

Components for smoke and heat control systems —

Part 5: Functional recommendations and calculation methods for smoke and heat exhaust ventilation systems, employing time-dependent design fires — Code of practice

ICS 13.220; 91.140.30

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee FSH/25, Smoke, heat control systems and components, upon which the following bodies were represented:

- Association of Fire Consultants
- Association of Roof Light Manufacturer
- British Blind and Shutter Association
- Building Research Establishment (BRE)
- Building Services Research and Information Association (BSRIA)
- Fire Resistant Glass and Glazing Federation
- HEVAC Association
- Institution of Fire Engineers (IFE)
- London Fan Company
- London Fire and Emergency Planning Authority
- Office of the Deputy Prime Minister (ODPM)
- Smoke Vent Association
- Steel Window Association
- Co-opted members

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 March 2005

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The following BSI references relate to the work on this British Standard:
Committee reference FSH/25
Draft for comment 03/117591DC

Amendments issued since publication

Amd No.	Date	Comments

ISBN 0 580 45520 3

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Foreword

This part of BS 7346 was prepared under the direction of Technical Committee FSH/25. The other parts that comprise BS 7346 are as follows:

- Part 1: *Specification for natural smoke and heat exhaust ventilators*;
- Part 2: *Specification for powered smoke and heat exhaust ventilators*;
- Part 3: *Specification for smoke curtains*;
- Part 4: *Functional recommendations and calculation methods for smoke and heat exhaust ventilation systems, employing steady-state design fires — Code of practice*;
- Part 6: *Specification for cable systems*.

Parts 1, 2 and 3 of BS 7346 will eventually be replaced by the equivalent parts of BS EN 12101. The parts of BS EN 12101, Smoke and heat control systems, relevant to BS 7346-5 will include:

- 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 7: *Smoke control ducts*¹⁾;
- Part 8: *Specification for smoke control dampers*¹⁾;
- Part 9: *Control panels and emergency control panels*¹⁾;
- Part 10: *Power supplies*¹⁾.

This British Standard gives recommendations for the design of smoke and heat exhaust ventilation systems.

It is assumed in the drafting of a standard that the execution of its provisions is entrusted to appropriately qualified and competent people.

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

¹⁾ In preparation.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 36, an inside back cover and a back cover.

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Introduction

0.1 General

Smoke and heat exhaust ventilation systems (SHEVS) create a smoke-free layer above the floor by using the buoyancy of the smoke to form a layer beneath the ceiling above the smoke-free layer, and by removing smoke from that buoyant layer, they allow the continuation of clear conditions.

SHEVS are of value in:

- assisting in the evacuation of people and animals from buildings;
 - preventing smoke logging by exhausting hot gases released by a fire in the developing stage;
- NOTE Ventilation systems for smoke exhaust serve simultaneously for heat exhaust.
- reducing roof temperatures;
 - retarding the lateral spread of fire;
 - reducing fire damage to property and thereby financial loss;
 - facilitating fire-fighting, while the fire is still in its early stages.

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 ought to be installed as part of a properly designed smoke and heat exhaust system.

Fire Safety Engineering (FSE) is the discipline whereby Fire Science is applied quantitatively to the design of buildings to ensure safety in the event of a fire. As such, the design procedures for a SHEVS can be seen as a subsidiary part of FSE, with FSE encompassing a much broader range of techniques and concerns. BS 7974 serves to guide the fire safety engineer through this wider field of application. It is the purpose of this British Standard to cover the design process for SHEVS in greater detail than is possible in BS 7974, and with a focus that is restricted to SHEVS. In brief summary, this British Standard is intended to be complementary to BS 7974 and is not to be regarded as an alternative to BS 7974.

This British Standard focuses on the design of SHEVS based on time-dependent design fires. It therefore complements BS 7346-4, which focuses on the design of SHEVS based on steady-state fires and which therefore bears a similar complementary relationship to BS 7974.

The flow of thermally buoyant smoky gases through a building depends on the properties of the gases and any influences imposed on the gases by the building through which the smoky gases pass. These influences include:

- the internal shape of the building controlling the flow path of the gases through the building;
- the heat losses from the smoky gases to the building;
- the heat losses to fire suppression systems in the building, such as sprinklers;
- the external shape and the situation of the building and the likely external pressure field.

The external pressure field is dominated by the wind. It follows that if SHEVS are to meet the recommended levels of performance in 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 (e.g. wind). If the building roof design is uncomplicated and it is unlikely to be affected by high adjacent buildings, normal assessment methods will be appropriate. If this is not the case, the design process ought to employ calculation procedures or directly measured data appropriate to the building concerned. Such data may come from studies of the existing building, from scale-model studies, or from generically similar building data.

Natural SHEVS operate on the basis of the thermal buoyancy of the gases produced by a fire. Powered SHEVS operate on the basis of removing fire gases using mechanical devices, usually fans.

The performance of the installations depends for example on:

- the temperature of the smoke;
- the aerodynamic free area of the ventilators, or the volume of smoke exhausted by powered ventilators;
- the wind influence;
- size, geometry and location of the air inlets;
- size, geometry and location of smoke reservoirs;
- 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 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 structure and the time recommended for initiation of successful fire-fighting. These assessment procedures fall outside the scope of this British Standard, which only outlines procedures for calculating the times to the onset of danger. It is essential that the time required for safe evacuation, and for initiation of successful fire-fighting, is assessed as accurately as possible.

Whilst fire brigade target arrival times are detailed within other documents (for example PD 7974-5), the set-up time for the fire brigade will be specific to the building (and to some extent to the fire type and location). This set-up time is vital to bringing the fire under control and thus limiting smoke production. It is therefore necessary to agree with the appropriate fire authority both the SHEVS systems, and the effects of operational fire-fighting times. Wherever doubt exists about the accuracy of these latter times, the designer needs to calculate in a safety margin when comparing the time to danger against the time needed for success.

It is essential that fire growth curves are selected which are appropriate to the circumstances of the building occupancies, fuel arrangements, and sprinkler performance. It is the purpose of this British Standard to present recommendations and guidance for the design of smoke and heat exhaust ventilation based on time-dependent, or “growing” fires.

Many of the detailed calculation procedures, and most of the danger criteria defining the boundary between success and failure, are the same for time-dependent design fires as for steady-state design fires, and it is essential that this British Standard be used in conjunction with BS 7346-4.

0.2 Smoke exhaust ventilation design philosophies – steady-state and time-dependent designs

The fundamental objectives as given in **0.3** are the same for time-dependent fire designs as for steady-state fire designs but it is the way in which these objectives are approached that differs.

Where 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 fire is not to be confused with steady fires that achieve full size instantly and then burn steadily. Rather, the procedure assumes that a SHEVS that is able to cope with the largest fire assumed for design will also cope with the (usually earlier) smaller stages of the fire. Design procedures based on steady-state design fires are presented in BS 7346-4.

The purpose of a steady-state designed SHEVS, as described in BS 7346-4, is to ensure that the objective is achieved throughout the entire duration of the fire – with the recognized exception of an acceptably small proportion of fires that can grow larger than assumed by the design. For example, although there is a finite mathematical probability of a meteorite crashing into the building, the probability is regarded as being too small to consider during design.

The purpose in a time-dependent designed SHEVS is to ensure that the time between ignition of the fire and the onset of a significant danger is acceptably longer than the time required to succeed in the design objective. Even in a successful design, an acceptably small proportion of design fires will grow faster and/or larger than assumed for the design. For example, the extreme of a fast-growing fire is an explosion, although the probability of an explosion in most buildings will usually be too low to be worth considering in most SHEVS designs.

0.3 Objectives for time-dependent design fire SHEVS designs

0.3.1 *Protection of means of escape (life safety)*

The objective is to delay the onset of dangers on escape routes (which are in the same space as the fire) for a long enough time for people to evacuate safely, by creating by calculation a desired smoke-free height beneath a smoke layer, and exhausting smoke from that layer at a rate that will slow the downward filling of the space with smoke. If the clear height and smoke layer temperature remain sufficient for safety until the fire is brought under control (or the fuel is exhausted), the time available can become effectively infinite in the same way as for a steady-state design.

0.3.2 *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 for **0.3.1** in a different way. The smoke exhaust can be designed to limit the temperature of the gases in the buoyant layer. This allows the use of materials that would otherwise be damaged by the hot gases. For example, where an atrium façade has glazing which is not fire resistant, 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. Further guidance on the incorporation of atria into new and existing buildings is given in BS 5588-7.

0.3.3 *Facilitating the fire-fighting operation*

In order for fire-fighters 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, the distance can 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 can also seriously hamper and delay fire-fighters' efforts to effect rescues and carry out fire-fighting operations. The provision of a SHEVS recommended to assist means of escape or to protect property will also aid fire-fighting. It is possible to design a SHEVS similar to that described in **0.3.1** to provide fire-fighters with a clear-air region below the buoyant smoke layer, which will not become dangerous to them, or have reduced visibility, for the time needed for them to find and control the fire.

This British Standard 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.

0.3.4 *Property protection*

Smoke exhaust ventilation does not by itself prevent fires growing larger. It guarantees that a fire in the ventilated space has a continued supply of oxygen. This, in turn, facilitates a quicker and more effective fire-fighting operation as described in **0.3.3**, which in turn results in a reduction in the damage caused by thermal decomposition products, hot gases and heat radiation and hence the protection of the building, equipment and furnishings.

0.4 Applications of smoke and heat exhaust ventilation

SHEVS help to:

- keep the escape and access routes free from smoke;
- facilitate fire-fighting 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 where the large dimensions, shape or configuration make smoke control necessary.

Examples include:

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

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

Depending on differing circumstances and the building's surrounding environment, either powered or natural SHEVS can be used.

0.5 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 this document:

- 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;
- smoke dilution, where wind-induced or fan-induced air currents mix with the smoke and other combustion products to dilute them to a safe concentration.

1 Scope

This British Standard gives functional recommendations and guidance on the calculation method for smoke and heat exhaust ventilation systems (SHEVS) for time-dependent design fires. A variety of building types is addressed.

For a pre-determined critical time, this British Standard can be used to determine required performance of a SHEVS needed to avoid the onset of a significant danger. Or, for a pre-determined SHEVS, this British Standard can be used to determine the time available between ignition and onset of significant danger.

This British Standard uses accepted and authoritative methods to define some design parameters, e.g. the time needed for safe evacuation or attendance time of the fire-fighting services. This information can be sought from other sources when generating the overall fire-safety concept for a specific building project.

Many of the detailed calculation procedures, and most of the danger criteria defining the boundary between success and failure, are the same for time-dependent design fires as for steady-state design fires, and it is essential that this British Standard be used in conjunction with BS 7346-4.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 5588, *Fire precautions in the design, construction and use of buildings*.

BS 7346 (all parts), *Components for smoke and heat control systems*.

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

BS EN 12101, *Smoke and heat control systems*.

BS EN 12259-1, *Fixed firefighting systems — Components for sprinkler and water spray systems — Part 1: Sprinklers*.

BS EN 12845, *Fixed firefighting systems — Automatic sprinkler systems — Design, installation and maintenance*.

3 Terms, definitions, symbols and units

3.1 Terms and definitions

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

3.1.1

aerodynamic free area

product of the geometric area and the coefficient of discharge

3.1.2

ambient

properties of the surroundings

3.1.3

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.

3.1.4

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

3.1.5

authority

organization or individual responsible for approving SHEVS equipment and procedures

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

3.1.6

calorimeter

device for measuring the heat produced by the combustion of a fuel material or an assembly of fuel materials

3.1.7

ceiling jet

flow of hot fire gases driven away from where the smoke plume impinges on the ceiling by the kinetic energy of the plume prior to impingement

3.1.8

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 BS EN 12101-2, or through an inlet opening (C_i)

NOTE The coefficient of discharge takes into account any obstructions in the ventilator such as controls, louvres and vanes, and the effect of external side winds.

3.1.9

computer-based zone model

zone model expressed as a computer program

3.1.10

convective heat flux

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

3.1.11

design fire

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

3.1.12

exhaust ventilator

device used to move gases out of the building

3.1.13

external pressure field

pattern of air pressures distributed over the external surfaces of the building

NOTE External pressure field can be due to, e.g. wind.

3.1.14

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 fire compartment has regulatory connotations. The term is not to be confused with room of origin or fire cell.

3.1.15

fire perimeter

length of the horizontal circumference of burning fuel material(s)

3.1.16

fire suppression device

device for limiting the size of fires and/or extinguishing fires

NOTE A sprinkler is an example of a fire suppression device.

3.1.17

flashover

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

3.1.18

free-hanging smoke barrier

smoke barrier fixed only along its top edge

3.1.19

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 No reduction is made for controls, louvres or other obstructions.

3.1.20

heat flux

total heat energy crossing a specified boundary per unit time

NOTE Heat flux includes radiant heat.

3.1.21

heat release rate

rate of heat release

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

3.1.22

inlet air

replacement air

ambient air entering the building to replace smoky gases being removed by the SHEVS

3.1.23

natural smoke and heat exhaust ventilator

smoke and heat exhaust ventilator using the thermal buoyancy of smoky gases to displace those gases through the ventilator

3.1.24**plugholing**

inefficient mode of operation of a smoke and heat exhaust ventilator whereby air is drawn through the buoyant smoke layer from below

3.1.25**powered smoke and heat exhaust ventilator**

smoke and heat exhaust ventilator using powered devices to displace smoky gases through a ventilator

NOTE Fans are usually used to produce powered ventilation.

3.1.26**powered ventilation**

ventilation using a source of power external to the gases to displace those gases through a ventilator

NOTE Fans are usually used to produce powered ventilation.

3.1.27**pressure differential system**

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

3.1.28**regulatory authority**

authority having responsibility for the enforcement of regulations

NOTE A regulatory authority is usually but not always a representative of local or central government.

3.1.29**set-up time**

time taken from the arrival of the fire service to the application of fire-fighting media to the fire

3.1.30**slot extract**

slot exhaust
slit extract
slit extraction

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

NOTE A slot extract could be, for example, a long intake grill in a ceiling, leading to a powered ventilator.

3.1.31**smoke control system**

arrangement of components installed in a building to control the production and/or movement of smoke within and/or from the building

3.1.32**smoke and heat control system**

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

3.1.33**smoke and heat exhaust system**

smoke control system which exhausts smoke and heat from a fire in a building or part of a building

3.1.34**smoke and heat exhaust ventilation system****SHEVS**

throughflow ventilation system

ventilation 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 For the purposes of this document, a smoke and heat exhaust ventilation system is abbreviated to SHEVS. SHEVS is used in both the singular and plural sense.

3.1.35

smoke and heat exhaust ventilator

device specially designed to move smoke and hot gases out of a building under conditions of fire

3.1.36

smoke barrier

smoke curtain
smoke blind
smoke screen

barrier to restrict the spread of smoke and hot gases from a fire, forming part of the boundary of a smoke reservoir or used as a channelling screen or a void edge screen

3.1.37

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).

3.1.38

smoke-free layer

layer of cooler air uncontaminated by smoke, below a thermally buoyant layer of smoky gases where the latter is formed beneath a soffit

NOTE A ceiling or the underside of a projecting balcony is an example of a soffit.

3.1.39

smoke logging

build-up of unacceptable quantities of smoke within a space or volume

3.1.40

smoke reservoir

region within a building limited or bordered by smoke barriers or structural elements that can retain a thermally buoyant smoke layer in the event of a fire

3.1.41

spill edge

rotation point

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 The soffit, for example, might be the underside of a balcony or canopy.

3.1.42

spill plume

vertically rising plume resulting from the rotation of a 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.

3.1.43

stagnant region

region within a smoke reservoir where the smoky gases do not move after the layer has been established

3.1.44

steady-state design fire

design fire based on the largest fire with which the SHEVS is expected to cope, assumed for calculation purposes to burn in a steady-state manner

NOTE Steady-state design fires are usually assumed to be either square or circular.

3.1.45**temperature control SHEVS**

temperature control system

SHEVS designed to cool a potentially hot smoke layer by the deliberate entrainment of cooler air into the rising plume

NOTE This can enable the use of façade materials that cannot withstand high temperatures.

3.1.46**time-dependent fire**

fire for which the heat release rate and/or other parameters change with time

3.1.47**time-dependent design fire**

design fire having time-dependent characteristics

3.1.48**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 the smoke will be exhausted from the building

3.1.49**ventilator**

device for moving gases into or out of a building

3.1.50**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.

3.1.51**zone model**

combination of mathematical formulae describing a physical process by reducing that process to a limited number of simplified zones or regions where each zone is described by a small number of formulae

NOTE 1 The zone model is usually empirically derived.

NOTE 2 Zone models are usually expressed in the form of a computer program.