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**System och komponenter för rök– och brandgaser –
Del 5: Riktlinjer för funktionella rekommendationer och beräkningsmetoder för ventilationssystem för rök och värmeutsläpp**

**Smoke and heat control systems –
Part 5: Guidelines on functional recommendations and calculation methods for smoke and heat exhaust ventilation systems**

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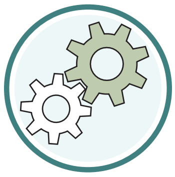

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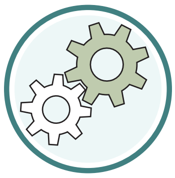

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TECHNICAL REPORT

RAPPORT TECHNIQUE

TECHNISCHER BERICHT

CEN/TR 12101-5

October 2005

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English Version

Smoke and heat control systems - Part 5: Guidelines on functional recommendations and calculation methods for smoke and heat exhaust ventilation systems

Systèmes de contrôle de fumées et de chaleur - Partie 5 : Guide de recommandations fonctionnelles et de calcul pour les systèmes d'exutoires de fumées et de chaleur

Rauch- und Wärmefreihaltung - Teil 5: Anleitung zu funktionellen Empfehlungen und Rechenverfahren für Anlagen zur Rauch- und Wärmefreihaltung

This Technical Report was approved by CEN on 30 September 2005. It has been drawn up by the Technical Committee CEN/TC 191.

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Foreword

This CEN Technical Report (CEN/TR 12101-5:2005) has been prepared by Technical Committee CEN/TC 191 “Fixed firefighting systems”, the secretariat of which is held by BSI.

This Technical Report supersedes CR 12101-5:2000.

This Technical Report is based on the text of British Standard BS 7346-4:2003.

Introduction

0.1 General introduction

Smoke and heat exhaust ventilation systems (SHEVS) create a smoke free layer above a floor by removing smoke. They can, therefore, improve conditions to allow the safe escape and/or rescue of people and animals, to protect property and to permit a fire to be fought while still in its early stages. Ventilation systems for smoke removal also serve simultaneously for heat exhaust and can exhaust hot gases released by a fire in the developing stage.

The use of such systems to create smoke free areas beneath a buoyant smoke layer has become widespread. Their value in assisting in the evacuation of people from buildings, reducing fire damage and financial loss by preventing smoke logging, facilitating fire-fighting, reducing roof temperatures and retarding the lateral spread of fire is firmly established. For these benefits to be realised it is crucial that smoke and heat exhaust ventilators operate fully and reliably whenever called upon to do so during their installed life.

Components for a SHEVS need be installed as part of a properly designed smoke and heat exhaust system. Natural SHEVS operate on the basis of the thermal buoyancy of the gases produced by a fire.

The performance of these installations depends, for example, on:

— the temperature of the smoke;

— the fire size;

— the aerodynamic free area of the ventilators, or the volume of smoke exhausted by powered ventilators;

— the wind influence;

— the size, geometry and location of the inlet air openings;

— the size, geometry and location of smoke reservoirs;

— the time of actuation;

— the arrangements and dimensions of the building.

Ideally the design fire upon which calculations are based shows the physical size and heat output of the fire changing with time in a realistic manner, allowing the growing threat to occupants, property and fire-fighters to be calculated as time progresses. Such time-based calculations of the time-to-danger usually have to be compared with separate assessments of the time recommended for safe evacuation of occupants of the building or of the time recommended for initiation of successful fire-fighting. These latter assessment procedures fall outside the scope of this Technical Report, although it is anticipated to supplement this Technical Report with design procedures for time-dependant fires in the future. In these calculations fire growth curves are selected that are appropriate to the precise circumstances of the building occupancies, fuel arrangements and sprinkler performance, where appropriate. Where such information is available, these calculations are conducted on a case-by-case basis using recommended fire safety engineering procedures. Even where such an approach is adopted, appropriate performance recommendations, e.g. minimum clear height, external influences, can be drawn from this Technical Report.

Where such time-based calculations are not feasible, it is possible to use a simpler procedure based on the largest size a fire is reasonably likely to reach in the circumstances. This time-independent or steady-state design is not to be confused with steady fires, which achieve full size instantly and then burn steadily. Rather the procedure assumes that a SHEVS that is able to cope with the largest fire can also cope with the (usually earlier) smaller stages of the fire.

In practice, it is much easier to assess the largest reasonably likely size of fire than to assess the growth rate of that fire.

0.2 Smoke exhaust ventilation design philosophies

0.2.1 Protection of means of escape (life safety)

A common approach to protect a means of escape is to achieve a smoke-free height beneath a thermally buoyant smoke layer below a ceiling. A SHEVS uses this principle to allow the continued use of escape routes that are in the same space as the fire, e.g. within enclosed shopping malls and many atria. The rate of smoke exhaust (using either natural smoke exhaust ventilators or powered smoke exhaust ventilators) is calculated to keep the smoke at a safe height above the heads of people using the escape routes, and to keep the radiated heat from the smoke layer at a low enough value to allow the escape routes to be used freely, even while the fire is still burning.

0.2.2 Temperature control

Where the height of clear air beneath the thermally buoyant smoke layer is not a critical design parameter, it is possible to use the calculation procedures in 0.2.1 in a different way. The rate of smoke exhaust can be designed to achieve (for a specified size of fire) a particular value for the temperature of the gases in the buoyant layer. This allows the use of materials that would otherwise be damaged by the hot gases. A typical example is where an atrium façade has glazing that is not fire-resisting, but which is known to be able to survive gas temperatures up to a specified value. The use of a temperature control SHEVS in such a case could, for example, allow the adoption of a phased evacuation strategy from higher storeys separated from the atrium only by such glazing.

0.2.3 Assisting the fire-fighting operation

In order for fire-fighters to deal successfully with a fire in a building, it is first necessary for them to drive their fire appliances to entrances that give them access to the interior of the building. They then need to transport themselves and their equipment from this point to the scene of the fire.

In extensive and multi-storey complex buildings this can be a long process and involve travel to upper or lower levels. Even in single-storey buildings the fire-fighters within the building need, amongst other things, an adequate supply of water at sufficient pressure to enable them to deal with the fire. The presence of heat and smoke can seriously hamper and delay fire-fighters' efforts to effect rescues and carry out fire-fighting operations. The provision of SHEVS to assist means of escape or to protect property aids fire-fighting. It is possible to design a SHEVS similar to that described in 0.2.1 to provide fire-fighters with a clear air region below the buoyant smoke layer, to make it easier and quicker for them to find and to fight the fire. Temperature control designs are of less benefit.

This Technical Report does not include any functional recommendations for key design parameters where the primary purpose of the SHEVS is to assist fire-fighting. Such functional recommendations need to be agreed by the fire service responsible for the building in question. However, the calculation procedures set out in the annexes of this Technical Report can be used to design the SHEVS to meet whatever recommendations have been agreed.

0.2.4 Property protection

Smoke exhaust ventilation cannot by itself prevent fires growing larger but it does guarantee that a fire in a ventilated space has a continuing supply of oxygen to keep growing.

It follows that smoke exhaust ventilation can only protect property by allowing active intervention by the fire services to be quicker and more effective. Property protection is therefore regarded as a special case of 0.2.3. Depending on the materials present, a property protection design philosophy can be based on the need to maintain the hot buoyant smoke layer above sensitive materials (similar in principle to 0.2.1), or the need to maintain the smoke layer below a critical temperature (similar to 0.2.2). In either case, the functional recommendations for key parameters on which the design is based need not be the same as where the primary purpose is life safety and will depend on the circumstances applying in each case. These key functional recommendations need to be agreed with all relevant interested parties. The calculation procedures in the annexes of this Technical Report can be used to design the SHEVS.

0.2.5 Depressurization

Where a smoke layer is very deep, and storeys adjacent to the layer are linked to it by small openings, e.g. door cracks or small ventilation grilles in walls, it can be possible to prevent the passage of smoke through the small openings by reducing the pressure of the gases in the smoke layer. This approach is known as depressurization, and in the form described is mainly used for atrium buildings. The primary purpose of the technique is to prevent the entry of smoke into the spaces adjacent to the atrium, and not to provide protection to the atrium itself. The most common name given to the technique is atrium depressurization.

The design of atrium depressurization places additional recommendations on the design of the SHEVS installed in the atrium. These recommendations are given in 6.11.

0.3 Applications of smoke and heat exhaust ventilation

SHEVS can create and maintain a clear layer beneath the smoke to:

a) keep the escape and access routes free;

b) facilitate fire-fighting operations;

c) reduce the potential for flashover and thus full development of the fire;

d) protect equipment and furnishings;

e) reduce thermal effects on structural components during a fire;

f) reduce damage caused by thermal decomposition products and hot gases.

SHEVS are used in buildings where the particular (large) dimensions, shape or configuration make smoke control necessary.

Typical examples are:

- single and multi-storey shopping malls;
- large retail units;
- single and multi-storey industrial buildings and sprinklered warehouses;
- atria and complex buildings;
- enclosed car parks;
- stairways;
- tunnels;
- theatres.

The choice of either a powered or natural SHEVS depends on aspects of the building's design and sitting in relation to its surroundings.

Special conditions apply where gaseous extinguishing systems, e.g. systems conforming to EN 12094 or ISO 14520, are used. Usually, gaseous extinguishing systems are not compatible with a SHEVS.

1 Scope

This Technical Report gives recommendations and guidance on functional and calculation methods for smoke and heat exhaust ventilation systems for steady-state design fires. It is intended for a variety of building types and applications, including single-storey buildings, mezzanine floors, warehouses with palletized or racked storage, shopping malls, atria and complex buildings, car parks, places of entertainment and public assembly and un-compartmented space within multi-storey buildings.

This Technical Report does not include any functional recommendations for design parameters where the primary purpose of the SHEVS is to assist fire-fighting.

NOTE Such functional recommendations need to be agreed with the fire service responsible for the building in question. The calculation procedures set out in the annexes of this Technical Report can be used to design the SHEVS to meet whatever recommendations have been agreed.

This Technical Report does not cover the following:

— smoke clearance, where smoke is exhausted from a building after the fire has been suppressed;

— cross-ventilation, where wind-induced or fan-induced air currents sweep smoke through and out of the building, usually as part of fire-fighting operational procedures;

— ventilation of stairwells, which usually represents a special application of smoke clearance and which does not necessarily protect the continued use of the stairwell;

— fully-involved fires.

2 Normative references

Not applicable.

3 Terms, definitions, symbols and units

3.1 Terms and definitions

For the purposes of this Technical Report, the following terms and definitions apply.

3.1.1
adhered plume
spill plume rising against a vertical surface and into which air entrains on one side, although there may be free ends

NOTE This is sometimes referred to as a single-sided plume.

3.1.2
aerodynamic free area
product of the geometric area and the coefficient of discharge

3.1.3
ambient
property of the surroundings

3.1.4
atrium
enclosed space, not necessarily vertically aligned, passing through two or more storeys in a building

NOTE Lift wells, escalator shafts, building services ducts and protected stairways are not classified as atria.

3.1.5
attendance time
time taken for the arrival of the fire services at a fire scene after receipt of the initial call at the fire brigade control room

3.1.6
authority
organization, officer or individual responsible for approving SHEVS and/or sprinkler systems, equipment and procedures

NOTE An authority might be a fire and building control authority, a fire insurer, or another appropriate public authority.

3.1.7
automatic activation
initiation of an operation without direct human intervention

3.1.8
backdraft
sudden deflagration caused by admitting fresh air into a room or compartment containing vitiated air, un-burnt fuel gases and a source of ignition

3.1.9
ceiling jet
flow of smoke under a ceiling, extending outwards from the point of fire plume impingement on the ceiling

NOTE The temperature of a ceiling jet is usually greater than the adjacent smoke layer.

3.1.10
channelling screen
smoke barrier installed beneath a balcony or projecting canopy to direct the flow of smoke and hot gases from a room opening to the spill edge

3.1.11
coefficient of discharge
ratio of actual flow rate, measured under specified conditions, to the theoretical flow rate through the ventilator (C_v) or through an inlet opening (C_i)

NOTE 1 This is sometimes referred to as aerodynamic efficiency.

NOTE 2 EN 12101-1 defines the coefficient of discharge in terms of the theoretical flow rate through the ventilator only. The coefficient of discharge takes into account any obstructions in the ventilator, such as controls, louvres or vanes and the effect of external side-winds.

3.1.12
convective heat flux
total heat energy carried by the gases crossing a specified boundary per unit time

3.1.13
depressurization
control of smoke using pressure differentials whereby the air pressure in the fire zone or adjacent accommodation is reduced to below that in the protected space

3.1.14
design fire
hypothetical fire having characteristics that are sufficiently severe for it to serve as the basis of the design of a smoke and heat exhaust ventilation system

3.1.15
exhaust ventilator
device used to move gases out of a building

3.1.16
fire compartment
enclosed space, comprising one or more separate spaces, bounded by elements of construction having a specified fire resistance and intended to prevent the spread of fire (in either direction) for a given period of time

NOTE The term is not to be confused with room of origin or fire cell.

3.1.17
fire operational position
position or configuration of a component specified by the design of the system during a fire

3.1.18
flashover
rapid transition from a fuel-bed controlled fire to a state of total surface involvement of combustible materials in a fire within an enclosure

3.1.19
free plume
spill plume into which air can be freely entrained into both long sides of the plume

NOTE The plume can also have free ends. Free plumes are sometimes referred to as double-sided plumes.

3.1.20
free-hanging smoke barrier
smoke barrier fixed only along its top edge

3.1.21
fuel-bed controlled fire
fire in which the rate of combustion, heat output and fire growth are primarily dependent on the fuel being burned

3.1.22
fully-involved fire
fire in which all surfaces of the combustible materials are totally involved

NOTE This is also referred to as a fully-developed fire.

3.1.23
geometric area
area of the opening through a ventilator, measured in the plane defined by the surface of the building, where it contacts the structure of the ventilator

NOTE Geometric area is expressed as A_v. No reduction is made for controls, louvres or other obstructions.

3.1.24
heat flux
total heat energy crossing a specified boundary per unit time

3.1.25
heat release rate
calorific energy released by a material, product or assemblage of fuels during combustion under specified conditions per unit time

3.1.26
manual operation
initiation of the operation of a smoke and heat exhaust ventilation system by a human action

NOTE This initiation might be performed, for example, by pressing a button or pulling a handle. A sequence of automatic actions started by an initial human action is regarded as a manual operation for the purposes of this Technical Report.

3.1.27
mass flux
total mass of gases crossing a specified boundary per unit time

3.1.28
mezzanine floor
intermediate floor level between any two storeys, or between the floor and roof of a building having a smaller area than the floor below

3.1.29
natural ventilation
ventilation caused by buoyancy forces resulting from differences in density between smoky and ambient air gases due to temperature differences

3.1.30
neutral pressure plane
height within a building where the internal air pressure is equal to the air pressure outside the building at the same height

3.1.31
powered ventilation
ventilation that is caused by the application of external energy to displace gases through a ventilator

NOTE Fans are usually used to produce powered ventilation.

3.1.32
pressure differential system
system of fans, ducts, vents and other features provided for the purpose of creating a lower pressure in a fire zone than in a protected space

3.1.33
quick response sprinkler
sprinkler that has a response time index of less than 50 $m^{½}s^{½}$ and therefore responds at an early stage of fire development

NOTE EN 12259-1 specifies requirements for the construction and performance of quick response sprinklers in fire-fighting systems.

3.1.34
replacement air
clean air entering a building, below the smoke layer, to replace smoky gases being removed by the smoke and heat exhaust ventilation system

NOTE This is sometimes referred to as inlet air.

3.1.35
safety management staff
staff designated for, and trained in, safety management procedures, who are familiar with the smoke control design philosophy, evacuation procedures and related matters

3.1.36
slot extract
physically extensive vent designed to prevent the passage of thermally buoyant smoky gases from one side of the vent to the other

NOTE This is sometimes referred to as slit extract or slit extraction. This could be, for example, a long intake grill in a ceiling, leading to a powered ventilator used to prevent any outflow of smoke from a shop into a mall.

3.1.37
smoke and heat control system
arrangement of components installed in a building to limit the effects of smoke and heat from a fire

3.1.38
smoke and heat exhaust system
smoke control system that exhausts smoke and heat from a fire in a building or part of a building

3.1.39
smoke and heat exhaust ventilation system
system in which components are jointly selected to exhaust smoke and heat in order to establish a buoyant layer of warm gases above cooler, cleaner air

NOTE 1 This is sometimes referred to as through flow ventilation.

NOTE 2 For the purposes of this Technical Report, smoke and heat exhaust ventilation is abbreviated to SHEVS. SHEVS is used in both the singular and plural sense.

3.1.40
smoke and heat exhaust ventilator
device designed to move smoke and hot gases out of a building under conditions of fire

3.1.41
smoke barrier
device used to channel, contain and/or prevent the migration of smoke

NOTE Smoke barriers are also referred to as smoke curtains, smoke blinds or smoke screens.

3.1.42
smoke control damper
device that can be opened or closed to control the flow of smoke and hot gases

NOTE In the fire operational position, the smoke control damper can be open (to exhaust smoke from the fire compartment) or closed (to avoid smoke spreading to other zones).

3.1.43
smoke reservoir
region within a building limited or bordered by smoke barriers or structural elements in order to retain a thermally buoyant smoke layer in the event of a fire

3.1.44
spill edge
edge of a soffit beneath which a smoke layer is flowing, and adjacent to a void or the top edge of a window through which smoke is flowing out of a room

NOTE This is sometimes referred to as a rotation point. The soffit, for example, might be a balcony or canopy.

3.1.45
spill plume
vertically rising plume resulting from the rotation of an initially horizontally-flowing smoke layer around a spill edge

NOTE Where the spill plume is longer parallel to the spill edge than it is broad, i.e. in a horizontal direction at a right angle to the spill edge, the plume is also often known as a line plume or a two-dimensional plume.

3.1.46
stagnant region
region within or below a smoke reservoir where the gases do not move after the thermally buoyant smoke layer has been established

3.1.47
standard response sprinkler
sprinkler with a response time index of between 100 $m^{1/2}s^{1/2}$ and 200 $m^{1/2}s^{1/2}$

NOTE EN 12259-1 specifies requirements for the construction and performance of standard response sprinklers in fire-fighting systems.

3.1.48
steady-state design fire
design fire based on the largest fire with which a smoke and heat exhaust ventilation system is expected to cope

NOTE This type of design fire is usually assumed to be either square or circular.

3.1.49
stratification
formation of distinct layers of clear and smoky gases within the height of the space

3.1.50
temperature control system
smoke and heat exhaust ventilation system designed to cool a potentially hot smoke layer by the deliberate entrainment of ambient air into the rising plume

NOTE A temperature control system can enable the use of façade materials that cannot withstand high temperatures.

3.1.51
transfer duct
duct and associated fan that moves smoky gases from a potentially stagnant region of a smoke reservoir to another region of the same smoke reservoir from where those smoky gases are exhausted from the building

3.1.52
ventilator
device for moving gases into or out of a building

3.1.53
void edge screen
smoke barrier deployed beneath the edge of a balcony or projecting canopy

NOTE Void edge screens can either be used to create a smoke reservoir beneath the balcony or canopy, or to restrict the length of spill edge in order to create a more compact spill plume.

3.1.54
wind pressure coefficient
ratio of the wind-induced pressure rise at a specified location on the exterior of the building to the dynamic pressure due to the wind speed at the highest part of the building

3.2 Symbols and units

For the purposes of this Technical Report, the following mathematical and physical quantities, represented by symbols and expressed in units, apply.

Symbol	**Unit**	**Quantity**
A_f	m^2	Plan area of fire
A_i	m^2	Total geometric free area of all air inlets
A_v	m^2	Geometric area of smoke exhaust ventilator, measured in square
A_{vn}	m^2	Geometric free area of the n'th individual ventilator
A_{vtot}	m^2	Total geometric free area of all smoke exhaust ventilators in one smoke reservoir
b_f	m	Length of wind-impacted façade of the building
$C_{ci}A_{ci}$	m^2	Aerodynamic free area of an individual opening through a suspended ceiling to a plenum chamber above
C_d	—	Effective coefficient of discharge for an opening in a room's wall
C_e	$kg{\cdot}m^{-5/2}{\cdot}s^{-1}$	Entrainment coefficient for a large fire plume
$C_{equivalent}$	—	Equivalent coefficient of discharge applied to the total geometric free area of natural smoke and heat exhaust ventilators exhausting smoke from a plenum above a suspended ceiling, to include the flow restrictive effects of the openings in the suspended ceiling as well as of the ventilators
C_i	—	Coefficient of discharge, i.e. coefficient of performance, of an opening supplying inlet air
C_{pi}	—	Wind pressure coefficient at the exterior of the dominant inlet
C_{pl}	—	Wind pressure coefficient at the topmost leeward storey of the building
C_{pv}	—	Wind pressure coefficient at the exterior of the ventilators
C_v	—	Coefficient of discharge, i.e. coefficient of performance, of a natural ventilator