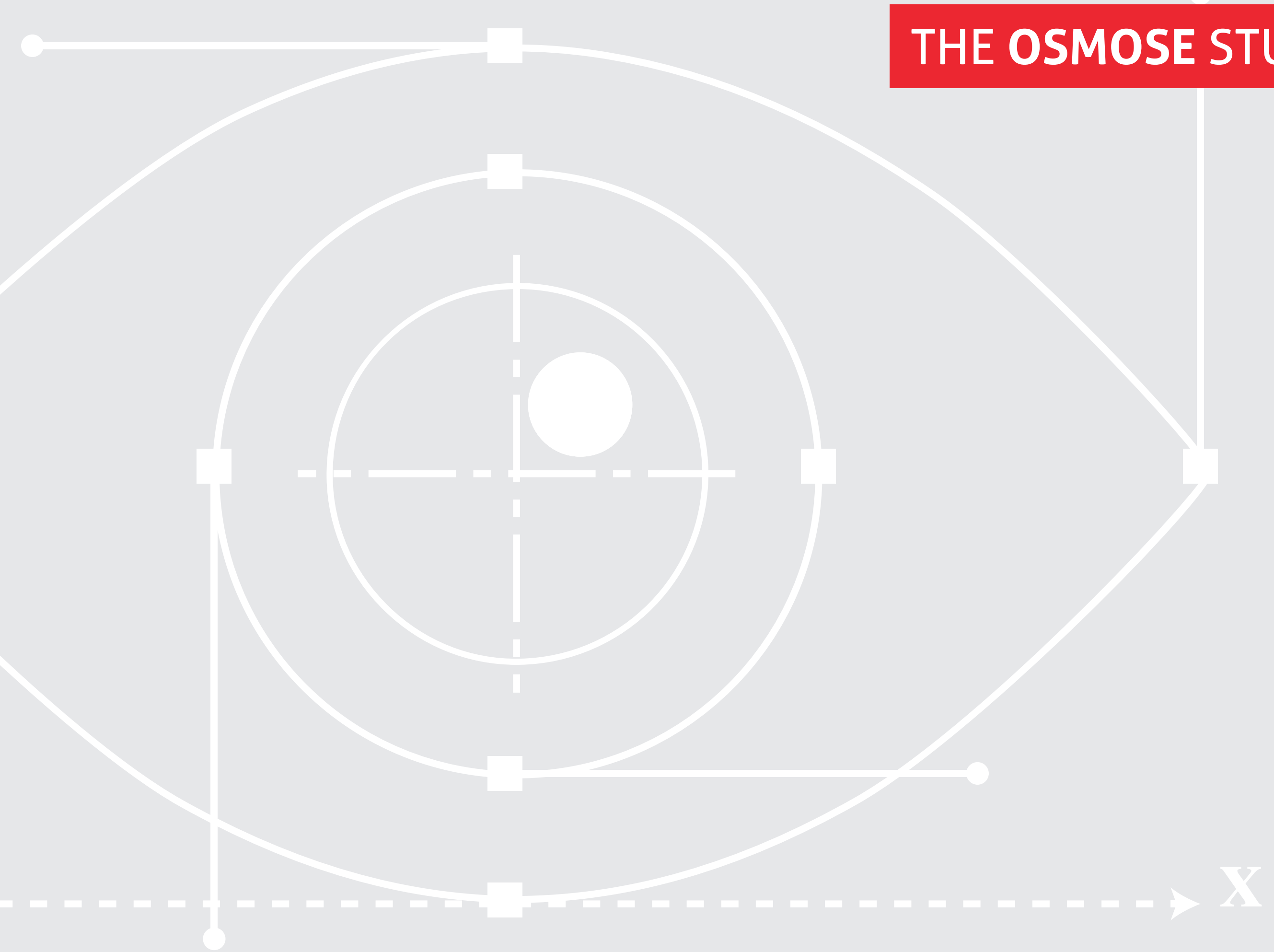
WHITE PAPER: KEY FINDINGS FROM THE **OSMOSE** STUDY



The first scientific study that proves the true efficiency of **natural smoke control**

Joint study conducted by the following laboratories:

CNPP Prévention et maîtrise des risques

Efectis

FFMI
FÉDÉRATION FRANÇAISE DES MÉTIERS DE L'INCENDIE

Created in 1976 as part of FFMI, GIF brings together all manufacturers, installers and maintainers of fire stopping, fire compartmentation and smoke exhaust systems in France.

Boasting such a diversity of trades and approaches, GIF is predicated on a vision shared by all its members — provide concrete and reliable solutions that ensure fire safety in buildings by reducing the associated risks to occupants and emergency services whilst mitigating the economic consequences of fire.
Since its creation, GIF is driven by the same desire to champion and promote the quality and reliability of smoke exhaust and compartmentation systems.
The lack of recent studies or genuine test campaigns prompted us, in 2014, to provide scientific evidence of natural smoke control's efficiency. The two studies presented herein enabled us to compare the results obtained by numerical simulation with those obtained in full-scale tests.
These studies provide indisputable evidence that smoke control is an efficient means of fire safety that helps to protect people's lives and property.

This white paper presents the findings of the studies conducted by Efectis and CNPP, two leading fire safety laboratories.

Raoul ROTH
Président of GIF

Acknowledgements:

- All members of the Natural Smoke Control division
- Bernard LEPAGE
- Jean-Pierre THEVENET
- The FFMI team
- Pascal VAN HULLE who led the EFECTIS study
- Nicolas TREVISAN who led the CNPP study
- Agence SIOUXE

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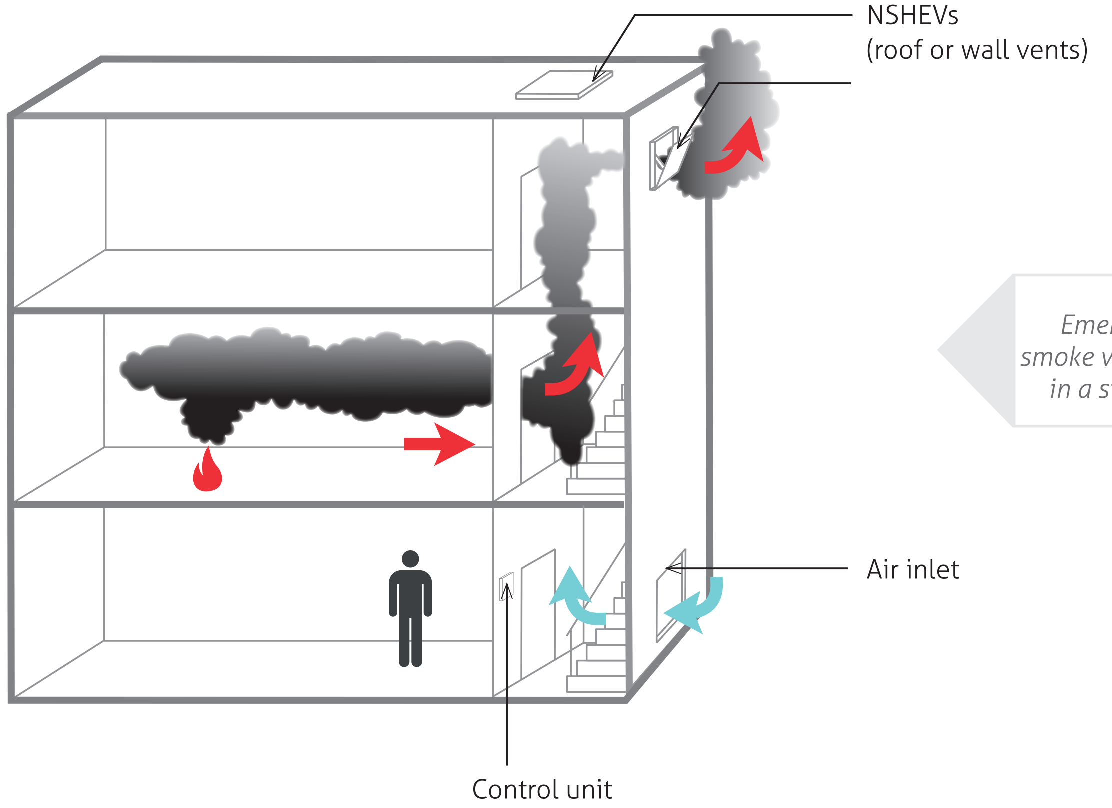
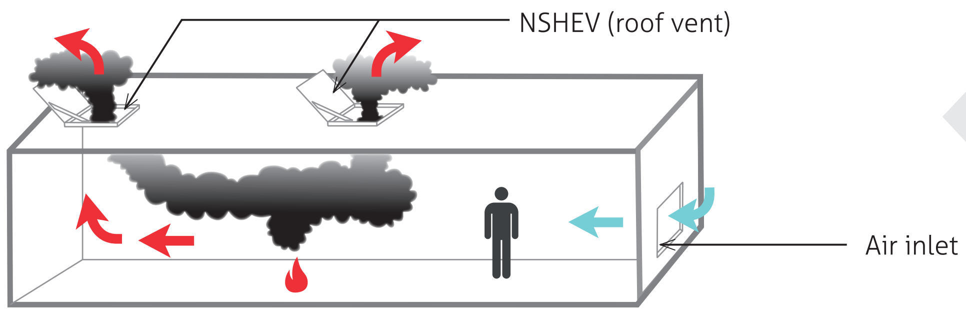


Emergency smoke ventilation in a stairwell



Smoke ventilation in a single-storey building

NATURAL SMOKE CONTROL'S FIRE-SAFETY OBJECTIVES

ENSURE SMOKE-FREE ESCAPE ROUTES FOR SWIFT AND SAFE EVACUATION OF OCCUPANTS REGARDLESS OF THEIR LOCATION WITHIN A BUILDING.

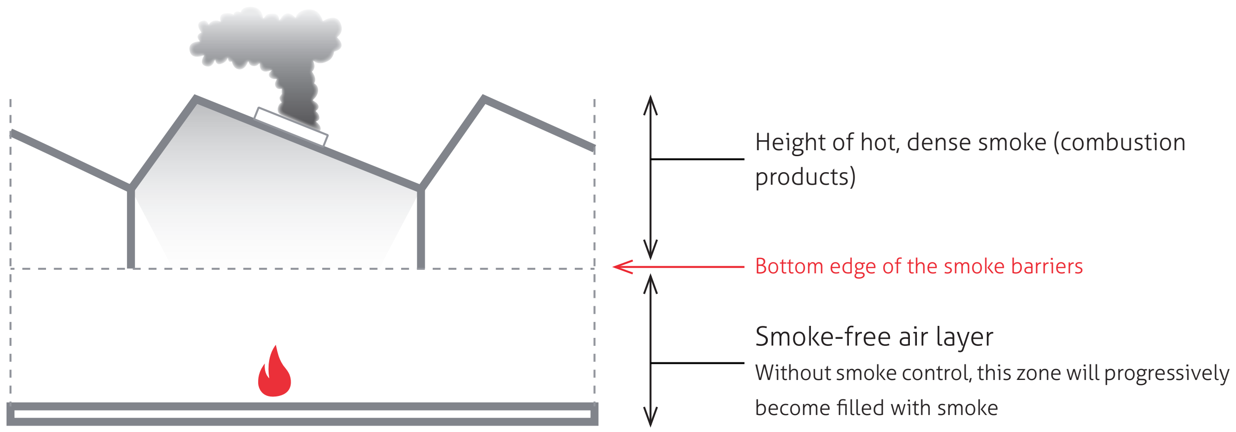
LIMIT FIRE SPREAD IN ORDER TO PROTECT BUILDINGS AND PROPERTY INSIDE THEM AND KEEP FIRE-DAMAGED BUILDINGS IN OPERATION.

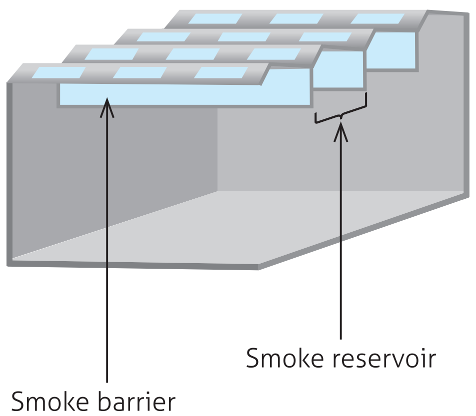
FACILITATE EMERGENCY RESPONSE BY KEEPING TEMPERATURES AT BEARABLE LEVELS, DELAYING FLASHOVER, AND IMPROVING VISIBILITY CONDITIONS.

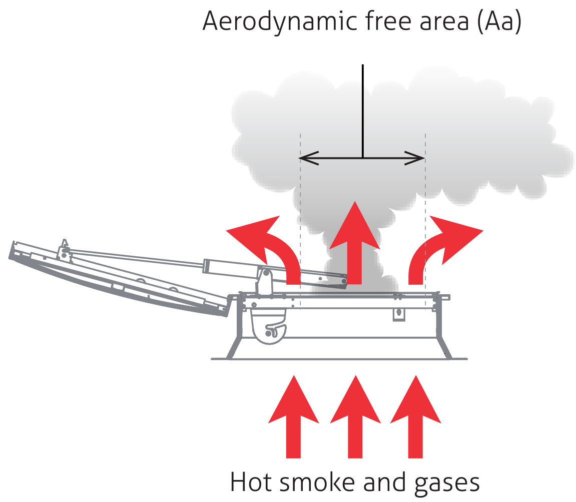
DEFINITIONS & LEGISLATION

How thermal stratification works

During a fire, hot smoke and gases rise vertically towards the roof of a building. There, they accumulate at the ceiling and then quickly roll down the walls to fill the space.







How smoke compartmentation works

Spaces larger than 2,000 m² must be divided into smoke compartments. Each compartment must measure no greater than 1,600 m² and its greatest dimension must not exceed 60 m. Smoke barriers are fitted directly under the roofs or ceilings of these spaces to prevent the spread of smoke and combustion gases.

Combined total aerodynamic free area (∑ Aa)

The combined total aerodynamic free area of a system of smoke vents varies depending on the building and applicable legislation. However, the main determining factors are the building's area and height, and the thickness of the smoke.

ENSURING THE EFFICIENCY OF NATURAL SMOKE CONTROL SYSTEMS IS CONTINGENT UPON COMPLIANCE WITH PREVAILING APPLICABLE LEGISLATION AND STANDARDS

In France, natural smoke control systems are governed by many pieces of legislation. Each piece applies to a specific type of building and must be followed when new build and refurbishment projects are undertaken.

- Industrial and commercial buildings:
- France's labour code:
  Art. R 4216-13 to R 4216-16
  Art. R 4216-26 and R 4216-27
  Art. R 4216-29
  Order of 5 August 1992
  DRT Circular No. 95-07 of 14 April 1995
- Facilities classified for environmental protection purposes

- Public buildings:
- French Technical Guidance Documents Nos. 246 and 247
- French Technical Guidance Document No. 263
- Order of 25 June 1980, as amended

- Residential buildings:
- France's Building Regulations
  Order of 31 January 1986, as amended

- High-rise buildings:
- Order of 18 October 1977, as amended
- Order of 30 December 2011

Natural smoke control is mandatory for:
. stairwells
. ground-floor and upstairs spaces measuring more than 300 m²
. enclosed or underground spaces measuring more
. than 100 m²
. circulation areas (under certain conditions)

Since 1st January 2007, all NSHEVs must bear **the CE marking (EN 12101-2).** This marking proves that they comply with applicable legislation and standards regarding their use and performance.

The NF marking is the preferred method for proving that an NSHEV complies with all applicable requirements.

All natural smoke control systems must be **regularly inspected.** In France, the labour code, the Order of 25 June 1980 on public buildings and rule APSAD R17 require annual inspections by qualified personnel and passing operational tests.

To learn more about this legislation, go to the Legifrance website at www.legifrance.gouv.fr

2 THE OSMOSE STUDY ON

THE EFFICIENCY OF NATURAL SMOKE

A NOVEL METHODOLOGY COMBINING FULL-SCALE FIELD TESTS WITH NUMERICAL SIMULATIONS

The Osmose study is the first study in 20 years that reflects the work of more than **50 experts** at the Efectis and CNPP* laboratories. Three years and more than **100 experimental and numerical studies** were necessary to scientifically demonstrate:

- The efficiency of natural smoke control
- The complementarity of Natural Smoke and Heat Exhaust Ventilators (NSHEVs) and sprinkler systems

1ST scientific study - in 20 years

3-year study - from 2015 to 2017

113 full-scale field tests

400+ numerical simulations

Calculation tool

The calculation tool used in both studies was Fire Dynamics Simulator (FDS), which was developed by the French Institute of Standards and Technology (NIST). FDS enables 3D modelling of volumes with the spread of hot gases, smoke and toxic species. Used daily in the field of smoke control engineering in France and around the globe, FDS is particularly useful in obtaining data that cannot be measured experimentally.

Efficiency criteria

The efficiency criteria used in both studies to evaluate the needs and efficiency of natural smoke control were those given in the LCPP guide**. Each criterion defines an acceptability limit for the evacuation of a building's occupants. For a height of 2 m, the temperature acceptability limit is set at 40°C and the visibility acceptability limit is set at 20 m (0.4 m^{-1}).

*Centre National de Prévention et de Protection (National Centre for Prevention and Protection)
**26 November 2016 edition of the Best Practices Guidelines for Smoke Control Engineering Studies published by the Central Laboratory of the Prefecture of Police of Paris (LCPP)

THE OSMOSE STUDY — A SCIENTIFIC FIRST FOR SMOKE CONTROL ENGINEERING

THE EFECTIS STUDY

Aim of the study

The aim of the Efectis laboratory study was to evaluate the efficiency of natural smoke control and analyse its role and design by looking at the behaviour of both a fire and the building in a situation where evacuation is required.

Methodology

Firstly, the study's researchers adopted a scientific approach that consisted in using numerical simulation tools to evaluate the performance of a natural smoke control system according to a range of parameters.

Secondly – in a scientific first – they conducted large-scale tests at one of the testing facilities operated by Aéroports de Paris (the company that runs Charles de Gaulle and Orly airports) and which was fitted with smoke vents for the purposes of the study. These tests confirmed the numerically obtained results and provided a unique testing panel for smoke control engineering.

THE CNPP STUDY

Aim of the study

Initiated by CNPP and the subject of a thesis written by Nicolas Trévisan*, this study analysed the complementarity of sprinkler and natural smoke control systems using an experimental and numerical approach.

Methodology

Two unprecedented full-scale test campaigns were carried out at the CNPP Group's Vernon site. A total of 98 fire tests involving natural smoke control and sprinkling were conducted in both a 110 m² building and a 900 m² building. They made it possible to assess the interaction between sprinkler and smoke control systems in the test facility.

Numerical simulations were then carried out and their results were compared with the experimental data obtained during the tests. This numerical approach made it possible to evaluate the ability of the computer code to reproduce the effects observed during the tests whilst assessing the complementarity of both fire protection systems.

* Available on line at http://www.theses.fr/

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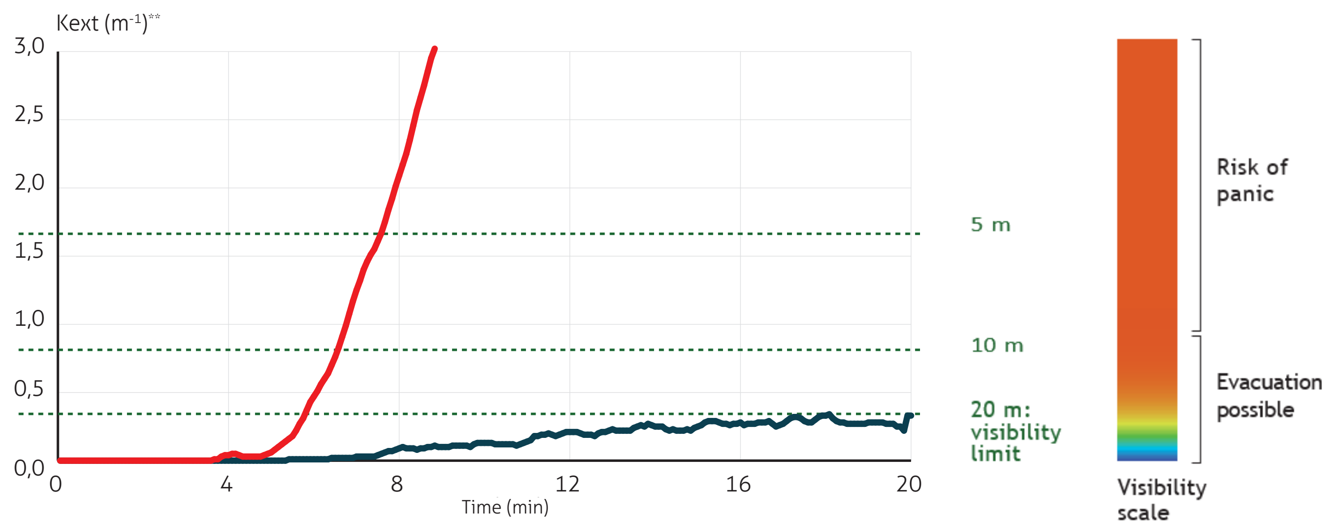
NATURAL SMOKE CONTROL'S EFFICIENCY
IN ENSURING VISIBILITY

NATURAL SMOKE CONTROL ENSURES VISIBILITY AT EYE LEVEL PENDING THE ARRIVAL OF EMERGENCY SERVICES (MEAN RESPONSE TIME: 18 MIN*)



— Without smoke control
— With smoke control (∑ Aa***: 2%)

Change in visibility at a height of 2 m as a function of time in medium-sized spaces measuring 1,000 m² and having a ceiling height of 8 m

Natural smoke control ensures that smoke remains 2 m above the floor (the height of a door lintel) for at least 20 minutes so that occupants may be evacuated and emergency services may respond more easily. In addition, emergency exit signs remain visible.

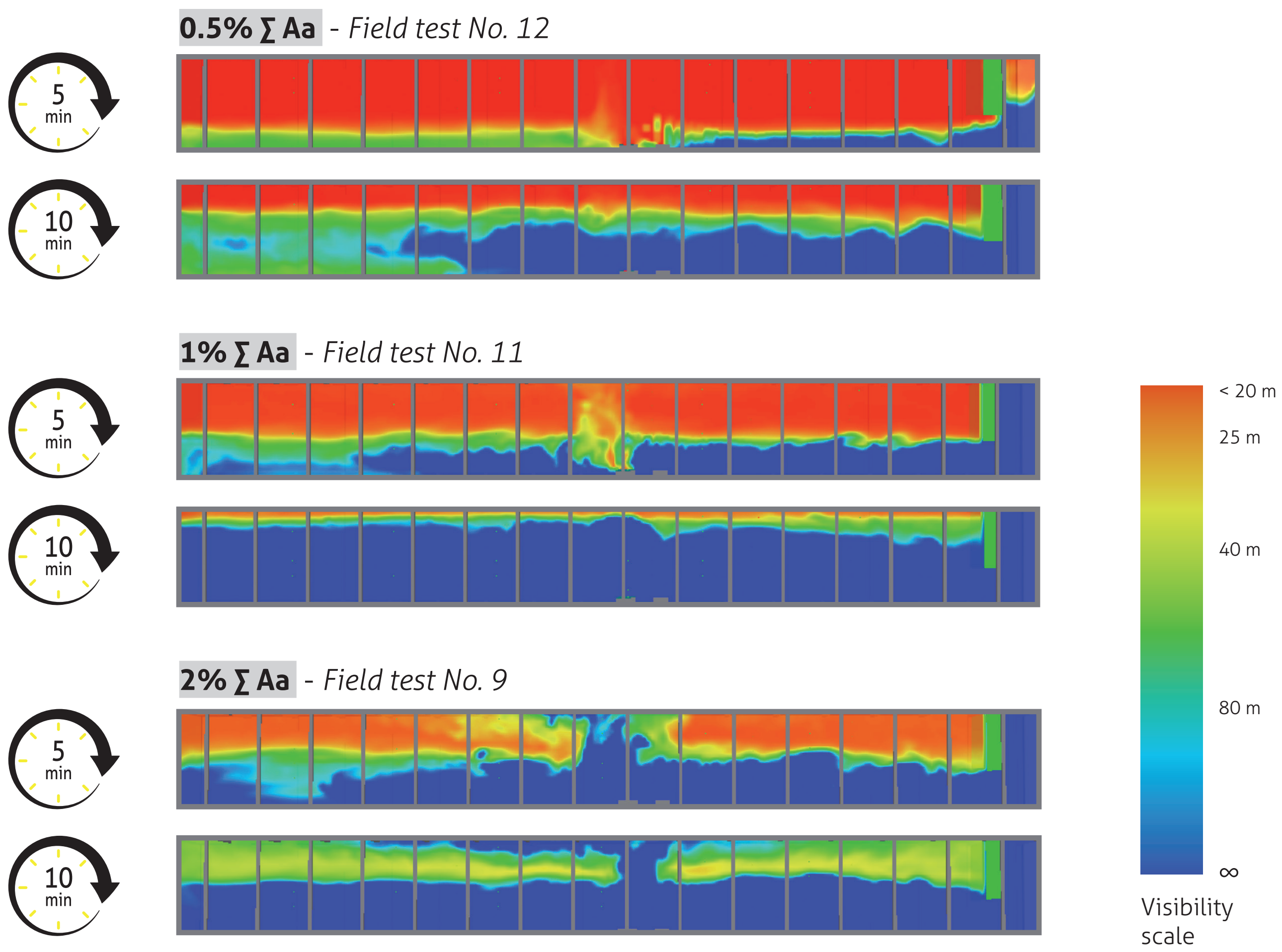
*Source: French Interior Ministry, SDIS Statistics, 2017

**Kext, light extinction coefficient. Used to measure visibility inside a building. The LCCP guide defines the following visibility limit as an acceptability criterion: at a height of 2 m, light extinction coefficient along routes < Klimit, where Klimit =0.4 m^{-1} =20 m.

***∑ Aa, combined total aerodynamic free area (see p. 6)

NATURAL SMOKE CONTROL'S EFFICIENCY IN ENSURING VISIBILITY INCREASES WITH THE COMBINED TOTAL AERODYNAMIC FREE AREA

CHANGE IN VISIBILITY AS A FUNCTION OF*∑ AA*, 5 AND 10 MINUTES AFTER SMOKE VENTS ARE



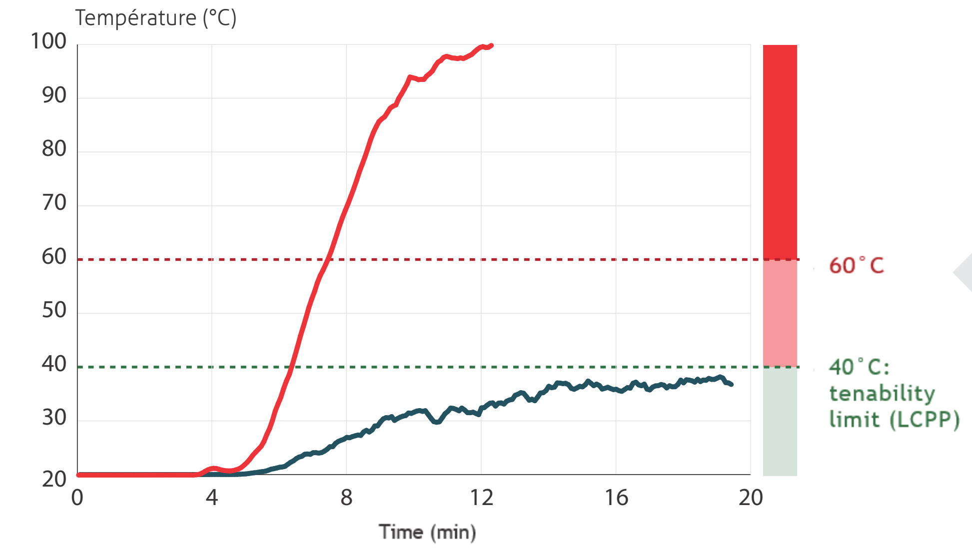
Increasing the combined total aerodynamic free area increases the efficiency of natural smoke control, **exhausts toxic smoke and gases more quickly, and improves visibility over time.**

*∑ Aa, combined total aerodynamic free area (see p. 6)

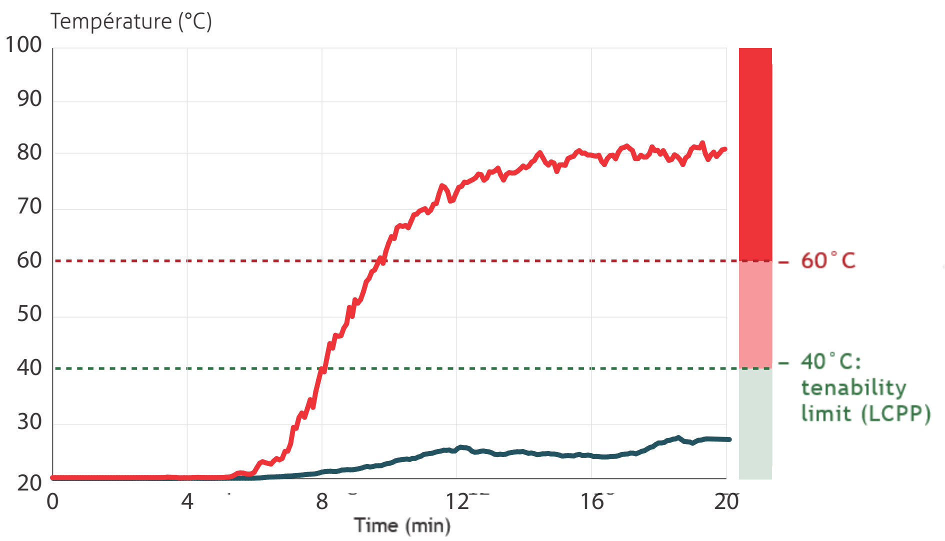
4 NATURAL SMOKE CONTROL'S EFFICIENCY IN ENSURING BEARABLE TEMPERATURES

Findings of the Efectis study

NATURAL SMOKE CONTROL KEEPS TEMPERATURES AT BEARABLE LEVELS BELOW 40°C*



Medium volume (single 1,000 m² compartment)



Large volume (single 1,600 m² compartment)

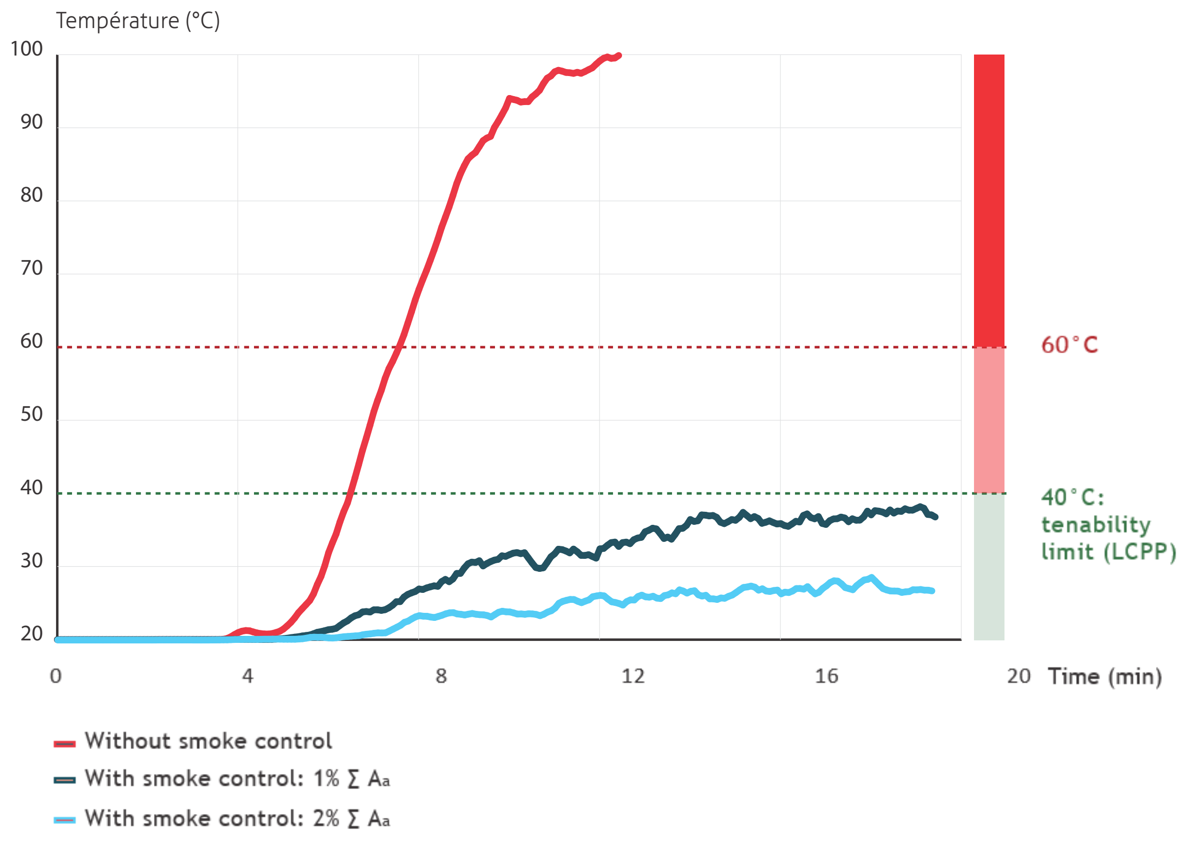
– Without smoke control
– With smoke control

Change in temperature at a height of 2 m as a function of time for a 6 MW fire and 1% ∑ Aa

Without smoke control, the critical temperature of 40°C is reached in less than seven minutes. **A smoke control system ensures that a layer of cool air remains near floor level for at least 20 minutes**, allowing occupants to be evacuated swiftly and emergency services to respond quickly.

*Criterion in the 2017 guide published by the Central Laboratory of the Prefecture of Police of Paris (LCPP) and below the 60°C limit for hyperthermia and burns

NATURAL SMOKE CONTROL'S EFFICIENCY IN CONTROLLING TEMPERATURE INCREASES WITH THE COMBINED TOTAL AERODYNAMIC FREE AREA



Change in temperature at a height of 2 m as a function of time and ∑ Aa for a 6 MW fire in a medium-sized space (1,000 m²) having a ceiling height of 8 m

The higher the combined total aerodynamic free area (∑ Aa), the longer the temperature remains below the tenable limit of 40°C so that precious time can be saved before emergency services arrive.

5 THE EFFICIENCY OF NATURAL SMOKE CONTROL ACCORDING TO FIRE INTENSITY

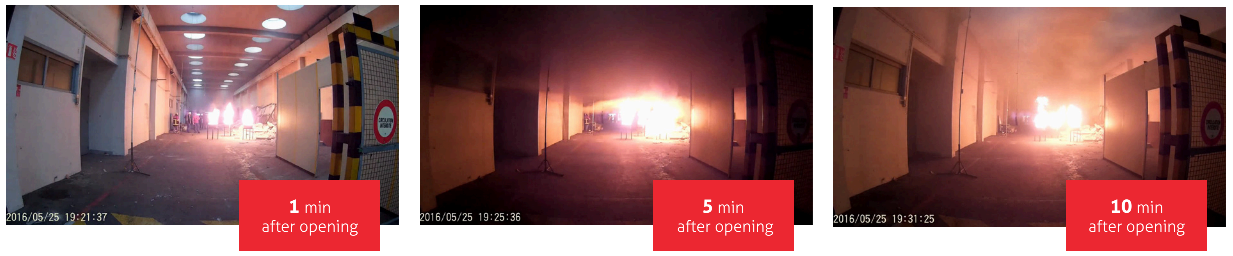
THE EFFICIENCY OF NATURAL SMOKE CONTROL IS CORRELATED WITH THE INTENSITY OF A FIRE

Fires of varying intensity were tested during a campaign conducted to observe stack effect phenomena during smoke generation.

- Eight tests involved warm smoke (corresponding to the combustion of a cinema seat, i.e. around 300 kW)
- Four tests involved hot smoke (corresponding to the combustion of a car, i.e. around 5 MW)

Note: Warm smoke generates smoke that is hot enough (> 300 kW) to evaluate the efficiency of a natural smoke control system.

Test No. 9
Change in visibility during a test involving warm smoke (2% ∑ Aa)



Test No. 6
Change in visibility during a test involving hot smoke (1% ∑ Aa)

The tests showed that **good smoke stratification occurs** when smoke is hot enough to increase the temperature in the space. This smoke then exits the space en masse through the vents, leaving a bearable layer of air near floor level.

HOT SMOKE CREATES A BETTER STACK EFFECT AND MORE EFFICIENT NATURAL VENTILATION

A natural smoke control system uses the stack effect to extract smoke. The higher the indoor-outdoor temperature (and pressure) difference at each NSHEV in a space, the greater the volume of extracted smoke.

The more intense the fire, the denser and hotter the smoke that will accumulate at the top of a space (under the roof vent) and the more efficient natural smoke extraction will be in exhausting it and reducing the height of the smoke layer. This system therefore ensures proper conditions for evacuating occupants.

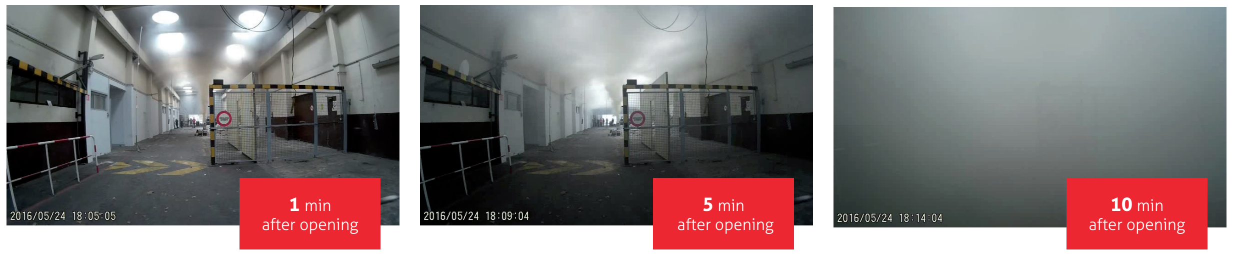
However, the combined total aerodynamic free area must be adjusted to the intensity of the fire.

THE LAB'S ADVICE

"Where there's fire, there's heat"

Warm or hot smoke is therefore required to reliably evaluate a natural smoke control system, which is based on the stack effect.

Trays filled with a smoke powder (a ternary mixture of potassium nitrate, potato starch and lactose) were used to generate sufficiently hot smoke without damaging the building.



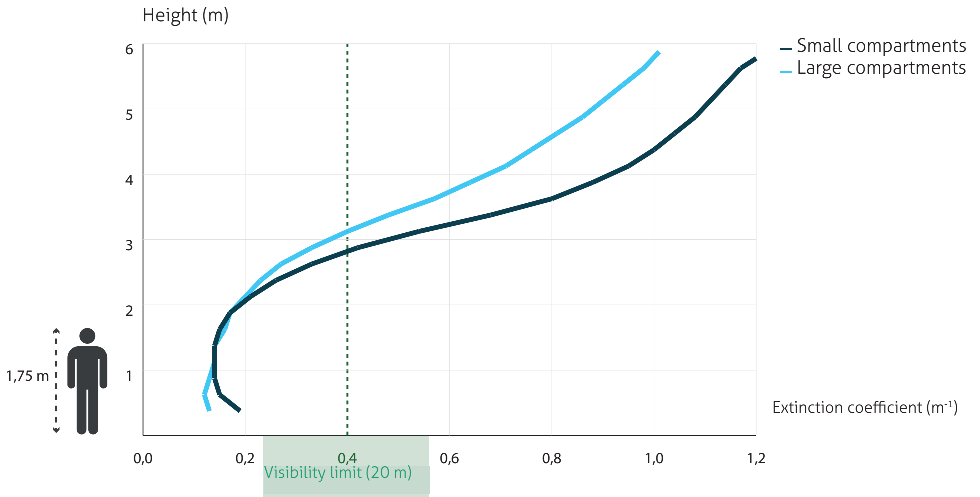
Test No. 3
Change in visibility during a test involving cool smoke (2% ∑ Aa)

6 THE EFFECT OF COMPARTMENTATION ON THE EFFICIENCY OF NATURAL SMOKE CONTROL

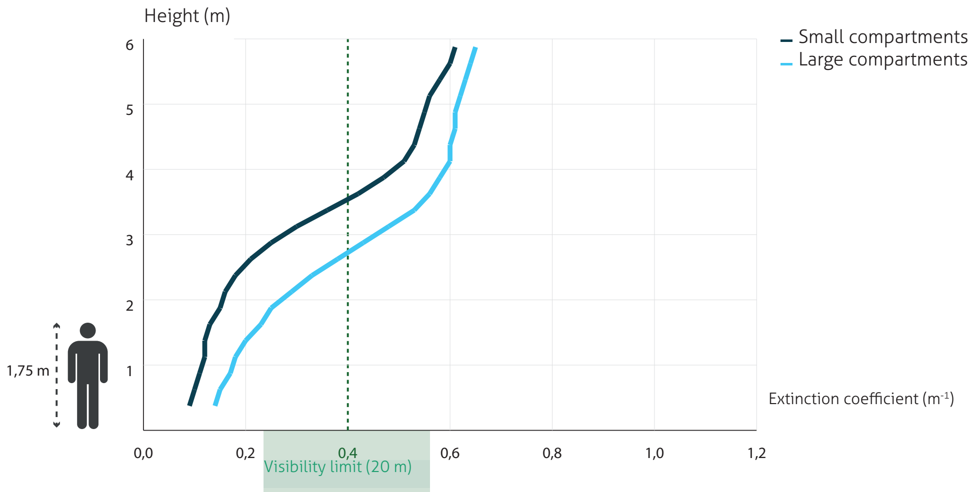
THE MORE THE COMPARTMENTS, THE LESS TRANSFER OF SMOKE, HEAT AND SOOT

Small and large compartments evaluated as part of the Osmose study

	No. of compartments	Area of one compartment (m²)	Area of the space (m²)
Small compartments	12	500	6,000
Large compartments	4	1,500	



Compartment containing the fire source



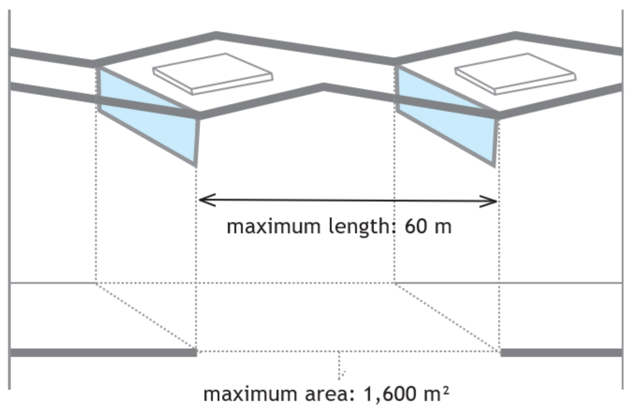
Compartments remote from the fire source

LE TIRAGE THERMIQUE EST PLUS EFFICACE DANS LE CAS DE PETITS CANTONS, QUI CONCENTRENT PLUS DE FUMÉES CHAUDES AU NIVEAU DES EXUTOIRES

The smaller the compartments, the more smoke will accumulate in those compartments near the seat of the fire and the less it will spread to other compartments. **Natural smoke control therefore limits the extent of smoke damage.**

FOCUS ON
Long compartments

The length-to-width ratio of a compartment plays a significant part in smoke control, particularly in the compartments adjoining the one containing the fire source. **The longer and narrower the compartment, the higher the risk that hot smoke will spread to adjoining compartments.**



Space divided into compartments (as per Technical Guidance Document No. 246)

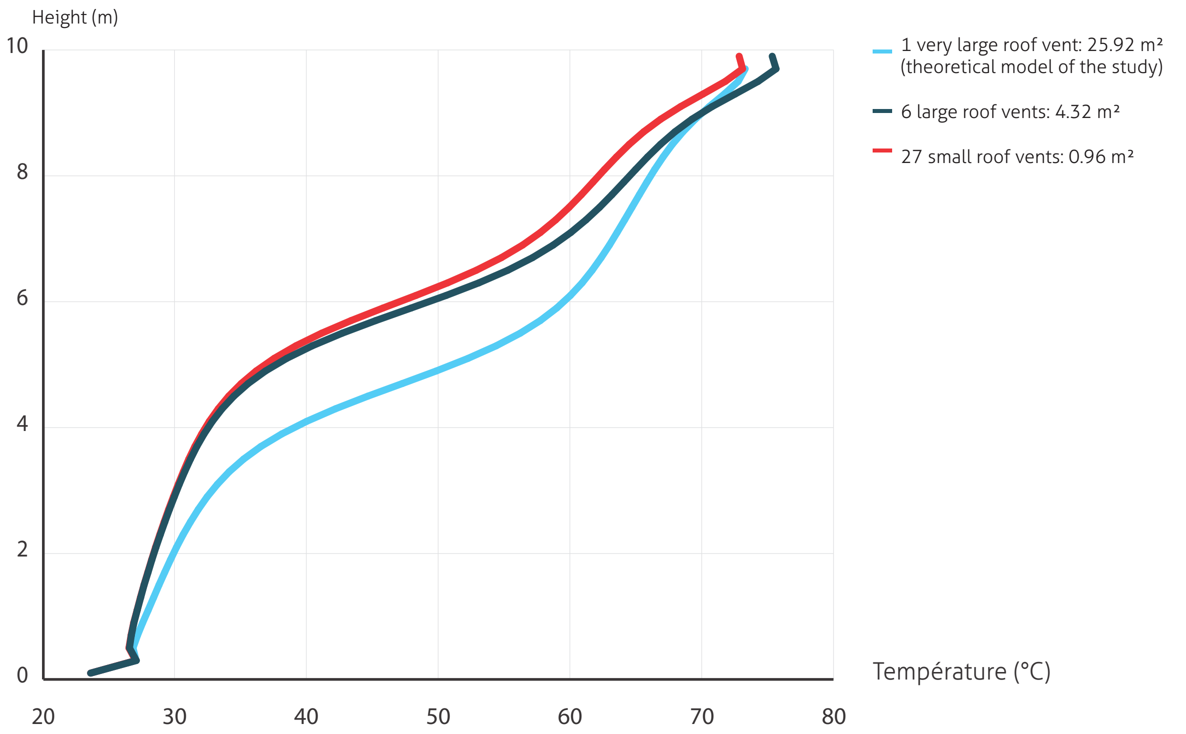
FOCUS ON
Delayed opening of smoke vents in compartments

When a space is divided into multiple compartments, opening simultaneously the vents in all compartments may decrease the efficiency of smoke control. **For this reason, it is recommended that the vents in the compartment containing the fire source are opened once thermal stratification occurs** so as to optimise the efficiency of the vents, and that the vents in the adjoining compartments are opened only when thermal stratification has taken place.

7 THE EFFECT OF ROOF VENTS ON THE EFFICIENCY OF NATURAL SMOKE CONTROL

COMBINED TOTAL AERODYNAMIC FREE AREA: A CRUCIAL EFFICIENCY CRITERION FOR ANY SMOKE CONTROL SYSTEM

THE EFFICIENCY OF NATURAL SMOKE CONTROL IS GREATEST WHEN MULTIPLE SMALL OR MEDIUM-SIZED ROOF VENTS ARE USED TO CONTROL TEMPERATURES



Change in temperature as a function of ceiling height and the number of installed roof vents (combined total aerodynamic free area of 25.92 m²)

Provided the combined total aerodynamic free area complies with prevailing legislation, the size and number of roof vents have a limited impact on the efficiency of natural smoke control.

Good to know!
If Aa>6 m², plugholing (the pulling of fresh air into a smoke exhaust) may occur and prevent proper smoke ventilation.

Findings of the Efectis study

Field tests Nos. 8-13
The field tests evaluated the average visibility within a space based on the distribution of roof vents and their distance from the seat of the fire. They demonstrated that t**he distribution and distance (no more than 50 m) had little impact on the efficiency of natural smoke control.**

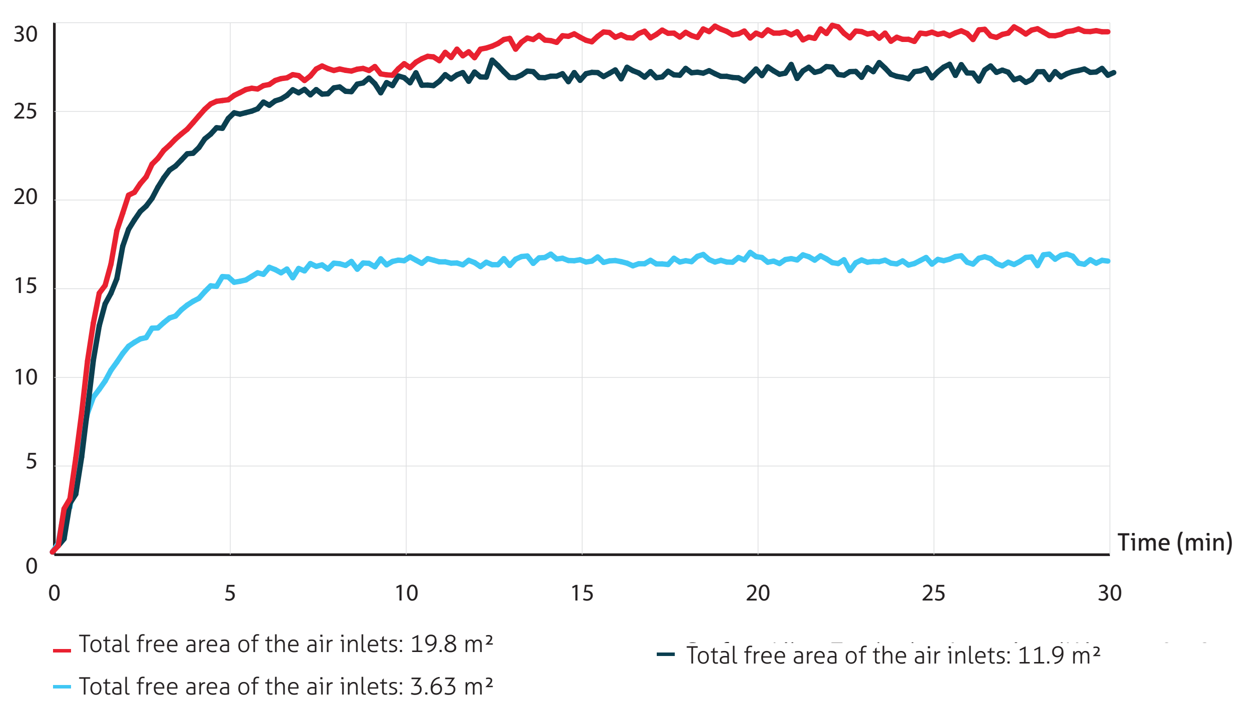
Test No. 8: distributed roof vents
Heat output: 150 kW
0.5% ∑ Aa

Test No. 13: roof vents around 50 m from the fire
Heat output: 150 kW
0.5% ∑ Aa

8 THE EFFECT OF AIR INLETS ON NATURAL SMOKE CONTROL

Findings of the Efectis study

THE GREATER THE TOTAL FREE AREA* OF THE AIR INLETS, THE GREATER THE NATURAL SMOKE CONTROL EFFICIENCY



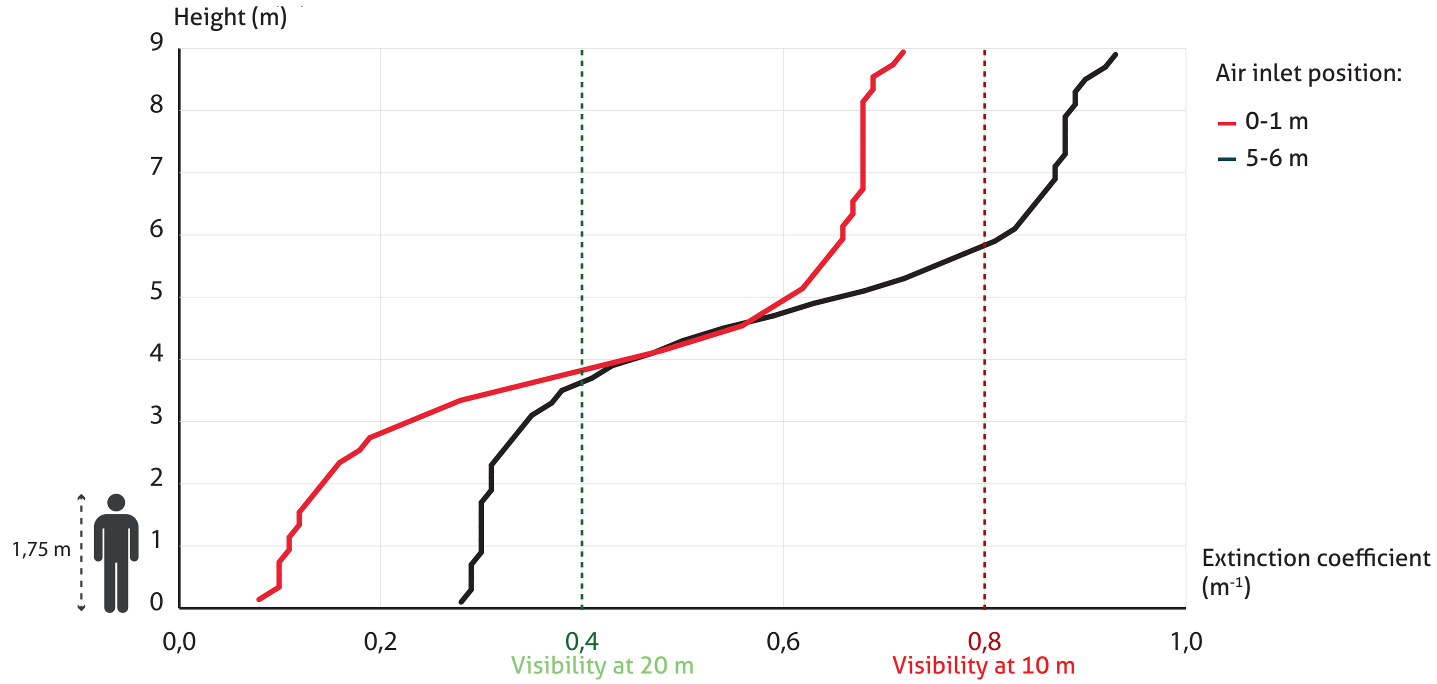
Change in the flow rate of hot gases exhausted by roof vents as a function of the total free area of air inlets (Aa=8.5 m²)

The total flow rate of the exhausted hot gases increases during the first 10 minutes and then levels off. It can be seen that for an identical aerodynamic free area, **the flow rate of hot air exhausted by the roof vents increases** with the total free area of the air inlets.

Good to know!
According to Technical Guidance Document No. 246, t**he total free area of the air inlets must be at least that of the total geometric area of the roof vents.** Distributing air inlets along the various sides of a space has little effect on rooftop smoke ventilation.

*Actual air flow area, not greater than the geometric area of the vent opening and taking potential obstacles (linkages, grilles, etc.) into consideration – source: Technical Guidance Document No. 246

THE EFFICIENCY OF NATURAL SMOKE CONTROL INCREASES WHEN AIR INLETS ARE POSITIONED NEAR FLOOR LEVEL



Change in average visibility as a function of the above-floor height of air inlets

Provided their total combined area is large enough, low-level air inlets of any size provide more efficient natural smoke control. They maintain better visibility conditions, allowing occupants to be evacuated swiftly and emergency services to respond quickly.

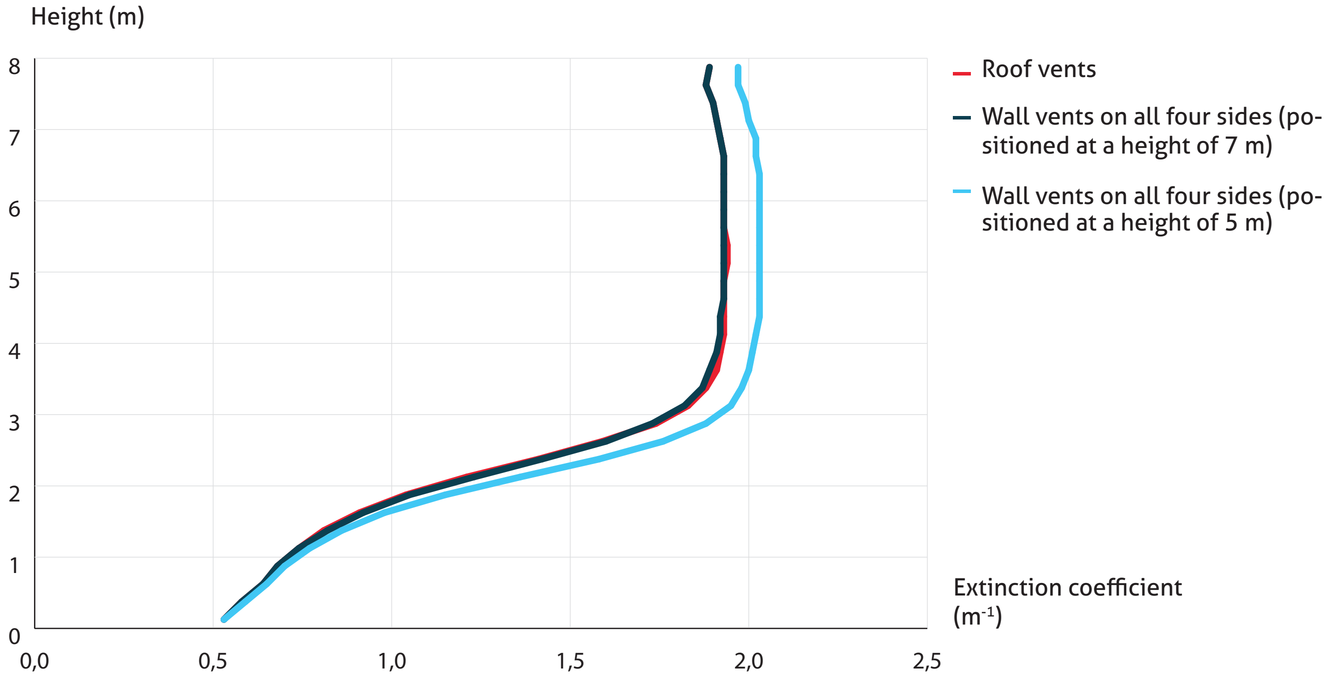
However, **multiple small air inlets are better than a single large air inlet at clearing smoke-filled spaces.**

Good to know!
Technical Guidance Document No. 246 requires that air inlets not have dimensions that are less than 0.20 m and that they have a free area greater than 10 dm². It also specifies that the top portion of air inlets located in partitioned circulation areas are no more than 1 m above floor level.

9 DO ROOF AND WALL VENTILATORS HAVE DIFFERENT IMPACTS ON NATURAL SMOKE CONTROL EFFICIENCY?

Findings of the Efectis study

ROOF AND WALL VENTILATORS ARE EQUALLY EFFICIENT IN EXHAUSTING SMOKE



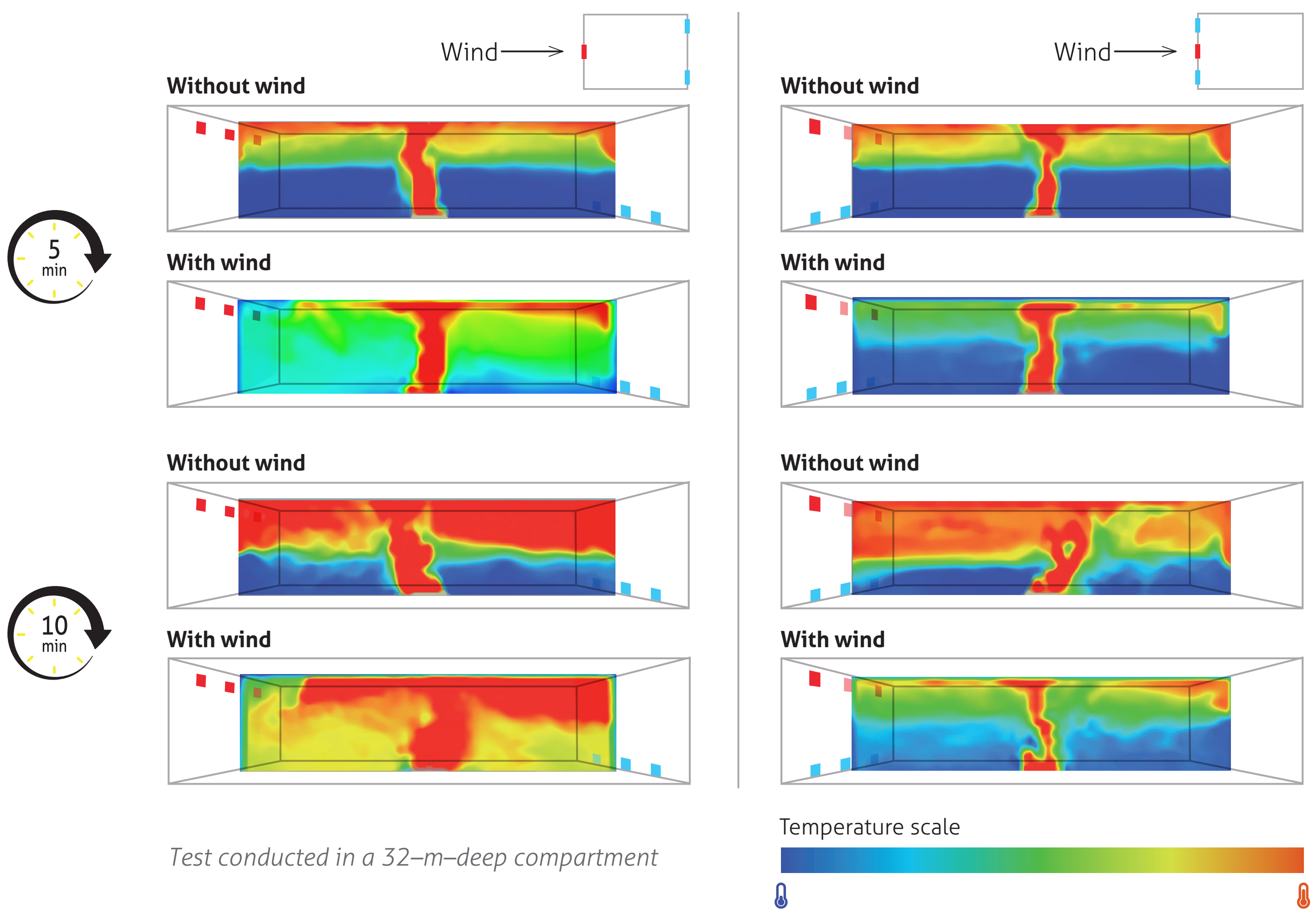
Change in visibility as a function of height for a smoke thickness of 4 m (theoretical model) in an 8-m-high building

With both roof and wall ventilators, stratified smoke logically accumulates at the top of a space. However, natural smoke control is more efficient when **wall vents are located under the roof or ceiling of the space.**

Good to know!
Technical Guidance Document No. 246 specifies that wall vents should be vertically tilted by less than 30 degrees.

THE LOCATION OF WALL VENTS AND AIR INLETS CAN HAVE A STRONG IMPACT ON SMOKE CONTROL

ANALYSIS OF THE EFFECTS OF WIND ON SMOKE CONTROL 5 AND 10 MINUTES AFTER WALL VENTS ARE OPENED



Test conducted in a 32–m–deep compartment

If the air inlets and smoke vents are located on opposite walls, the wind pulls fresh air into the space, mixing it with the smoke and causing the smoke to destratify, leaving a high-temperature and highly opaque homogeneous volume instead of separate hot and cold layers.

THE LAB'S ADVICE
To avoid wind-induced smoke destratification, we recommended placing **air inlets and smoke vents on the same wall.**

10 THE FUNDAMENTALS OF SPRINKLER SYSTEMS

SPRINKLER SYSTEMS ARE USED TO CONTROL OR EXTINGUISH FIRE BY SPRAYING WATER AUTOMATICALLY

Sprinkler systems limit fire spread by controlling the fire and wetting nearby combustibles pending the arrival of emergency services.

- A sprinkler head is held closed by a temperature-sensitive bulb (or fusible link). When the heat generated by a fire reaches a given ceiling temperature, the bulb bursts and sprays water over the seat of the fire. This spray is local and progressive. If the sprinkler is unable to sufficiently lower the temperature, the neighbouring sprinklers also open to help to control the fire.

- The time that elapses before a sprinkler is set off by a heat source is dependent on the properties of the bulb and the liquid contained in it. The temperature rating depends on the risk to which the sprinkler will be exposed. In France, the typical temperature rating for sprinklers in public buildings is 68°C. The liquid inside a bulb is colour-coded to easily identify its operating temperature.

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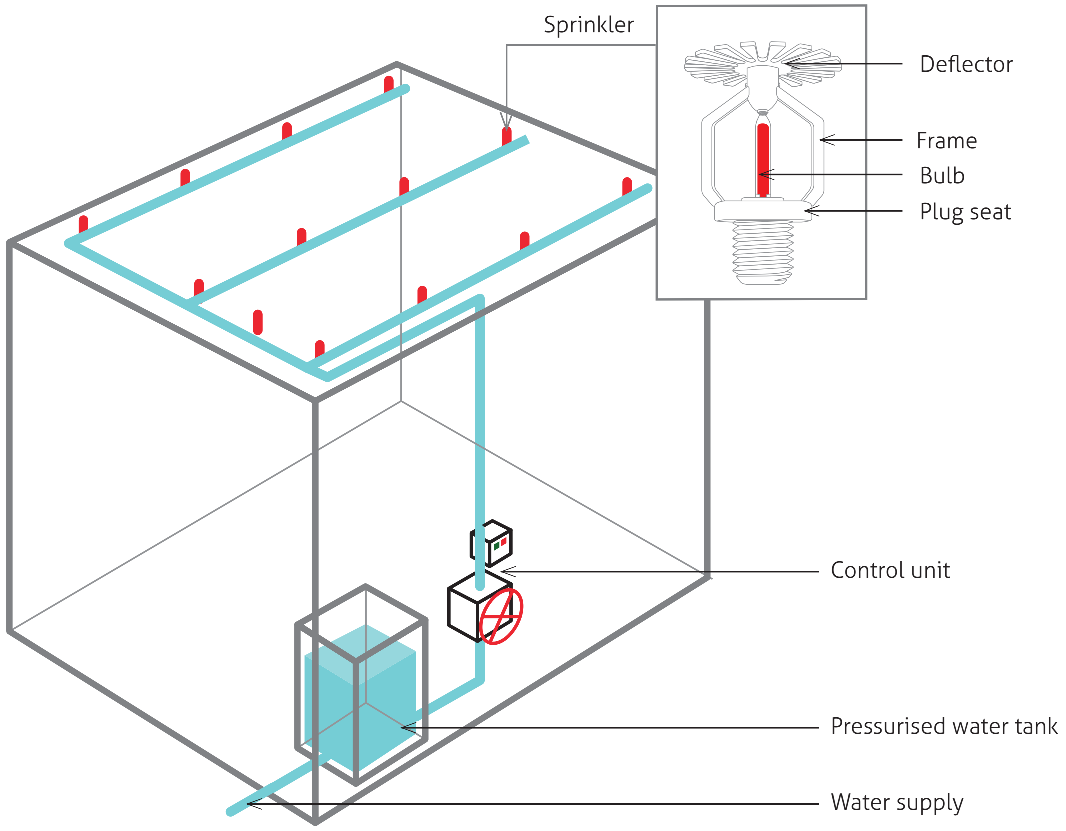


LEGISLATION

In France, various pieces of legislation govern the applications in which sprinklers may be used, the requisite number and position of sprinkler heads and even the water flow rates to be used according to the risk class of the protected activity.

- Industrial and commercial buildings:
  - France's labour code:
    Art. R 4227-30
  - Facilities classified for environmental protection purposes (sections 1432, 1435, and 1530)

- Public buildings:
  - Article MS 25 – Fire Safety Regulations for Public Buildings
    Order of 12 October 2006, as amended

Most sprinkler systems used in France are designed in compliance with standard NF EN 12845 and rule APSAD R1.

STUDY INTO THE COMPLEMENTARITY OF SPRINKLER AND NATURAL SMOKE CONTROL SYSTEMS

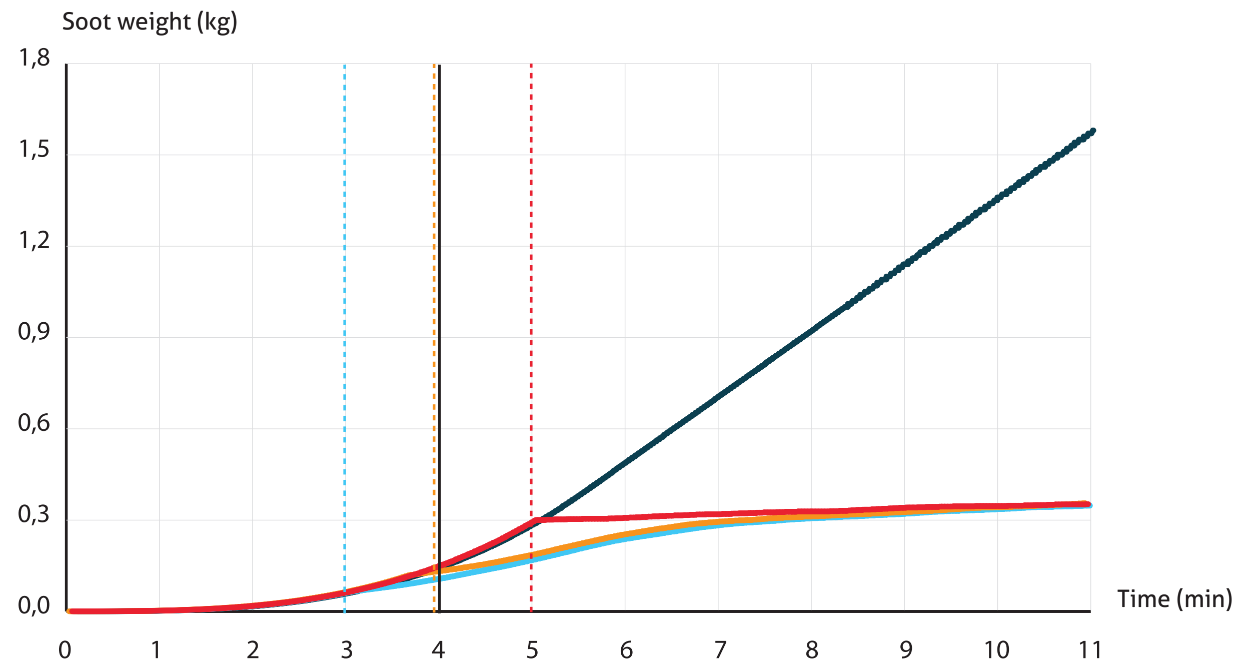
Sprinkler systems and NSHEVs each have an important role to play in fire safety. Although each has different mechanisms of action, both contribute to improving the safety of people and property in the event of fire.

The reciprocal interactions of one system on the other and their combined use are the focus of the CNPP study, whose findings are presented on the following pages.

11 THE COMBINED EFFECT OF SPRINKLER AND SMOKE CONTROL SYSTEMS

ON SOOT EXHAUST AND FIRE SPREAD

ACTIVATING THE NATURAL SMOKE CONTROL SYSTEM CAN REMOVE UP TO 80% OF SOOT



Change in the amount of soot accumulated in a commercial building of around 4,300 m² and fitted with 20 NSHEVs and 528 sprinklers

- After activation of the first sprinkler
- Simultaneous opening of the roof vent and activation of the first sprinkler
- Opening of the roof vent before activation of the first sprinkler
- No opening of the roof vent

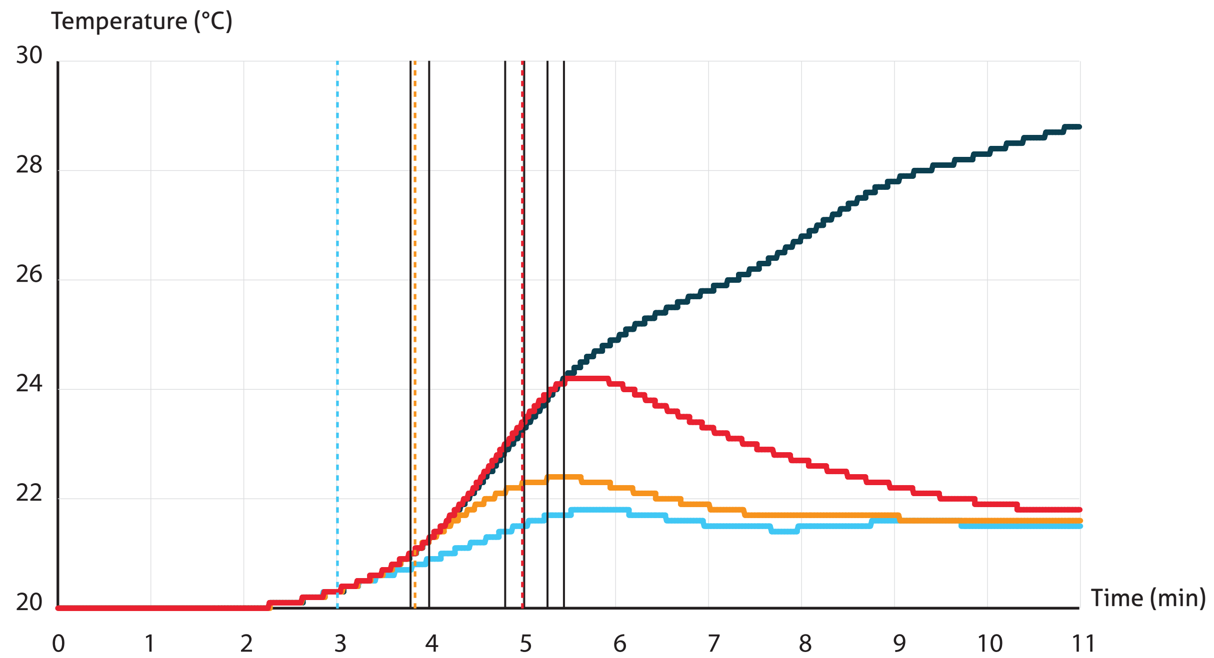
Opening of the roof vent

Activation of the first sprinkler

When combined with a sprinkler system, natural smoke control can efficiently remove up to 80% of soot from a space.
The sooner the natural smoke control system is activated (before the sprinkler system is set off), the less soot will build up in a space.

THE LAB'S ADVICE
Natural smoke control's efficiency in exhausting soot can be applied to buildings not fitted with sprinkler systems.

NATURAL SMOKE CONTROL IS MORE EFFICIENT IN LIMITING THE TRANSFER OF SMOKE FROM ONE COMPARTMENT TO ANOTHER



Change in the average temperature of sprinklers located in the adjoining compartment – based on a model of a warehousing facility divided into two compartments of 1,290 m² and 1,260 m², respectively, containing 12 NSHEVs and 296 sprinklers

- Opening of the roof vent after activation of the first sprinkler
- Simultaneous opening of the roof vent and activation of the first sprinkler
- Opening of the roof vent before activation of the first sprinkler
- No opening of the roof vent

Opening of the roof vent

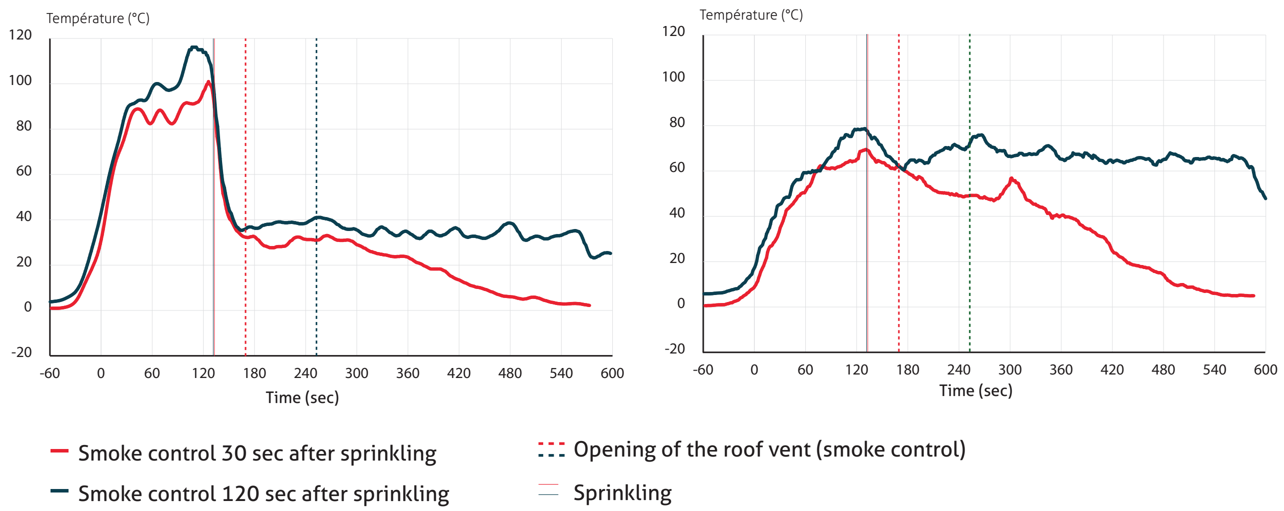
Sprinkling

The opening of the roof vents in the compartment containing the fire source immediately limits the transfer of heat to the adjoining compartment. **The sooner the smoke control system is activated, the lower the temperature rise in the second compartment.**

Although sprinklers lower the temperature of smoke by absorbing a significant amount of heat, smoke control is more efficient in limiting the spread of heat and combustion products to adjoining compartments. **As a result, it enables occupants to be evacuated more quickly and emergency services to respond more easily and also reduces hot-smoke damage.**

THE DISTRIBUTION OF THE SMOKE VENTILATION AREA PLAYS AN IMPORTANT ROLE IN THE SYSTEM'S EFFICIENCY

Roof vent No. 1 (above the fire) *Roof vent No. 2*



Comparison of the change in temperature measured in two adjacent NSHEVs during testing with sprinkling followed by smoke ventilation (fire located under roof vent No. 1)

The temperature inside roof vent No. 1, which was located directly above the fire, plummeted when sprinkling was activated.
Cooling induced by sprinkling was lower in the adjacent roof vent (No. 2).

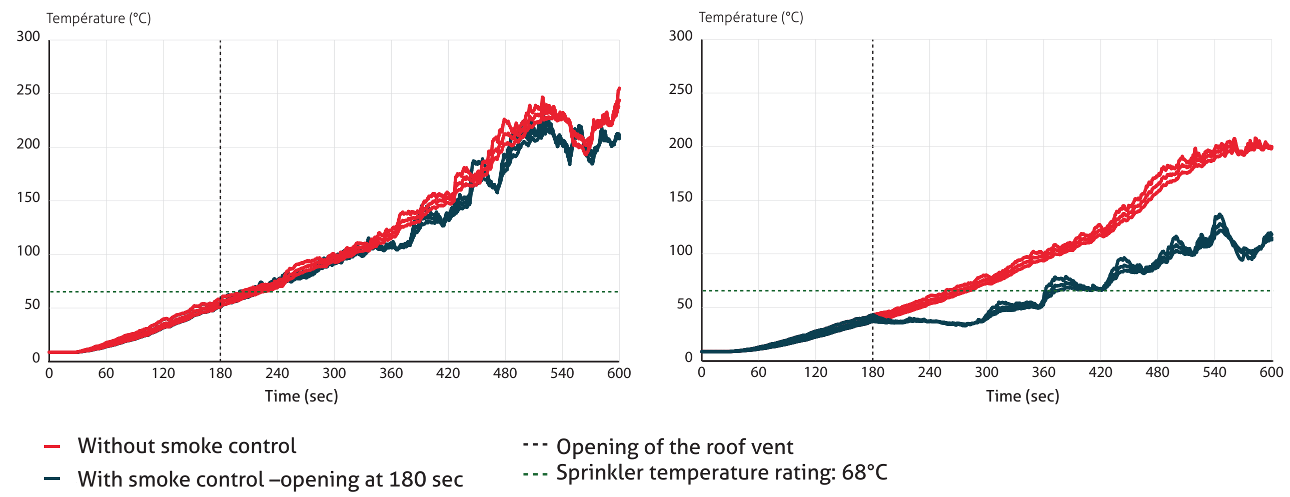
When the fire is located under a roof vent, cooling from sprinkling has an adverse effect on natural smoke control's efficiency as the gases contained in the hot smoke cool down instead of accumulating under the roof vent and cause it to open.
The efficiency of the roof vent located directly above the fire is impaired, whereas the efficiency of the other vents in the compartment is only slightly impaired.

THE LAB'S ADVICE

Based on these findings, **the smoke ventilation area must be distributed across multiple roof vents** to prevent such a situation from occurring and avoid impairing the system's overall efficiency.

THE DISTRIBUTION OF THE SMOKE VENTILATION AREA PLAYS AN IMPORTANT ROLE IN THE SYSTEM'S EFFICIENCY

Sprinkler fitted under the roof vent *Sprinkler fitted next to the roof vent*

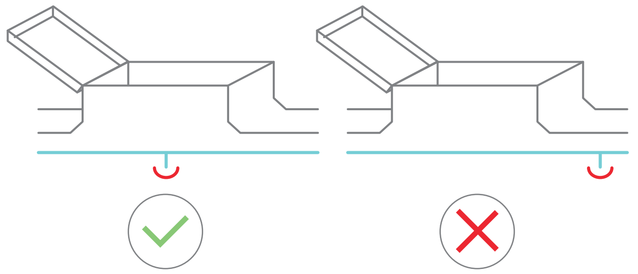


Comparison of the change in temperature at the sprinkler based on its position (fire located directly under the roof vent)

When the fire is located directly under a roof vent, the smoke control system kicks in to draw heat out, thus lowering the temperature at the ceiling and the adjacent sprinkler, and potentially delaying or blocking sprinkling.
When a sprinkler is positioned directly under a roof vent, it will immediately go off when the smoke control system has been activated.

Good to know!

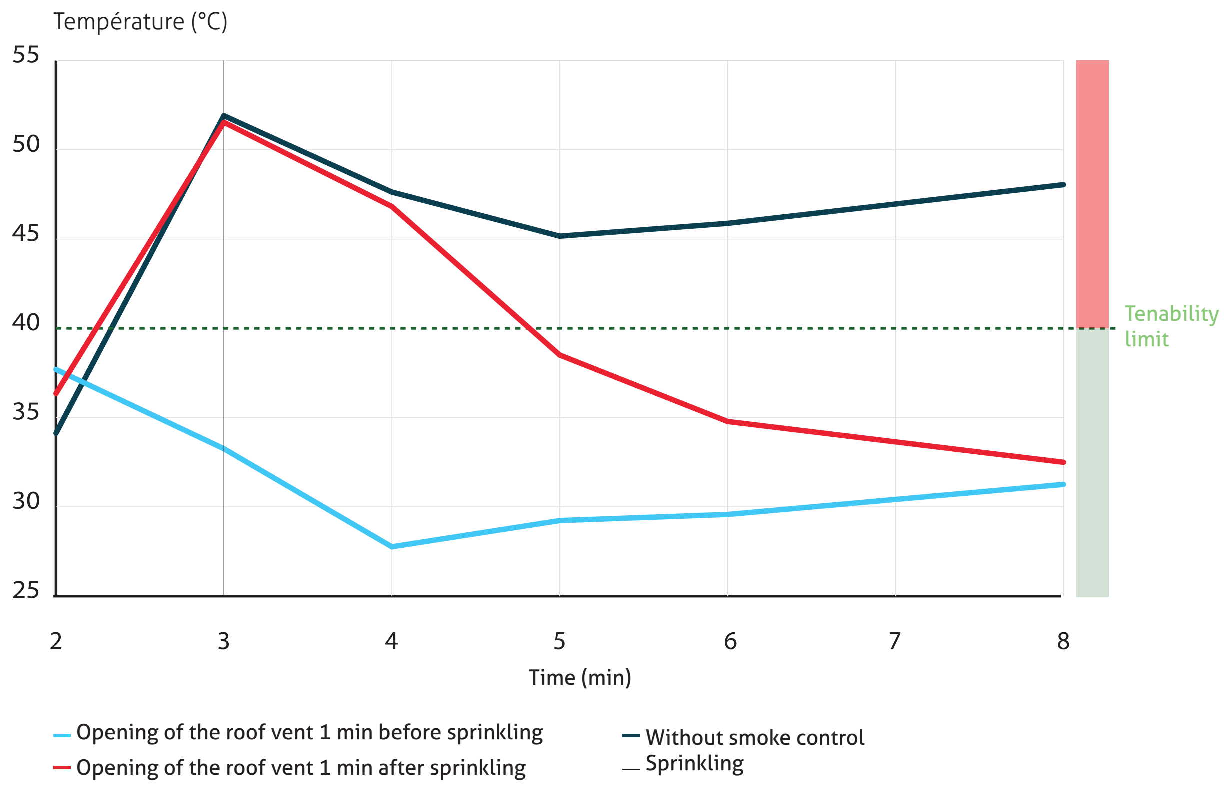
If a sprinkler system is combined with smoke control, a sprinkler head should be fitted under each roof vent.



13 THE COMBINED EFFECT OF SPRINKLER AND SMOKE CONTROL SYSTEMS

ON TEMPERATURE AND VISIBILITY

WHEN COMBINED WITH A SPRINKLER SYSTEM, NATURAL SMOKE CONTROL WILL LOWER TEMPERATURES INSIDE A BUILDING MORE QUICKLY

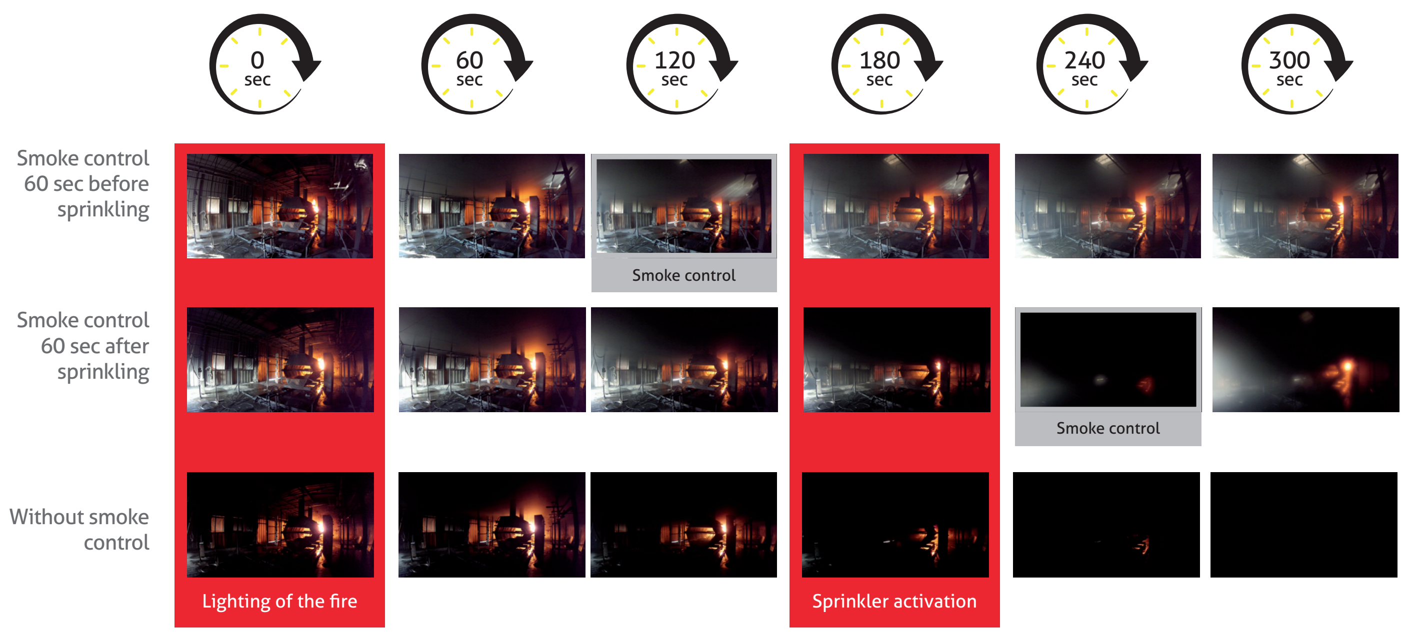


Change in temperature at 2 m from floor level for the three smoke ventilation scenarios

Activating the smoke control system before sprinkling avoids exceeding the 40°C tenability limit at head height. However, when activated after sprinkling, the natural smoke control system steadily lowers thermal stresses and cools spaces more efficiently than sprinkling alone.

NATURAL SMOKE CONTROL IMPROVES VISIBILITY, ESPECIALLY WHEN IT IS ACTIVATED BEFORE SPRINKLING

Medium-scale tests (400 kW fire)



Visibility comparison for two different NSHEV activation times

When sprinkling alone was activated, visibility decreased to zero and made proper evacuation impossible.

When roof vents were opened prior to sprinkling, smoke control maintained good visibility throughout the test.

Good to know!

Natural smoke control is more efficient when activated before sprinkling.
Even when activated after the first sprinkler goes off, it improves visibility although slightly dense cool smoke remains near floor level.

14 TAKEAWAYS
FROM THE OSMOSE STUDY

THE THREE-YEAR **OSMOSE STUDY** EVALUATED THE ACCURACY OF NUMERICAL CALCULATION MODELS USED IN SMOKE CONTROL ENGINEERING AND SCIENTIFICALLY VALIDATED THE RECOMMENDATIONS IN TECHNICAL GUIDANCE DOCUMENT NO. 246. IT ALSO CONFIRMED THAT PREVAILING FRENCH REGULATIONS ENSURE SAFETY.

The Osmose study demonstrates that natural smoke control systems are truly efficient in:

- **Controlling and managing fire hazards** so that people can be evacuated and emergency services can respond effectively and safely
- **Limiting fire spread** to protect buildings and property inside them

The study also demonstrated for the very first time the reliability of simulations compared with field tests. These field tests showed that the efficiency of natural smoke control varies with the type of combustible and the heat of the smoke given off. A natural smoke control system can therefore only be reliably tested when smoke is hot enough to produce the thermal stratification required for its proper operation.

Lastly, the field tests also helped to establish a number of implementation rules for helping to ensure the proper performance of a natural smoke control system.

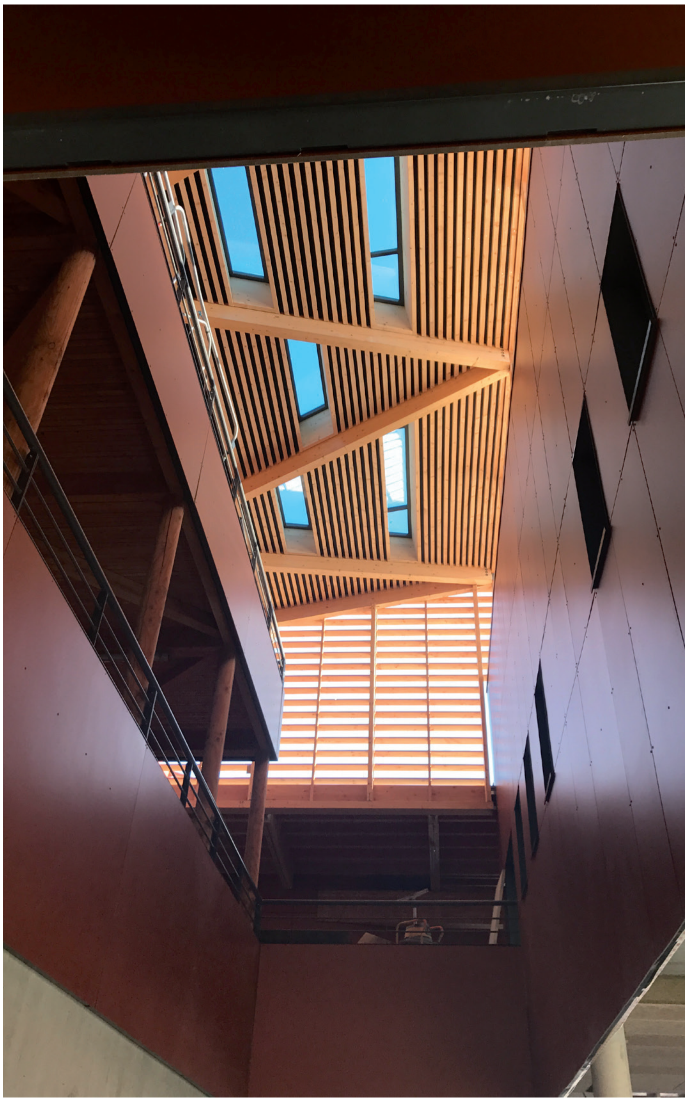
The method of natural smoke control, which is closely governed by prevailing applicable legislation and standards, must be selected according to a building's architectural design and use. A mechanical smoke control system is a potential alternative in buildings where natural smoke control is impossible (see the FFMI's brochure on mechanical smoke ventilation published in 2018).

THE 10 GOLDEN RULES
OF NATURAL SMOKE CONTROL

- The greater the ventilation area of the system, the more efficient the natural smoke ventilation. Toxic smoke and gases are cleared more quickly, greater visibility is guaranteed over time and temperatures are kept at more tolerable levels so that occupants may be evacuated faster pending the arrival of emergency services.
- Provided the combined total aerodynamic free area complies with prevailing legislation, natural smoke control will be efficient regardless of the number and size of roof vents in a building.
- Whether provided by roof or wall ventilators, the efficiency of natural smoke control is the same.
- Natural smoke control is more efficient when compartments are small. This is because small compartments are better at containing smoke and increase the efficiency of the stack effect.
- The greater the area of the air inlets, the more efficient the natural smoke control system. Their area should be at least that of the smoke vents.
- Natural smoke control clears away smoke better when air inlets are located as close to floor level as possible.
- When a building is exposed to wind, natural smoke control is most efficient when smoke vents and air inlets are all located on the same wall.
- Sprinkler and natural smoke control systems work together to improve visibility and lower temperatures provided smoke control is activated first.
- Sprinkler and natural smoke control systems are most efficient when the smoke ventilation area is distributed across multiple NSHEVs.
- Sprinkler and natural smoke control systems work together best when sprinklers are fitted in roof vent frames.

15 NATURAL SMOKE CONTROL: DEFINITIONS AND KEYWORDS

- **Aerodynamic free area (Aa):** the smoke ventilation area, which is product of the geometric area of the smoke vent and the coefficient of discharge.
- **Combined total aerodynamic free area (∑ Aa):** the sum of the aerodynamic free areas of all NSHEVs.
- **Natural Smoke and Heat Exhaust Ventilators (NSHEVs):** the roof and wall vents designed for exhausting smoke and hot gases.
- **Plugholing:** the pulling of fresh air into a smoke exhaust.
- **Smoke barrier:** a vertical separation placed under a roof or ceiling to prevent the lateral spread of smoke and combustion gases.
- **Smoke reservoir:** the space between the floor and ceiling that is bounded by smoke barriers.
- **Roof ventilator or roof vent:** a remote-controlled roof-mounted NSHEV.
- **Stack effect (or chimney effect):** the natural movement of air out of buildings resulting from temperature differences between indoor and outdoor air.
- **Thermal stratification:** the phenomenon observed during fires whereby temperatures vary with height. Hot gases rise to the ceiling of a building, where they build up and form a top layer of hot, dense smoke. At floor level, which is clear of smoke, temperatures remain close to the initial ambient conditions (at least during the first few minutes of the fire).
- **Visibility limit:** the distance beyond which visibility becomes poor and complicates the evacuation of occupants. Calculated using the extinction coefficient, it has been set at 20 m (or 0.4 m^{-1}) in the reference guide produced by the Central Laboratory of the Prefecture of Police of Paris (LCPP).
- **Wall ventilator or wall vent:** a wall-mounted NSHEV.



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