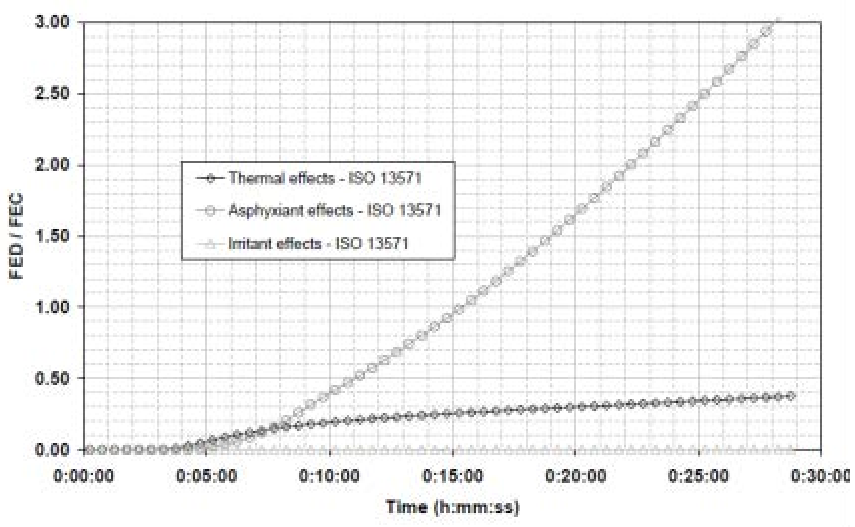
Series “Tests 1”

- Test 1A (ignition with cigarette) and Test 1B (ignition with match)
  - No significant elevation of temperature, heat flux or gas concentration is recorded in the room.

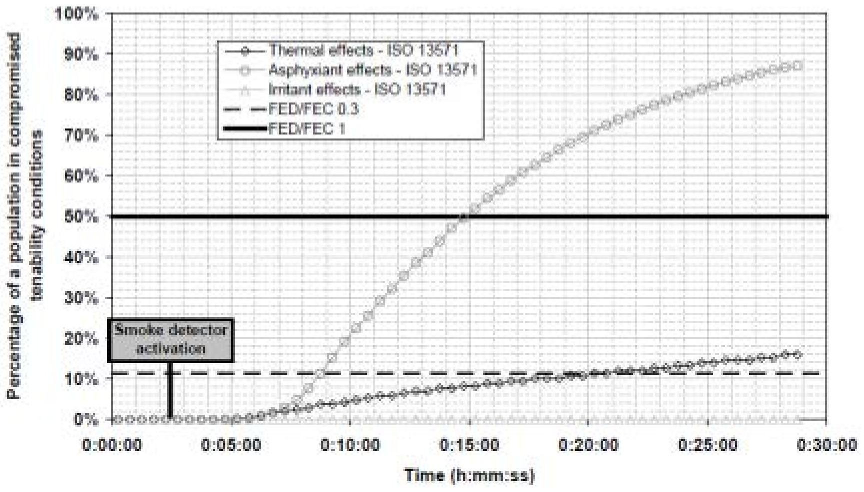
- Test 1C (ignition with wood crib)
  - At the end of the test, **87% of people facing this exposure scenario are in compromised tenability conditions, as a result of the action of the asphyxiant gases (CO and HCN);**
  - at the end of the test, approximately **16% people facing this exposure scenario are in compromised tenability conditions because of thermal effects and irritant effects**;
  - irritant effects are due to nitric oxide in this scenario, hydrogen chloride contribution remains negligible;
  - smoke alarm activates before any compromised tenability conditions are observed in the room.

Results

FED/FEC calculation according to ISO 13571



Percentage of the population in compromised tenability conditions



Interpretation of the test 1C according to ISO 13571

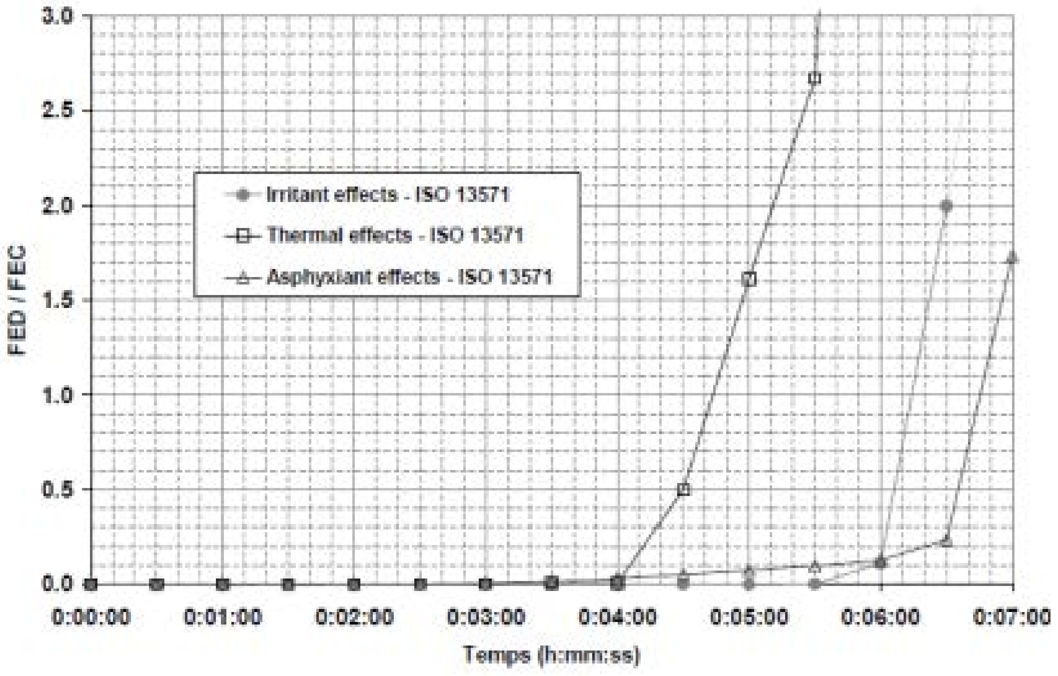
Results

Series “Tests 2”

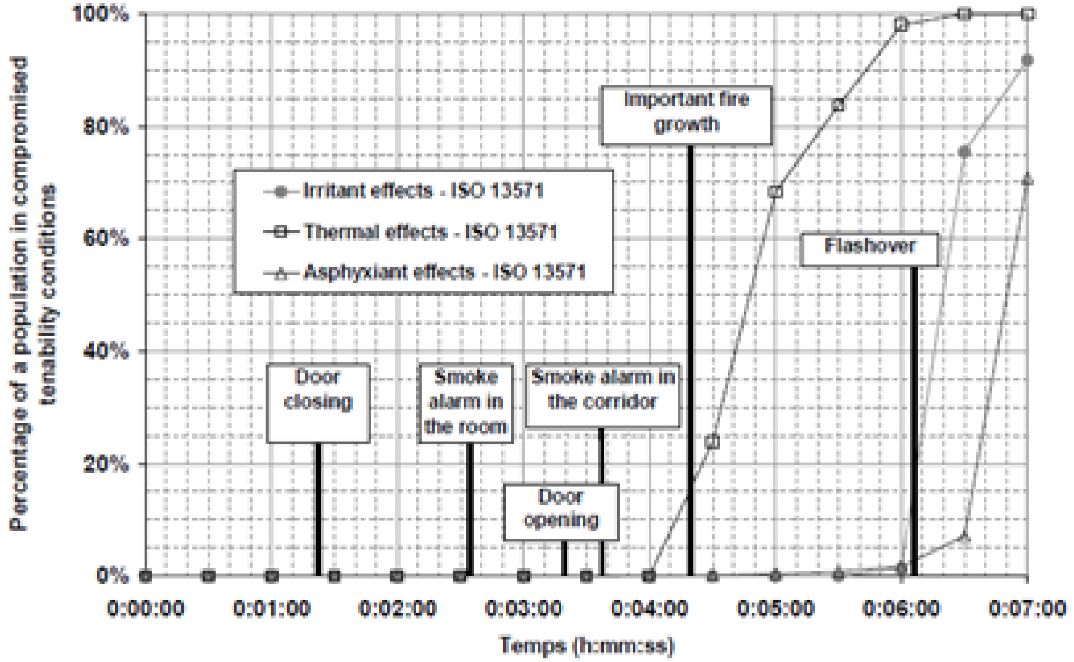
- Test 2A
  - The main effect of combustion gases is the asphyxiant effect for only 1.4% of the population.
  - Irritants or thermal effects remain low in comparison during whole test.
- Test 2B
  - **Effects of asphyxiant and irritant gases appear around 6 min, when the tenability is already compromised for the whole population by thermal effects.**
  - Smoke opacity remains low under 1.50m height for the first 5min, thus not compromising evacuation, even for unknown path.

Results

FED/FEC calculation according to ISO 13571



Percentage of the population in compromised tenability conditions



Interpretation according to ISO 13571 – Scenario 2B

Synthesis

When the occupant evacuates the room quickly after the alarm activates, he is not affected by any significant impact due to fire effects.

In under-ventilated condition (Scenario 1) the fire is limited by ventilation in a few minutes. In this situation,

- **Tenability inside the room is driven by the toxic effect related to asphyxiant gases, and effect due to dioxygen decay.**
- **Thermal and irritant effects remain negligible in comparison.**

In a ventilated fire situation (Scenario 2), fire may grow to flashover, depending on the initial fire source. In this situation,

- **Thermal effects drive tenability inside the room.**
- **Toxic effects (asphyxiant or irritant) appear inside the room only when thermal effects have already compromised tenability.**

Conclusion

- To my mind the 2B (ventilated fire) scenario of this study is comparable to a situation of bus fire.

- Toxic effects (asphyxiant or irritant) appear only when thermal effects have already compromised tenability.

- Therefore the first important parameter is to control the spread of fire.

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