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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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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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Contents

Foreword

This European Standard had been drawn up by Technical Committee CEN/TC 191/SC1, Smoke and heat control systems and components, the Secretariat of which is held by BSI.

This European Standard is one of six parts of the European Standard EN12101, which has the general title "Smoke and heat control systems" and consists of the following separate parts :

Part 1 : Specification for Smoke barriers – requirements and test methods

Part 2 : Specification for natural smoke and heat exhaust ventilators.

Part 3 : Specification for powered smoke and heat exhaust ventilators.

Part 4 : Smoke and heat exhaust ventilation systems, (natural/powered) components, installation commissioning and maintenance.

Part 5 : Guidelines on the functional recommendations and calculation methods for smoke and heat exhaust ventilation systems.

Part 6 : Pressure differential smoke control systems - Design, calculation methods and installation procedures.

EN 12101 is included in a series of European Standards planned to also cover:

a) CO2 systems (EN 12094 & EN ISO 14520)

b) sprinkler systems (EN 12259)

c) powder systems (EN 12416)

d) explosion protection systems (EN 26 184)

e) foam systems (EN 13565)

g) hose reel systems (EN 671)

h) water spray systems (EN BKWX).

This part of EN 12101 is restricted to "steady-state" design procedures.

It is the intention of the committee to publish a later addendum to EN 12101-5 which will describe the use of "growing design fires".

0 Introduction

0.1 General introduction

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

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 construction works, 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 obtained it is essential that smoke and heat exhaust ventilators operate fully and reliably whenever called upon to do so during their installed life. A SHEVS is a scheme of safety equipment intended to perform a positive role in a fire emergency.

Components for a SHEVS should be installed as part of a properly designed smoke and heat exhaust system.

The flow of thermally-buoyant smoky gases through a building depends on the properties of those gases, on the flow path, i.e. the internal shape of the building, on the external pressure field of the building, i.e. the external shape and the situation of the building, and heat losses from smoky gases. The external pressure field is dominated by the wind. It follows that if any SHEVS needs to be able to meet the recommended level of performance in a building and outside the building, it is essential that the design of that system takes explicit account of the shape of the building (external and internal) and of the external influences (wind).It is essential that the design process employs appropriate calculation or scale-model testing procedures as set out in this standard.

Natural SHEVS operate on the basis of the thermal buoyancy of the gases produced by a fire.

The performance of the installations depends on :

- the temperature of the smoke;
- the aerodynamic free area of the ventilators;
- the wind influence;
- size, geometry and location of the inlet air openings;
- the time of actuation;
- the location and conditions of system (for example arrangements and dimensions of the building).

Ideally the design fire upon which calculations are based should show the physical size and heat output of the fire changing with time in a realistic manner, allowing the growing threat to occupants, property and firefighters 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 structure, or of the time recommended for initiation of successful fire-fighting. These latter assessment procedures fall outside the scope of this European Standard. It is also essential that fire growth curves are selected which are appropriate to the precise circumstances of the building occupancies, fuel arrangements, and sprinkler performance where appropriate. Where such information is available, it is necessary to conduct these calculations 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, etc.) can be drawn from this European Standard.

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 should not be confused with steady fires which achieve full size instantly and then burn steadily. Rather the procedure assumes that a SHEVS which is able to cope with the largest fire will 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 commonly-used approach to protect means of escape is to achieve a desired smoke-free height beneath a smoke layer. The purpose of the SHEVS is to allow the continued use of escape routes which are in the same space as the fire (examples include enclosed shopping malls and many atria). The thermally buoyant smoke forms a layer beneath the ceiling. The smoke exhaust (using either natural smoke exhaust ventilators or powered smoke exhaust ventilators) is calculated to be large enough to keep the smoke at a safe height above the heads of people using the escape routes, 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 same calculation procedures (formulae) as in **0.2.1** in a different way. The smoke exhaust can be designed to achieve (for a specified size of fire) a particular value of temperature of the gases in the buoyant layer. This allows the use of materials which would otherwise be damaged by the hot gases. A typical example is where an atrium facade has glazing which 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 firefighters to successfully deal with a fire in a building, it is first necessary for them to drive their fire appliances to entrances giving 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 may be long and involve travel to upper or lower levels. Even in single-storey buildings the fire-fighters within will 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 may also seriously hamper and delay firefighters' efforts to effect rescues and carry out firefighting operations. The provision of heat and smoke venting systems recommended to assist means of escape or to protect property, will also aid firefighting. It is possible to design a SHEVS similar to those of **0.2.1**. to provide firefighters 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 will be of less benefit.

Because of the training and specialist equipment of the firefighters, it may be reasonable to accept more severe conditions than would be recommended for other people. This part of EN 12101 does not include any functional recommendations for key design parameters where the primary purpose of the SHEVS is to assist firefighting. Such functional recommendations need to be agreed by the fire service responsible for the building in question.

> NOTE It should, however, be noted that the calculation procedures set out in the annexes of this European Standard 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 largerbut it will guarantee that a fire in the 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 should therefore be regarded as a special case of **0.2.3.**. Depending on the materials present, a property protection design philosophy may 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 recommendation for key parameters on which the design should be based, need not to be the same as where the primary purpose is life safety. They will depend on the circumstances applying in each case. As in **0.2.3.** these key functional recommendations need to be agreed with all relevant interested parties. The calculation procedures in the annexes of this European Standard 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, small ventilation grilles in walls, etc.) it may 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.**.

0.2.6 Other forms of smoke ventilation

Although the term "smoke ventilation" has been applied in the past to other design philosophies, none of the following are covered by prEN 12101-5:

- 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, again usually as part of firefighting operational procedures; and
- ventilation of stairwells, which usually represents a special application of smoke clearance and which does not necessarily protect the continued use of the stairwell.

0.3 Applications of smoke and heat exhaust ventilation

SHEVS help to:

- keep the escape and access routes free from smoke ;
- facilitate firefighting operations by creating a smoke free layer ;
- reduce the potential for flashover and thus full development of the fire ;
- protect equipment and furnishings ;
- reduce thermal effects on structural components during a fire ;
- reduce damage caused by thermal decomposition products and hot gases.

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

Typical examples are :

- single and multistorey shopping malls ;
- single and multistorey industrial buildings and sprinklered warehouses ;
- atria and complex buildings ;
- enclosed car parks ;
- stairways ;
- tunnels ;
- theatres.

SHEVS are not suitable for any unsprinklered fuel array taller than 4 m (e.g. high bay warehouses). It is important to note that any serious fire in a high-piled or high-racked storage building or fire compartment without sprinklers can be expected to result in the loss of that building or fire compartment.

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

Depending on differing circumstances and the building's or construction work's situation which can effect their performance powered or natural SHEVS may be used.

1 Scope

This European Standard gives guidelines on functional and calculation methods for smoke and heat exhaust ventilation systems (SHEVS)
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, carparks, places of entertainment and public assembly, multistorey buildingsand tunnels.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in if by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 54 (all parts), Fire detection and fire alarm systems.

ISO 834:1975, *Fire resistance tests – Elements of building construction*

EN 4501:1989 *General criteria for the operation of testing laboratories*

pr EN 12094 CO2 systems

prEN 12101-1, Smoke and heat control systems - Part 1 : Smoke barriers. Recommendations, test methods, installation and maintenance

prEN 12101-2, Smoke and heat control systems - Part 2 : Specification for natural smoke and heat exhaust ventilators

prEN 12101-3, Smoke and heat control systems - Part 3 : Specification for powered smoke and heat exhaust ventilators.

prEN 12101-4, Smoke and heat control systems - Part 4 : Smoke and heat exhaust ventilation systems - Recommendations and test methods for systems.

PrEN 12101-6, Smoke and heat control systems - Part 6 : Pressure differential smoke control systems - Design, calculation methods and installation procedures.

EN 12259-1, Fixed firefighting systems – components for sprinkler and waterspray systems - Part 1: Sprinklers

prEN 12845, Fixed firefighting systems - Automatic sprinkler systems - Design and installation.

prEN 12848, Bitumen emulsions - Determination of mixing stability with cement

pr EN BKWY Halon systems.

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ENV 1991-2-5,

3 Terms, definitions, symbols and units

3.1 Terms and definitions

For the purposes of this European Standard, the following terms and definitions apply.

3.1.1
adhered plume
single-sided plume
spill plume rising against a vertical surface and into which air can only be entrained on one side

3.1.2
aerodynamic free area
product of the geometric area multiplied by the coefficient of discharge

3.1.3
ambient
properties of the surroundings

3.1.4
aspect ratio
ratio of length to width

3.1.5
atrium
enclosed space, not necessarily vertically aligned, passing through two or more storeys in a construction work

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

3.1.6
attendance time
time for the arrival of the fire services at the fire scene after receipt of the initial call

3.1.7
authorities
organizations, officers or individuals responsible for approving SHEVS and/or sprinkler systems as appropriate, equipment and procedures, e.g. the fire and building control authorities, the fire insurers, or other appropriate public authorities

3.1.8
automatic activation
initiation of operation without direct human intervention

3.1.9
automatic natural smoke and heat exhaust ventilator
smoke and heat exhaust ventilator which is designed to open automatically after the outbreak of fire, if called upon to do so

NOTE : Automatic natural smoke and heat exhaust ventilators may also be fitted with a manual control or release device.

3.1.10
automatic smoke curtain
drop smoke curtain
smoke curtain which moves into its operational position automatically when called upon to do so

3.1.11
automatically initiated powered smoke and heat exhaust ventilator
powered smoke and heat exhaust ventilator which operates automatically after the outbreak of fire

3.1.12
backdraft
sudden deflagration caused by admitting fresh air into a room or compartment containing vitiated air, unburnt fuel gases, and a source of ignition

3.1.13
ceiling jet
flow of smoke under the ceiling, extending radially from the point of fire plume impingement on the ceiling

NOTE Usually, the temperature of the ceiling jet will be greater than the adjacent smoke layer.

3.1.14
channelling screen
smoke curtain installed beneath a balcony or projecting canopy to direct the flow of smoke and hot gases from a room opening to the spill edge

3.1.15
closed mezzanine floor
mezzanine floor which is either solid or does not meet the criteria for an open mezzanine floor

3.1.16
coefficient of discharge
aerodynamic efficiency
ratio of actual flow rate, measured under specified conditions, to the theoretical flow rate through the ventilator (C_v), as defined in prEN 12101-2, or through an inlet opening (C_i)

NOTE : The coefficient takes into account any obstructions in the ventilator such as controls, louvres, vanes, etc. and the effect of external sidewinds.

3.1.17
convective heat flux
total heat energy carried by the gases across a specified boundary per unit time

3.1.18
depressurization
smoke control using pressure differentials where the air pressure in fire zone or adjacent accommodation is reduced below that in the protected space

3.1.19
design fire
hypothetical fire having characteristics which are sufficiently severe for it to serve as the basis of the design of a SHEVS

3.1.20
destratification
downward mixing of smoke from an initially buoyant smoky gas layer into initially clear air beneath

NOTE: Destratification is usually due to loss of buoyancy in the smoke layer due to cooling.

3.1.21
dual purpose ventilator
smoke and heat exhaust ventilator which has can be used for comfort (i.e. day to day) ventilation

3.1.22
equivalent Gaussian source
infinitely broad virtual source for a spill plume, located at the same height as a spill edge, and used for spill plume entrainment calculations

3.1.23
exhaust ventilator
device used to move gases out of the construction work

3.1.24
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: Fire compartment often has regulatory connotations. The term should not be confused with “room of origin” or “fire cell”.

3.1.25
fire open position
configuration of the ventilator specified by its designer to be achieved and sustained while venting smoke and heat

3.1.26
fire suppression device
device for limiting the size of fires and/or extinguishing fires, e.g. sprinklers

3.1.27
fixed smoke curtain
smoke curtain static in its operational position

3.1.28
flashover
rapid transition to a state of total surface involvement in a fire of combustible materials within an enclosure

3.1.29
free plume
spill plume into which air can be freely entrained on both sides

3.1.30
free-hanging smoke curtain
smoke curtain fixed only along its top edge

3.1.31
fuel-bed-controlled fire
fire in which the rate of combustion, heat output, and fire growth are primarily dependent on the fuel being burned

3.1.32
fully-developed fire
fully-involved fire
fire in which the combustible materials are totally involved

3.1.33
gas container
vessel containing gas in a compressed form, the energy of which, when released, will operate the device (e.g. will open the ventilator)

3.1.34
geometric area (A_v)
area of the opening through a ventilator, measured in the plane defined by the surface of the construction work, where it contacts the structure of the ventilator

NOTE No reduction will be made for controls, louvres or other obstructions.

3.1.35
heat flux
total heat energy crossing a specified boundary per unit time

3.1.36
heat release rate
rate of heat release
calorific energy released per unit time by a material, product or assemblage of fuels during combustion under specified conditions

3.1.37
high hazard
sprinkler hazard classification for specified storage categories and storage heights and for specific process occupancies as specified in EN 12259-1

3.1.38
initiation device
device which activates the operating mechanism of the component (e.g. of a damper or ventilator etc., e.g. on receipt of signal from a fire detection system or thermal device)

3.1.39
manual operation
initiation of the operation of a SHEVS by a human action (e.g. pressing a button, or pulling a handle)

NOTE A sequence of automatic actions in the operation of a SHEVS started by the initial human action is regarded as manual operation for the purposes of this European Standard.

3.1.40
manually initiated powered smoke and heat exhaust ventilator
powered smoke and heat exhaust ventilator which can be initiated by human actions only after the outbreak of fire

3.1.41
manually opened smoke and heat exhaust ventilator
smoke and heat exhaust ventilator which can only be opened by a manual control or release device

3.1.42
mass flux
total mass of gases crossing a specified boundary per unit time

3.1.43

mezzanine floor
intermediate floor level between any two storeys in a construction work having a smaller area than the floor below

3.1.44
natural ventilation
ventilation caused by buoyancy forces due to differences in density of the gases because of temperature differences

3.1.45
neutral pressure plane
height within the construction work where the pressure is equal to the air pressure outside at the same height

3.1.46
open mezzanine floor
mezzanine floor which has at least 25 % of its total plan area evenly distributed as free area for the passage of smoke

3.1.47
opening mechanism
mechanical device which operates the ventilator to the fire open position

3.1.48
opening time
period between the information to open being received by the ventilator, to achieving the fire open position of the ventilator