BS 7346-7:2006

BRITISH STANDARD

Components for smoke and heat control systems

Part 7: Code of practice on functional recommendations and calculation methods for smoke and heat control systems for covered car parks

Publishing and copyright information

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Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 40, an inside back cover and a back cover.

Foreword

Publishing information

This part of BS 7346 was published by BSI and came into effect on 31 October 2006. It was prepared by Subcommittee FSH/25/4, *Smoke control systems — Impulse fans for car parks and similar*, under the authority of Technical Committee FSH/25, *Smoke, heat control systems and components*. A list of organizations represented on this committee can be obtained on request to its secretary.

Use of this document

As a code of practice, this part of BS 7346 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.

Any user claiming compliance with this part of BS 7346 is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is ““should””.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

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 cannot confer immunity from legal obligations.

Introduction

0.1 Background to smoke control in car parks

Ventilation of covered car parks is usually recommended in order to limit concentrations of carbon monoxide (CO) and other vehicle emissions in the day to day use of car parks and to remove smoke and heat in the event of a fire. The same equipment is often used to satisfy both requirements. This standard, recognising the dual use of systems, also provides guidance on usage for vehicle emission ventilation.

There is no requirement in the *Building Regulations 2000* [1], *Building (Scotland) Regulations* [2], *Building Regulations (Northern Ireland)* [3] for sprinkler systems to be provided in car parks, although there are requirements in some local acts. The recommendations in this standard are provided for smoke and heat control systems installed in car parks with or without sprinkler protection. The main benefit of sprinklers is to control the size of fire to be dealt with by the fire and rescue service. This is reflected in the design fire sizes recommended for car parks with and without sprinklers.

Modern cars are generally larger than their predecessors and contain a larger quantity of flammable materials, in particular plastics. This has led to a review of the heat output from burning cars and the risk of fire spread between cars. As a result the design fires recommended in this standard are larger and have a greater heat output than those in some previous guidance.

Car park ventilation systems can be designed for one or more of three purposes in the event of a fire:

1) to assist fire-fighters to clear smoke from a car park during and after a fire;

2) to provide clear smoke-free access for fire-fighters to a point close to the seat of the fire;

3) to protect means of escape from the car park.

The system requirements will differ depending upon the purpose. Not all types of ventilation systems are suitable for all purposes. Recommendations and criteria are provided for the design of systems for all three purposes.

a) *To assist fire-fighters to clear smoke from a car park during and after a fire.*

Smoke clearance systems are intended to assist fire-fighters by providing ventilation to allow speedier clearance of the smoke once the fire has been extinguished. The ventilation might also help reduce smoke density and temperature during the course of a fire.

These systems are not specifically intended to maintain any area of a car park clear of smoke, to limit smoke density or temperature to within any limits or to assist means of escape.

It is possible that some smoke clearance systems could actually worsen conditions for means of escape if set in operation too early by encouraging smoke circulation and descent of the smoke layer. For this reason it might be preferable to either delay operation after automatic actuation or to provide only manual actuation from a fire service override switch.

b) *To provide clear smoke-free access to fire-fighters to a point close to the seat of the fire.*

This is provided specifically in order to assist fire-fighters to carry out fire-fighting operations. The system is designed to operate automatically in response to a suitable fire detection system and ensures clear, smoke-free access by fire-fighters to a point close to the seat of the fire. Primarily, such systems will assist fire-fighting by:

1) detecting the origin of the fire to a specific location in the car park, allowing easier identification by fire crews;

2) moving the smoke and heat from that location towards a specific extraction point or points;

3) creating a smoke free approach zone or bridgehead clear of the fire. This allows fire-fighters to assemble personnel and equipment in favourable conditions and fire-fighting operations to be carried out more quickly, safely and efficiently.

Because of 3) it is vitally important that the location of all fire-fighting access points into the car park are accounted for during the design process. It is of little benefit if the smoke and heat is moved towards, for example, the only access route available to fire-fighters for fire-fighting purposes.

In large or complex car parks where jet fans are employed, there might be multiple extraction points. Such systems could be configured to move the smoke in one of several directions, depending on the location of the fire. Again it is important to ensure that there are suitably located fire-fighting access points to allow the bridgehead to be created for each design fire scenario considered.

In addition, correctly designed smoke and heat control systems of this type could also prove advantageous to fire-fighters by diluting and cooling smoke and preventing the build-up of high local temperatures. As a result it is possible to install them as part of a fire engineered solution or as compensation for the lack of other fire protection measures e.g. sprinklers.

It is important that no smoke and heat control system''s design, when installed, worsens the level of safety for occupants and fire-fighters, using as a basis for comparison above-ground car parks with natural cross-ventilation with permanent openings.

c) *To protect means of escape from the car park.*

Smoke control is not required in UK legislation to protect means of escape in car parks. Nevertheless it is possible in some cases to design a ventilation system that will assist protection of means of escape. SHEVS or impulse ventilation systems might be suitable. Where smoke and heat control systems are installed in car parks for purposes other than protecting the means of escape, there is a need to avoid smoke prejudicing escape. If there is any concern that automatic operation of a smoke and heat control system could prevent persons from escaping it is preferable to either select an alternative system design or introduce an appropriate delay period before full activation of the system.

Smoke ventilation recommendations in car parks are outlined in Approved Document B to the *Building Regulations (England and Wales)* [4], *Technical Booklet E to the Building Regulations*

(Northern Ireland) [5] and *Scottish Building Standards Technical Handbooks* [6]. These guidance documents recommend provision of systems for purpose a), smoke clearance, only. Systems for purposes b) and c) are therefore usually provided either as part of a fire engineered solution or as a compensating feature for other fire protection measures that might not fully conform to those recommendations.

The following types of ventilation might be considered as alternatives:

- natural ventilation;
- ducted mechanical ventilation;
- impulse ventilation;
- smoke and heat exhaust ventilation system (SHEVS).

The design criteria for each of the above systems are given later in this standard.

0.2 Further considerations

Any ventilation system, unless permanently open, is dependent upon suitable power supplies and controls for correct operation. Ventilation systems will interact with other building services and fire protection systems in normal operation, whether by design or as a by-product of operation.

In some car parks, especially underground car parks associated with residential buildings, there are storage areas accessed directly from the car park. These are used by residents to store personal possessions, and thus such storage areas will contain materials which are not known to the designer since there is no control over such private areas.

1 Scope

This part of BS 7346 gives recommendations and guidance on functional and calculation methods for smoke and heat control systems for covered parking areas for cars and light commercial vehicles.

NOTE It is assumed that cars powered by fuels other than petrol or diesel will have a fire performance similar to vehicles powered by petrol or diesel. This assumption might have to be revised when further information suggests it is necessary.

It is intended for system designers, installers of systems, regulatory authorities, for example building control officers and fire safety officers, and the fire safety management of the car park.

It makes recommendations for systems designed for open-sided car parks and for enclosed car parks. It covers systems intended to protect means of escape for occupants of the car park or building housing the car park; systems intended to assist active fire-fighting operations; and systems intended to provide smoke clearance following suppression of a fire. It includes recommendations for natural open-sided ventilation and for ducted mechanical ventilation. It includes guidance on performance-based smoke control using impulse ventilation systems and smoke and heat exhaust ventilation systems (SHEVS). Time-dependent and steady-state design methods are included as appropriate for each smoke control approach. Control of vehicle pollutant emissions is included where it influences the optimization of smoke control.

The standard only covers traditional means of single vehicle parking, that is, those car parks with cars parked alongside each other with common access roadways/lanes for cars to be driven in and out. It does not cover other forms of car parking systems, such as stacking systems.

Smoke and heat control systems for lorry parks and coach parks are not covered by this standard.

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 848-10, *Fans for general purposes — Part 10: Performance testing of jet fans*

BS 5839-1, *Fire detection and fire alarm systems for buildings — Part 1: Code of practice for system design, installation, commissioning and maintenance*

BS 5588-12, *Fire precautions in the design, construction and use of buildings –– Part 12: Managing fire safety*

BS 7346-4, *Components for smoke and heat control systems — Part 4: Functional recommendations and calculation methods for smoke and heat exhaust ventilation systems, employing steady-state design fires — Code of practice*

BS 7346-5, *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*

BS 7346-6:2005, *Components for smoke and heat control systems — Part 6: Specifications for cable systems*

BS 7671, *Requirements for electrical installations — IEE wiring regulations — Sixteenth edition*

BS 8434-2:2004, *Methods of test for assessment of the fire integrity of electric cables — Part 2: Test for unprotected small cables for use in emergency circuits — BS EN 50200 with a 930 °C flame and with water spray*

BS EN 12101-2, *Smoke and heat control systems — Part 2: Specification for natural smoke and heat exhaust ventilators*

BS EN 12101-3, *Smoke and heat control systems — Part 3: Specification for powered smoke and heat exhaust ventilators*

3 Terms and definitions

For the purposes of this part of BS 7346, the following terms and definitions apply.

3.1 addressable fire detection system

system in which signals from detectors, manual call points, or any other devices are individually identified at the control and indicating equipment

3.2 aerodynamic free area

product of the geometric area and the coefficient of discharge

[BS 7346-4]

3.3 approving authority

organization, officer or individual responsible for approving smoke and heat control systems, equipment and/or procedures

3.4 bridgehead

area or part of a building, from which fire-fighting teams can be safely committed to attack a fire

3.5 ceiling jet

any layered flow of ceiling level gases away from the point of impingement, driven by that layer’’s buoyancy

3.6 coefficient of discharge

ratio of actual flow rate, measured under specified conditions, to the theoretical flow rate through an opening *NOTE Adapted from BS 7346-4.*

3.7 computational fluid dynamics model (CFD model)

computer simulation model where the fundamental equations of heat and mass transfer are solved using numerical methods
[PD 7974-2:2002]

3.8 cross-flow ventilation

ventilation system based on creating an airflow throughout the volume of a space, from outside, through an inlet, and exiting to the outside *NOTE A space can be a car park or car park storey.*

3.9 design fire

hypothetical fire having characteristics which are sufficiently severe for it to serve as the basis of the design of the smoke and heat control system

NOTE Adapted from BS 7346-4.

3.10 directed message

specific message/warning through a public address system to individuals identified by CCTV as being at risk

3.11 dispersal

removal of a smoke hazard by dilution to a safe concentration using clean air

3.12 element of structure

member forming part of the structural frame of a building or any other beam or column

NOTE Examples of elements of structure are:

a) a loadbearing wall or loadbearing part of a wall;

b) a floor;

c) a gallery (but not a loading gallery, fly gallery, stage grid, lighting bridge, or any gallery provided for similar purposes or for maintenance and repair);

d) an external wall;

e) a compartment wall (including a wall common to two or more buildings).

3.13 equivalent area

area of a sharp-edged orifice through which air would pass at the same volume flow rate, under an identical applied pressure difference as the opening under consideration

NOTE 1 This is a measure of the aerodynamic performance of an opening.

NOTE 2 For a plain opening with no obstructions the equivalent area is equal to the measured area. For other openings the equivalent area is equal to the aerodynamic free area divided by 0.6.

3.14 exhaust ventilation system

combination of exhaust ventilators, ducts, power supplies, and controls used to remove smoky gases from a car park

NOTE The exhaust ventilators are usually fans.

3.15 exhaust ventilator

device used to move gases out of a car park *NOTE*

Adapted from BS 7346-4.

3.16 extraction point

location of an intake opening to an exhaust ventilator or to a duct which leads to an exhaust ventilator, where smoke is removed from a car park

3.17 fire compartment

enclosed space, comprising one or more separate spaces, bounded by elements of structure having a specified fire resistance and intended to prevent the spread of fire (in either direction) for a given period of time. [BS 7346-4]

3.18 fire engineered solution

fire safety strategy and design based upon calculations tailored to the circumstances of a specific building

3.19 fire load

sum of the heat energies which could be released by the complete combustion of all the combustible materials in a space including the facings of walls, partitions, floors and ceilings, and contents including for car parks all cars present

NOTE Adapted from PD 7974-1:2003.

3.20 fire operational position

position or configuration of a component specified by the design of the system during a fire
[BS 7346-4]

3.21 fire resistance

ability of an item to fulfil for a stated period of time the required fire stability and/or integrity and/or thermal insulation, and/or other expected duty specified in a standard fire resistance test
[BS 4422:2005]

3.22 fire service override switch

manually operated switch to enable fire fighters to initiate or terminate the operation of a fire safety system or other device

3.23 fixing

device used to secure plant or equipment to the structure of a building

3.24 frequency inverter

electronic device used to control the speed of fans by controlling the frequency of the electrical power feeding the electric motor driving the fans

3.25 impulse

product of force and the time for which that force acts

NOTE This is numerically equal to force (jet thrust) when the time is taken to be 1 s. When divided by the cross-sectional area over which the force acts this equals a pressure.

3.26 jet fan

fan designed to transfer momentum into the air as part of an impulse ventilation system

NOTE A jet fan is also known as an impulse fan.

3.27 impulse ventilation system (IVS)

set of fans used to exert thrust on the air within a space to accelerate air to create a desired pattern of movement of air and smoke within that space

NOTE An example of a space is a car park or storey.

3.28 integrity

the ability of a specimen of a separating element to contain a fire to specified criteria for collapse, freedom from holes, cracks, and fissures and sustained flaming on the unexposed face
[BS 476-20:1996]

3.29 means of escape

structural means whereby in the event of fire a safe route or routes is or are provided for persons to travel from any point in a building to a place of safety

3.30 mechanical cross ventilation

system of smoke control where mechanical means are used to sweep air horizontally through the space to remove smoke

NOTE 1 The mechanical means is usually fans.

NOTE 2 An example of a space is a car park storey.

3.31 multi criteria fire detection

fire detection system with detector heads monitoring two or more fire phenomena

3.32 natural cross ventilation

system of smoke control where openings are used to allow wind and/or buoyancy to sweep air horizontally through a space to remove smoke *NOTE An example of a space is a car park storey.*

3.33 override control

control included in an automatically operating smoke and heat control system to allow manual operation or manual shut-down of all or part of that system

3.34 pressure differential system

system of fans, ducts, vents, and other features provided for the purpose of creating a lower pressure in a smoke control zone than in a protected space [BS 7346-4]

3.35 rate of rise heat detection

automatic fire detection which initiates an alarm when the rate of change of the measured phenomenon with time exceeds a certain value, for a sufficient time

3.36 replacement air

clean air entering a building to replace smoky gases being removed by the smoke and heat control system *NOTE Adapted from BS 7346-4.*

3.37 signalling system

network of electrical cables, radio and optical cables, carrying signals between sensors, control panels, computers, and active devices or any combination of these

NOTE This does not include power supply cables.

3.38 smoke clearance system

smoke and heat control system whose primary purpose is to remove smoke from a space after a fire has been controlled or extinguished

NOTE Secondary benefits might include an easing of the conditions to which fire-fighters are exposed while approaching and fighting the fire.

3.39 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 space) or closed (to avoid smoke spreading to other zones).
[BS 7346-4]

3.40 smoke control zone

defined area within a car park provided with smoke control to prevent smoke moving into adjacent zones

3.41 smoke and heat control system

arrangement of components installed in a building to limit the effects of smoke and heat from a fire
[BS 7346-4]

3.42 smoke and heat exhaust ventilation system (SHEVS)

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
[BS 7346-4]

3.43 steady-state design method

fire-engineering method of calculating the design of a smoke and heat control system based on the largest fire with which the smoke and heat control system is expected to cope

3.44 steady-state design fire

design fire based on the largest fire with which a smoke control system is expected to cope

3.45 time-dependent design fire

design fire based on the most severe fire growth rate with which a smoke control system is expected to cope

3.46 thrust

force created at the discharge of a jet fan

NOTE Thrust is a function of velocity and air mass usually measured in Newtons.

3.47 vehicle emission ventilation

ventilation system designed to remove or dilute to a safe concentration products of combustion emitted by vehicle engines in normal use

3.48 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 often expressed in the form of a computer program.

[BS 7346-5]

4 Smoke and heat control system selection

*COMMENTARY ON Clause **4***

The major potential source of ignitable material in a car park is the cars themselves. Smoke from a car fire will spread through the car park, directed by the shape of the building and the effects of wind pressures on openings, unless that smoke flow is controlled.

4.1 Design objectives

The designer can choose one of the following design objectives.

•• Clearance of smoke during the fire and after the fire has been suppressed, the smoke control serving to assist in checking for secondary seats of fire as well as returning the building to its normal use.

•• Creating and maintaining a smoke-free route through the car park open space on the fire''s storey for fire-fighters to approach close to the car on fire, with the intention of facilitating active fire suppression.

•• Protection of escape routes for occupants within the same storey as the car on fire, to preserve a smoke-free path to either the exterior of the building, or to a protected stairwell which leads to a final exit to a place of safety.

*COMMENTARY ON **4.1***

The techniques available to achieve these objectives are:

•• smoke and heat exhaust ventilation systems (SHEVS), where a sustained region of clear air is maintained beneath a smoke reservoir containing thermally buoyant smoke;

•• cross-flow ventilation where air is induced to flow through the car park driven either by wind forces or by fans;

•• impulse ventilation intended to provide smoke free access close to the car on fire for fire-fighters.

The systems are designed to control smoke from one fire at a time situated at any one point within the car park.

4.2 Selection of objectives

4.2.1 Where the objective is solely to achieve clearance by horizontal cross flow through the car park storey one of the following may be used.

•• Natural cross ventilation specified as permanent openings, see Clause **7**.

•• Mechanical cross ventilation achieved using conventional mechanical ventilation, see Clause **8**.

•• Mechanical cross ventilation using jet fans, see Clause **9**.

NOTE The above three forms of cross-flow ventilation are only suitable for achieving smoke clearance.

4.2.2 Where the objective is to provide for fire-fighters a clear air access path to the car on fire, the following methods may be used. •• A SHEVS, having a minimum clear height, see Clause **12.**

•• An impulse ventilation system designed to achieve a clear approach for fire-fighters to at least one side of the car on fire, see Clause **10**.

4.2.3 If there is any concern that automatic operation of a smoke and heat control system could adversely affect persons escaping the system designer should either select an alternative system design or introduce an appropriate delay period before full activation of the system.

5 Design fires

*COMMENTARY ON Clause **5***

Reliable design fire information is essential for the design of systems intended to assist fire-fighter intervention or to protect means of escape. A design fire is not used for the design of systems intended for smoke clearance only as these systems can follow separate prescriptive rules.

A developing fire in a car or light commercial vehicle typically starts in the engine compartment or in the passenger compartment. Violent crashes causing rupture of the fuel tank and immediate large fires are unlikely in a car park. Typical fire growth in the passenger compartment starts slowly, accelerating once the fire becomes reasonably well ventilated. This often occurs when a window or sun-roof breaks. The contents of the passenger compartment usually represent the main fuel load, and the seating, linings, and instrument panel are often made of materials which burn vigorously.

For many years the best available information on the heat output of burning cars was based on experiments in the 1960s. On the basis of these, it became the established view that fires rarely spread beyond the vehicle initially on fire. The belief has grown in the 1990s and since that the more widespread use of plastics in body panels and other parts has led to multiple-vehicle fires becoming more common. There is statistical and experimental evidence to the effect that fire spread from car to car needs to be considered as a distinct possibility, and that the heat output from a single car needs to be regarded as being larger than in past decades [7].

*Sprinklers are unlikely to extinguish a fire inside a vehicle, as most vehicles are designed to keep water (rain) out. Nevertheless, the effect of sprinklers in wetting the external surface of adjacent vehicles can be expected to slow or prevent fire spreading to the adjacent vehicle. See **9.1.17** and **16.2** for recommendations to reduce the risk of interaction between sprinklers and jet fans.*

There are two distinct approaches to using a design fire. One is to adopt a steady-state design fire and the other is to adopt a time-dependent design fire.

A steady-state design fire is based on the assumption that fires larger than the design size occur acceptably infrequently, and that the smoke and heat control system based on this design fire can cope successfully with all smaller fires (and by implication with all earlier stages of the same fire). A steady-state design fire does not require the assumption that a real fire burns steadily. Calculation procedures are relatively straightforward, and might use simple computer zone-model techniques, although simple calculation methods can often serve.

A time-dependent design fire tracks the growing and often the declining stages of the heat output as a function of time, and is used to calculate the consequences typically in terms of the onset of a defined hazard. These methods tend to be complicated, and to rely on computer modelling. Sources for time-dependent design fires are ideally full-scale test fires using large calorimeters. Some of these empirical fire growth curves for cars can be used in a simplified form, although none correspond very closely to the ""time-squared"" growing fires commonly adopted for growing fires in buildings.

5.1 Car fires

For steady-state design methods, the design fire should either adopt the appropriate value of heat release rate and other parameters from Table 1 or the design fire should adopt an alternative appropriate in the circumstances of the particular design which should be detailed in the documentation specified in Clause **18** together with a justification as to why this alternative is appropriate. Where the experimental data has been placed in the public domain a reference to the publication may be used as justification.

Table 1 **Steady-state design fires**

Fire parameters	Indoor car park without sprinkler system	Indoor car park with sprinkler system
Dimensions	5 m × 5 m	2 m × 5 m
Perimeter	20 m	14 m
Heat release rate	8 MW	4 MW

Time-dependent design fires should be based on an experimental test fire, which should be described and justified in the documentation specified in Clause **18**. Where the experimental data has been placed in the public domain a reference to the publication may be used as justification.

5.2 Stores and storage within car parks

As well as the vehicles themselves, other combustible storage, if any, within car parks should be considered.

Provided that the nature of the combustible storage and the associated fire load would not give rise to a fire that would exceed the original design fire for the cars, the system can be assumed to be capable of dealing with a fire involving the storage.

The values for fire parameters in Table 1 should be used when comparing the likely steady state design fire output adopted for the combustible storage.

However, the following should be taken into consideration.

a) The type of combustible materials stored.

a) The amount and disposition of the fire load.

b) The degree of fire resisting enclosure if provided.

c) The provision of sprinklers.

Where the combustible materials are of a quantity or type that would result in a much larger or more severe fire than the car-based design fire, they should either be prohibited, removed or enclosed in a fire-resisting construction.

6 Vehicle exhaust pollution control

*COMMENTARY ON Clause **6***

As well as providing smoke control for car parks in the event of a fire there is an equally important every day requirement for the ventilation of vehicle exhaust fumes. This is needed to avoid, in particular, excessive concentrations of carbon monoxide or other noxious gases.

For additional guidance on ventilation for vehicle exhaust pollution control in car parks see Approved Document F to the Building Regulations (England and Wales) [9], Technical Booklet K to the Building Regulations (Northern Ireland) [10] and Scottish Building Standards Technical Handbooks Section 3 [6].

6.1 General

Any dual-purpose system intended to fulfil both environmental ventilation and smoke control during a fire, should meet the performance recommendations for both roles.

One of the four alternative approaches to vehicle exhaust pollution control in **6.2** to **6.5** should be used.

6.2 Naturally ventilated car parks

For naturally ventilated car parks, permanent ventilation should be provided. The ventilation should have an aggregate equivalent area of at least 5% of the floor area of each car park storey. At least half of this should be equally arranged between two opposing walls.

6.3 Mechanical and natural ventilation of car parks

Permanent natural ventilation with an aggregate equivalent area of at least 2.5% of the floor area can be combined with a mechanical ventilation system capable of at least three air changes per hour.

6.4 Mechanically ventilated car parks

For basement or enclosed car park storeys, mechanical ventilation should be provided to at least 6 air changes per hour. In addition, wherever cars could queue in the building with engines running, e.g. at exits and ramps, provision should be made for a local ventilation rate of at least 10 air changes per hour. See Figure 1.

6.5 Detailed quantitative assessment of contaminants

As an alternative to **6.4,** the mean predicted pollution levels may be calculated and the ventilation designed to limit the concentration of carbon monoxide to not more than 30 parts per million averaged over an 8 h period and peak concentrations, such as by ramps and exits, not to go above 90 parts per million for periods not exceeding 15 minutes.

NOTE More detailed quantitative engineering guidance is available where the pattern of vehicle movements in the car park throughout the day and night can be predicted with confidence. See for example Verein Deutscher Ingenieure''s ""Air treatment systems for car parks"" [8].

7 Natural dispersal smoke ventilation

7.1 Car parks which are open sided

7.1.1 Car parks may be naturally ventilated using the principle of wind assisted cross-flow ventilation.

7.1.2 This form of ventilation should not be used for protection of means of escape in case of fire. It is suitable for smoke clearance and for fire-fighter assistance.

7.1.3 Due to the required area and locations of openings, natural ventilation can be unsuitable for underground car parks.

7.1.4 Ventilation openings should be permanently open and free of obstructions.

7.2 Car parks which are not open sided

7.2.1 Naturally ventilated car parks that are not open sided should be provided with some natural ventilation on each storey. The natural ventilation should be by permanent openings at each car parking level with an aggregate equivalent area of at least 2.5% (1/40) of the floor area at each level. The distribution arrangements of the openings should be such that an aggregate equivalent area of 1.25% (1/80) is equally provided between two opposing walls to give a good cross flow.

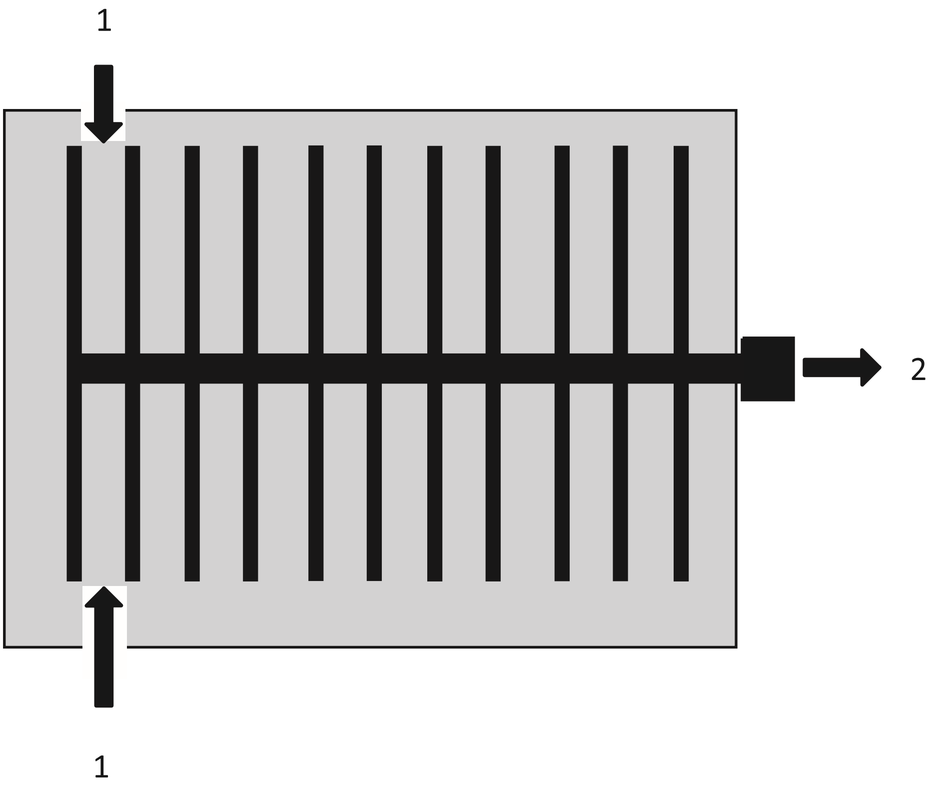
7.2.2 Smoke vents at ceiling level may be used as an alternative to permanent openings in the walls. These smoke vents should also have an aggregate equivalent area of permanent openings totalling at least 2.5% [1/40] of each floor area, at each level and be arranged to provide a through draft.

7.2.3 Where openings have louvres, grilles, bird guards or similar devices installed, the equivalent area provided should take into account the restriction caused by these devices.

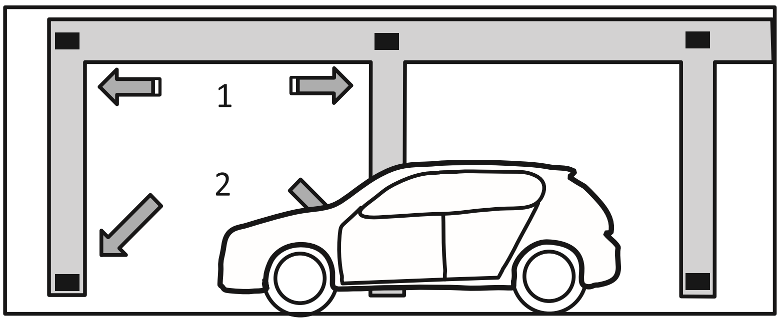
7.2.4 Where part of the open area is provided by ramps, entrances, etc., the ventilation area provided should include only the permanently open equivalent area of any doors, grilles or shutters across these openings.

7.2.5 For the purpose of smoke control, and as an alternative to permanent openings in the walls, automatic smoke ventilators conforming to BS EN 12101-2 may be provided in the ceiling, arranged to provide a through draught. The smoke ventilators may provide all or part of the required equivalent area. The smoke ventilators should open automatically upon detection of a fire in the car park.

Figure 1 **Typical mechanical ventilation using a ducted smoke dispersal system**



a) Plan view



b) Section view

Key to Figure 1 a)
1 Inlet
2 Extract

Key to Figure 1 b)
1 50% high level
2 50% low level

8 Conventional mechanical extract

*COMMENTARY ON Clause **8***
The objective of the smoke clearance system design (see Figure 2) is to: a) assist fire-fighters by providing ventilation to allow speedier clearance of the smoke once the fire has been extinguished;

b) help reduce the smoke density and temperature during the course of a fire.

This system is not specifically intended to maintain any area of a car park clear of smoke, to limit smoke density or temperature to within any limits or to assist means of escape.

8.1 General

8.1.1 The system should be independent from any other system (other than any system providing normal ventilation to the car park) and be designed to operate at 10 air changes per hour. See Figure 1.

8.1.2 The discharge points for the smoke exhaust system should be located such that they do not cause smoke to be recirculated into the building, spread to adjoining buildings, or adversely affect the means of escape.

8.1.3 The main extract system should be designed to run in at least two parts, such that the total exhaust capacity does not fall below 50% of the rates set out in **8.1.1** in the event of failure of any one part and should be such that a fault or failure in one will not jeopardize the others.

8.1.4 The system should have an independent power supply, designed to operate in the event of failure of the main power supply.

8.1.5 Extract points should be arranged so that 50% of the exhaust capacity is at high level and 50% is at low level and evenly distributed over the whole car park.

8.1.6 The fans and associated control equipment should be wired in protected circuits designed to ensure continued operation in the event of a fire (see Clause **14**).

8.1.7 The system should be initiated by one or more of the following:

a) smoke detection;

b) rapid rate of rise heat detection;

c) multi-criteria fire detection;

d) a sprinkler flow switch;

e) a fire service override switch.

8.1.8 Care should be taken to ensure that there are no stagnant areas in either daily ventilation or smoke ventilation operational mode.

8.1.9 Provision should be made for the supply of replacement air to the car park.

8.1.10 The velocity of air within escape routes and ramps should not exceed 5 m/s in order to avoid impeding the escape of occupants of the building.

8.2 Performance recommendations for equipment

8.2.1 All fans intended to exhaust hot gases used within a car park ventilation system should be tested in accordance with BS EN 12101-3 to verify their suitability for operating at 300 °C for a period not less than 60 minutes (class F300).

NOTE For further information on equipment for removing hot smoke refer to BS EN 12101-3.

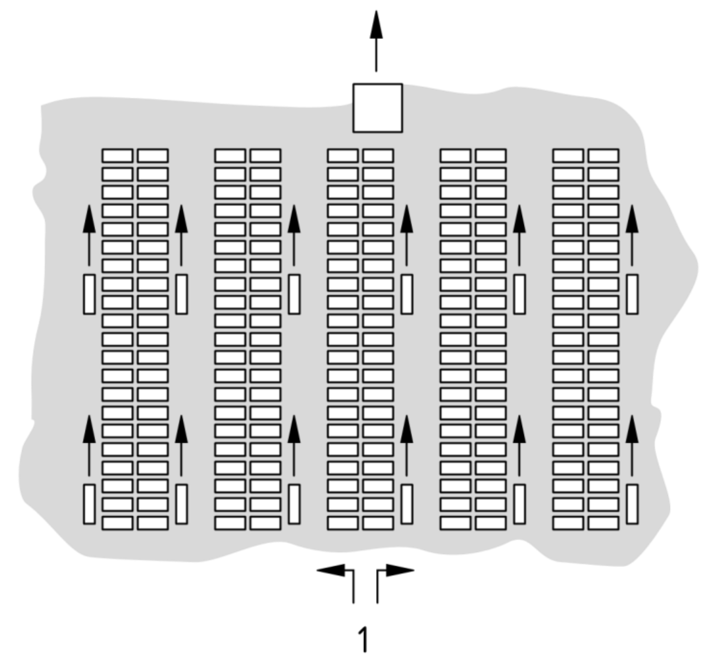
8.2.2 Where fans are located within the building, but outside the fire compartment which they serve, they should be enclosed with elements of structure having a fire resistance at least equal to that required for the part of the building within which it is situated and in no case less than 1 h.

8.2.3 Ductwork, dampers and fixings should conform to Clause **13**.

8.3 Calculation procedures

The exhaust ventilation system should be designed to provide a minimum of 10 air changes per hour for each car park storey or fire compartment served by that system.

Figure 2 **Typical mechanical ventilation using an impulse smoke dispersal system**



Key
1 Fresh air supply

9 Impulse ventilation to achieve smoke clearance

COMMENTARY ON Clause ***9***

The objective of the smoke clearance system design (see Figure 2) is to: a) assist fire-fighters by providing ventilation to allow speedier clearance of the smoke once the fire has been extinguished;

b) help reduce the smoke density and temperature during the course of a fire.

This system is not intended to maintain any area of a car park clear of smoke, to limit smoke density or temperature to within any specific limits or to assist means of escape.

It is possible that some smoke clearance systems, if set in operation too early, might actually worsen conditions for means of escape by encouraging smoke circulation and descent of the smoke layer. For this reason it could be preferable to delay operation after automatic detection of fire.

9.1 General

9.1.1 On detection of a fire, the main extract fans should immediately respond to provide the required rate of extract.

9.1.2 After an appropriate delay, the jet fans should activate in such numbers as necessary to direct the smoke efficiently towards the main extract points for a fire. The delay period should reflect the designed means of escape period.

The delay is necessary to ensure that escaping occupants are not compromised by the action of the jet fan system. The system should be designed so that escaping occupants can walk to a clear storey exit such that they are not inhibited by the smoke and heat generated by the fire and moved by the fans operating during the initial escape period.

The delay employed to achieve this outcome will depend on one or more factors, e.g.:

- the size and geometry of the car park;
- the number and location of extract and jet fans;
- the numbers and type of occupants; and
- the number and location of suitable exits.

9.1.3 The delay period, if any, should be confirmed in agreement with the approving authorities.

9.1.4 The air change rate within the car park should be at least 10 air changes per hour.

9.1.5 Consideration should be given to the location of the means of escape within the car park when locating the position of the extract point(s).

9.1.6 The positions of the stairwell, means of escape corridor, and lobby doors, where present, should be co-ordinated with jet fan locations and jet orientations to avoid exposing the doors to dynamic pressure effects which might cause smoke to enter the lobby, stairwell and/or corridors.

9.1.7 Care should be taken to ensure that there are no stagnant areas in either daily ventilation or smoke ventilation operational mode.

9.1.8 Provision should be made for the supply of replacement air to the car park.

9.1.9 The velocity of air within escape routes and ramps should not exceed 5 m/s in order to avoid impeding the escape of occupants of the building.

9.1.10 The resistance to airflow and turbulence caused by downstand beams and any other obstruction should be taken into account when siting the jet fans.

9.1.11 Notwithstanding the requirements for daily ventilation, in the event of fire, the main extract fans, where present, should be immediately activated to provide a minimum airflow rate equivalent to 10 air changes per hour within the car park.

9.1.12 Care should be taken to ensure that the number of jet fans activated will not induce the movement of a volume of air greater than that which the main extract fans are capable of extracting.

9.1.13 The system should be independent from any other system (other than any system providing normal ventilation to the car park).

9.1.14 The discharge points for the smoke exhaust system should be located such that they will not cause smoke to be recirculated into the building, spread to adjoining buildings, or adversely affect the means of escape.

9.1.15 The main extract system should be designed to run in at least two parts, such that the total exhaust capacity does not fall below 50% of the rates set out in **9.1.1** in the event of failure of any one part and should be such that a fault or failure in one will not jeopardize the others.

9.1.16 Where a sprinkler system is to be installed, the location of the sprinkler heads and jet fans should be co-ordinated to ensure that the effect of the jet fans on the spray pattern of the sprinklers is minimized.

9.1.17 Each part of the main extract system should have an independent power supply, which will operate in the event of failure of the main power supply.

9.1.18 The fans and associated control equipment should be wired in protected circuits designed to ensure continued operation in the event of a fire (see Clause **14**).

9.1.19 The system should be initiated by one or more of the following:

a) smoke detection;

b) rapid rate of rise heat detection;

c) multi-criteria fire detection;

d) sprinkler flow switch;

e) fire service override switch.

9.1.20 All fans intended to exhaust hot gases used within a car park ventilation system should be tested in accordance with BS EN 12101-3 (class F300) to verify their suitability for operating at 300 °C for a period not less than 60 minutes.

NOTE For further information on equipment for removing hot smoke refer to BS EN 12101-3.

9.1.21 Where fans are located within the building, but outside the fire compartment which they serve, they should be enclosed with elements of structure having a fire resistance at least equal to that required for the part of the building within which it is situated and in no case less than 1 h.

9.1.22 Ductwork, dampers and fixings should conform to Clause **13**.

9.2 Calculation procedures

The exhaust ventilation system should be designed to provide a minimum of 10 air changes per hour for the largest car park storey or fire compartment served by that system and should be applied to the calculated volume of each car park storey or compartment.

10 Impulse ventilation to assist fire-fighting access

*COMMENTARY ON Clause **10***

The objective of the smoke control design is to aid access by the fire service to more quickly locate and tackle a fire and carry out search and rescue as necessary. See Figure 3.

10.1 System design criteria

10.1.1 The design should be based on calculation. Whatever calculation method is adopted, the design should be based on the following performance criteria.

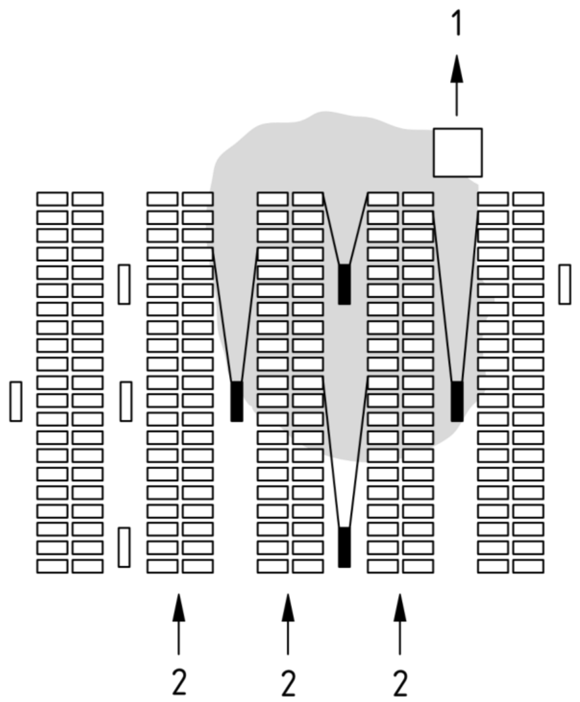
10.1.2 The extract rate should be calculated for the removal of the mass of mixed air and smoke impelled towards the exhaust intakes. Calculations should be based on a design fire from Table 1, or another design fire acceptable to the approving authorities. All supporting calculations and justifications should be fully documented (see Clause **18**).

10.1.3 The system should be such that all car park levels and other parts of the building, other than the one where the fire is located, are kept substantially free of smoke.

10.1.4 Designs should be such that the bulk air velocity induced by the jet fans is sufficient to halt the advance of the ceiling jet within 10 m from the fire location for all possible fire locations in the direction opposite to the induced bulk air flow.

10.1.5 There should be fire-fighter access (from the exterior, or from protected stairwells) available, positioned to allow fire-fighters to have at least one clear approach route to any possible fire location.

Figure 3 **Typical mechanical ventilation using an impulse system for fire-fighter access**



NOTE Fans coloured black are operating.

Key

1 Extract

2 Fire-fighting access upstream of the fire

10.1.6 Designs should be such that the fire-fighters can move through substantially clear smoke-free air when approaching the fire up to a distance of 10 m from that fire.

10.1.7 The design should take account of the presence of any downstand beams and of their orientation in assessing the effect on the ceiling jet, and hence on the minimum induced airspeed necessary to overcome and to turn back the ceiling jet.

10.1.8 The positions of the stairwell, means of escape corridor, and lobby doors, where present, should be co-ordinated with jet fan locations and jet orientations to avoid exposing the doors to dynamic pressure effects which might cause smoke to enter the lobby, stairwell and/or corridors.

10.1.9 The distribution of the jet fans should be such that there are no stagnant areas in daily ventilation operational mode.

10.1.10 The design objectives of the system should be met even after failure of the jet fan closest to the fire.

10.1.11 The ventilation system should be able to control the flow of smoke wherever the fire occurs within the car park.

10.1.12 The capacity of main smoke extract fans and any associated ducting should be calculated on the basis that the pressure in the car park close to the extract intakes is equal to the external atmospheric pressure.

10.1.13 Provision should be made for the supply of replacement air to the car park.

10.1.14 The velocity of air within escape routes should not exceed 5 m/s in order to avoid impeding the escape of occupants of the building.

10.1.15 Inlets for replacement air should be large enough (if natural openings) or should be sufficiently extensive and evenly distributed (if air is supplied by fans via ducts) to ensure that the airspeed in the incoming jets formed inside the inlets does not create a recirculation of smoke. The maximum inlet air speed should be 2 m/s.

10.1.16 Jet fans should be designed to overcome the flow resistance of any natural inlets for replacement air, for the total volume rate of flow of air needed to overcome the ceiling jet near the fire.

NOTE 1 This is intended to ensure that the car park storey is maintained below external atmospheric pressure except close to the intakes for the main smoke extract. This will give a measure of additional protection to lobbies, stairwells and/or corridors used for fire-fighting access and for evacuation of occupants.

NOTE 2 This approach can also be used to calculate the minimum area of inlets required.

10.1.17 The number of jet fans activated should not cause the volume of air movement to be greater than that volume extracted by the main extract fans.

10.1.18 For a smoke and heat control system, the car park should be divided into smoke control zones of not more than 2000 m^2, with a fully addressable fire detection system able to indicate the fire’’s location to the system’’s main control panel.

10.1.19 An addressable fire detection system will also assist the fire and rescue service to locate and tackle the fire more quickly.

10.1.20 The system should be initiated by one or more of the following:

a) smoke detection;

b) rapid rate of rise heat detection;

c) multi-criteria fire detection.

The fire service override switch is required in addition to any of a) to c).

10.1.21 Designs based on the creation of smoke control zones within a larger volume should either:

- have physical partitions to create channels for the smoke and the induced air flow, thus separating neighbouring zones; or
- demonstrate, using a CFD model conforming to **15.2**, that smoke is contained within the zone boundaries, is channelled to the extract fans, and does not allow smoke to circulate in other zones in the car park; or
- demonstrate conformity to the design by carrying out an appropriate commissioning test, see Table 2.

10.1.22 Where a sprinkler system is to be installed, the location of the sprinkler heads and jet fans should be co-ordinated to ensure that the effect of the jet fans on the spray pattern of the sprinklers is minimized.

10.1.23 On detection of a fire, the main extract fans should immediately respond to provide the calculated rate of extract for a fire condition. After an appropriate delay, the jet fans should activate in such numbers as necessary to direct the smoke efficiently towards the main extract points for a fire condition.

NOTE The delay is necessary to ensure that escaping occupants are not compromised by the action of the jet fan system. Within the affected smoke zone, escaping occupants need to be able to walk to a clear storey exit such that they are not inhibited by the smoke and heat generated by the fire and moved by the fans operating during the initial escape period. The delay employed to achieve this outcome will depend on one or more factors, e.g.:

- *the size and geometry of the car park;*
- *the number and size of smoke zones;*
- *the number and location of extract and jet fans;*
- *the numbers and type of occupants; and*
- *the number and location of suitable exits.*

10.1.24 Alternatively, the design should be based on a fire engineering methodology and show that the available safe egress time from the affected smoke zone is greater than the required safe egress time plus a suitable safety margin. The delay period, if any, should be confirmed in agreement with the approving authorities.

10.1.25 Information as to the clear approach routes should be automatically displayed at the fire service main point of entry into the building.

10.1.26 The jet fans designated to operate to control the flow of smoke and to protect the other parts of the car park should be activated in sufficient numbers so as to limit the spread of smoke.

10.2 Equipment rating

10.2.1 The aerodynamic performance of the jet fan should be tested in accordance with BS 848-10 or an appropriate European Standard.

10.2.2 At least two main extract fans should be installed to serve each smoke control zone of the car park.

The fans should be mounted in parallel and should have sufficient capacity to give the full design extract rate with any one fan discounted.

10.2.3 All fans should conform to at least class F300 of BS EN 12101-3:2001, that is, they should be suitable for handling a temperature of 300 °C for a period of not less than 60 minutes.

10.2.4 All ancillary equipment, electrical or mechanical, associated with the main fan installation and potentially exposed to the same hot fire gases, should be capable of maintaining its performance and structural integrity for the same time/temperature criteria as specified for the fans, i.e. 300 °C for a period of at least 60 minutes.

11 Impulse ventilation to protect means of escape

11.1 System design objectives

*COMMENTARY ON **11.1***
The objective of the smoke and heat control system is to provide for the protection of escape routes for occupants within the same storey as the car on fire, to preserve a smoke-free path to either the exterior of the building, or to a protected stairwell which leads to a final exit to a place of safety. See Figure 3.

Care should be taken to ensure that routes for access to a point of escape are not compromised due to poor visibility or accessibility.

11.2 System design criteria

11.2.1 Impulse ventilation to protect means of escape should conform to Clause **10**, with the following additional recommendations.

11.2.2 There should be a sufficient number of storey exit doors/escape routes maintained unaffected by smoke for the estimated population initially in the car park storey to evacuate safely, with all storey exits in the extract direction in the affected smoke control zone discounted.

11.2.3 All zones outside the defined smoke path between fire source and extract point should be usable.

11.2.4 Within the affected smoke control zone, escaping occupants should be able to move to a clear storey exit such that they are not affected by the smoke and heat generated by the fire. The design should show that the available safe egress time from the affected smoke zone is greater than the required safe egress time plus a suitable safety margin.

*NOTE Because, following any delay considered appropriate (see **10.1.22**), the jet fans will operate and move smoke and heat more rapidly than by natural means, the impact of the fans operating in the smoke affected zone needs also to be considered as part of this analysis.*

11.3 Equipment rating

The same criteria detailed in **10.2** also apply here.

12 Smoke and heat exhaust ventilation systems (SHEVS)

*COMMENTARY ON Clause **12***
In a smoke and heat exhaust ventilation system (SHEVS) the hot smoky gases resulting from the fire float above the denser cold air beneath. This maintains good visibility in the clear air beneath the smoke layer, allowing free movement either for evacuation, or for fire-fighter access to the fire. See Figure 4.

The minimum clear height can be different for these two objectives, in view of the protective clothing and training available to fire-fighters.

The concept and design procedures are described in detail in BS 7346-4 for steady-state design fires, and in BS 7346-5 for time-dependent design fires.

The design of a SHEVS should follow these guidance documents, with certain exceptions specific to car parks detailed in a) to g).

a) If the SHEVS can meet the airflow requirements for vehicle exhaust emission control (see Clause **7**) with a reduced volume flow rate compared to the requirements for smoke control, it might be used to fulfil both sets of requirements.

b) Where the SHEVS is designed to protect means of escape for occupants, the clear height should be at least as detailed in BS 7346-4 (i.e. 2.5 m or 0.8 times the ceiling height, if lower than 2.5 m).

c) Where the SHEVS is designed to provide a clear, smoke-free approach to the fire for fire-fighters, the clear height should be at least 1.75 m.

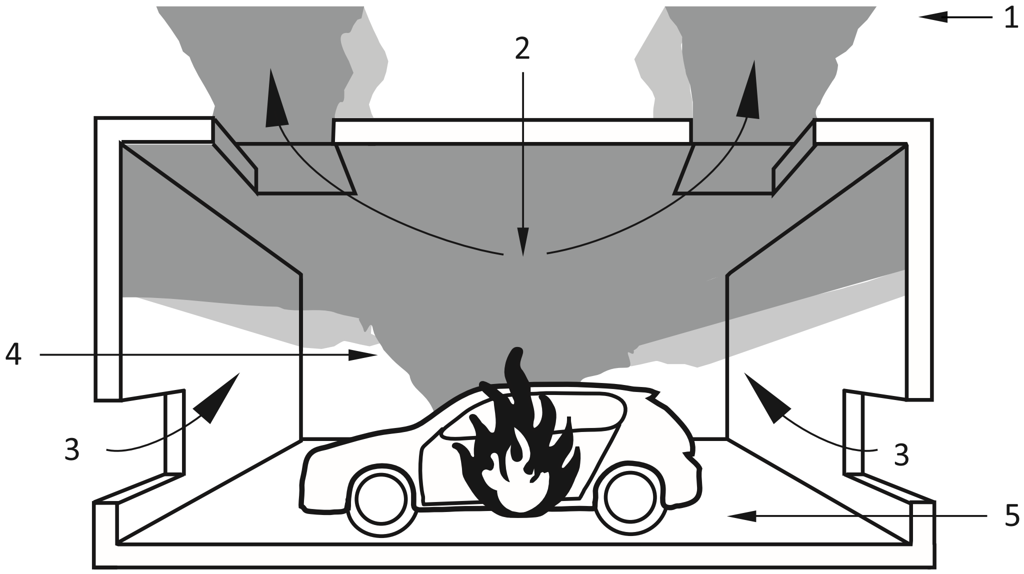
d) The design fire, whether steady-state or time-dependent, should be based on **5.1** rather than the car fire cited in BS 7346-4.

e) The system should be independent from any other ventilation or HVAC system in the building other than for the control of vehicle emission pollutants.

f) All other performance recommendations and calculation procedures should be as detailed in BS 7346-4 for steady-state designs, and as detailed in BS 7346-5 for time-dependent designs, of the SHEVS as well as for recommendations specific to car parks within the scope of this standard.

g) Openings should be provided to allow the air to enter or exit the car park. These inlets should conform to the recommendations of BS 7346-4, and where the vehicle entrances and/or exits are required for the SHEVS, e.g. in emergency mode, the system should ensure that any gates are automatically moved into the fire operational position specified by the design of the SHEVS.

Figure 4 **Design regions for a single volume space**



Key

1 Wind, snow, etc.

2 Smoke reservoir and exhaust

3 Air inlets and doors

4 Smoke plume

5 Fire

13 Ductwork, fixings, and smoke dampers

*COMMENTARY ON Clause **13***

It is generally the case that in car park smoke and heat control systems, ductwork is used together with fans. It is necessary to ensure that the ductwork, its fixings, and any other components such as smoke dampers, perform satisfactorily at least as long as the fans in the case of a fire.

13.1 Ductwork and fixings within the car park should be constructed of materials capable of surviving exposure to gases having temperatures greater than or equal to 800 °C and should maintain their stability and integrity under fire conditions.

13.2 Where ductwork penetrates through a fire compartment wall or slab the ductwork should have a fire resistance at least equal to that required for the compartment or be in an enclosure with a fire resistance at least equal to that required for the compartment.

13.3 A smoke control damper construction should not contain a device that is able to change the position of the damper once the safety position has been reached, i.e. the damper should not change position unless required by direct instruction from a control system. It is assumed that power is maintained throughout the car park where the system is installed. Consequently smoke control damper assemblies should have no thermal devices to cause uncontrolled operation and no automatic return mechanisms that might, for instance, operate on loss of power.

14 Controls and power supplies

14.1 General

Where power is essential to initiate or maintain operation of smoke and heat control systems the controls and power supplies should be suitably rated or protected to ensure that power remains available for the required period.

A secondary power supply should be provided to operate automatically in case of failure of the primary supply.

NOTE This is not necessary when natural ventilation, failing to the fire condition on loss of power, is used.

14.2 Controls

14.2.1 The system should be initiated by one or more of the following:

a) smoke detection;

b) rapid rate of rise heat detection;

c) multi-criteria fire detection;

d) sprinkler flow switch.

A fire service override switch is required as part of any of option a) to d).

NOTE A fire service override switch is not suitable as the only form of initiation for systems designed to assist fire-fighting access and/or protect means of escape.

14.2.2 Operation in the case of a fire should override any environmental controls associated with the smoke and heat control system for controlling the normal environmental ventilation arrangements for the car park.

14.2.3 A smoke, rapid rate of rise heat detection, or multi criteria, system should conform to the requirements of BS 5839-1.

14.2.4 The type and location of detectors should be selected to initiate operation of the system as early as possible. The detectors should be located to minimise adverse effects from air movement caused by the environmental ventilation system.

*NOTE In some situations a delay may be built into the operating system to hold off operation of all or part of the system for a set period. See Clauses **9** to **11**.*

14.2.5 Where zonal control is required, the detection system should be capable of locating the fire with an accuracy that allows the different zones of the smoke and heat control system to operate appropriately within the design.

14.2.6 Control panels for the smoke and heat control system should be separated from the main car parking area by a fire-resisting separation of at least 1 h.

14.2.7 Clearly labelled fire service override switches should be provided at agreed fire service access points. For automatic systems the switches should provide off/auto control and where appropriate off/auto/on control. For manual systems the switches should provide off/on control.

14.2.8 Where the smoke and heat control system is provided with speed control using frequency inverters, each main extract and supply fan should be provided with a dedicated inverter. The inverters should be installed within the control panel or should be located separate from the main car parking area by a fire-resisting separation of at least 1 h. The mode of control in the event of an inverter failure should enable the fan to operate at its maximum speed.

14.3 Computerised control systems

14.3.1 Computerised control systems can be used to control a car park smoke and heat control system, and will rely on the use of specific software to carry out the modes of operation required of that system.

14.3.2 Where computerised control systems are used as part of the operational requirements of a smoke and heat control system, any changes to the software controlling the fire safety functions should not adversely affect the operation of the smoke and heat control system.

14.3.3 A comprehensive description of the control software should be provided to the building owner and/or his site agent by the system designer, together with documentation of all changes made to the system after installation. This should be added to the documentation detailed in Clause **18** (see also BS 5588-12).

14.3.4 When changes are made to the software or associated computer system, a full check of the smoke and heat control system operation should be carried out in accordance with Clause **17** to confirm the continual functioning of the system and the results included in the documentation in accordance with Clause **18**.

14.3.5 Signalling systems providing the information to and from the computerised control centre should be protected from the effects of fire for a period of 1 h.

14.4 Electrical power supplies

14.4.1 Where electrical services in the building are essential to maintain the operation of the smoke and heat control system, a secondary power supply e.g. an automatically started generator or a supply from another substation, should be provided which will, independently of the primary supply, be of sufficient capacity to maintain any powered smoke and heat control systems in operation for at least 1 h and be capable of operating safely in fire conditions.

NOTE For further information on power supplies refer to BS EN 12101-10.

14.4.2 All electrical services should be installed by suitably qualified engineers in accordance with BS 7671:1992 (IEE Wiring Regulations).

14.4.3 The electrical primary power supply to life safety and fire protection ventilation equipment should be separate from all other circuits in the building so that the failure of other equipment does not render the installation inoperative.

- Each connection to the power supply should be via an isolating protective device reserved solely for life safety and fire protection equipment and independent of any other main or sub-main circuit. Such isolating protective devices should be clearly labelled and identified as to their purpose. They should be secured against unauthorized operation.

- Monitoring facilities should be provided at the fire control room (where provided) to show, as far as is reasonably practical, that power is available up to the final control point, e.g. motor contactor, for the car park jet fan ventilation systems.

14.4.4 The primary and secondary power sources, electrical distribution board, cables and control equipment supplying power to the fire-fighting equipment should be protected against fire and water damage for a period of at least 1 h. They should be kept separate so that a failure in a cable or equipment, either by mechanical breakdown or damage by fire, in either supply does not affect the other supply.

Protection against fire can be achieved through choice of cable, choice of route (e.g. through protected areas, or external to the building) or by the use of a fire-resisting construction.

14.4.5 The primary and secondary power supply cables should be terminated in a changeover device located within the fire resistant compartment housing the main control panel. The changeover device should automatically effect a transition from the primary to the secondary power supply if any phase of the primary power supply fails.

14.4.6 Whichever secondary source is provided, the distribution should be organised such that the secondary supply remains live when the remainder of the supplies in the building are isolated in an emergency.

14.4.7 Cables supplying current to the fire-fighting facilities should be:

a) classified as LS60 in accordance with BS 7346-6:2005;

b) in accordance with BS 8434-2:2004; or

c) in accordance with BS EN 60702-1:2004.

15 Pre-installation verification

*COMMENTARY ON Clause **15***
Confidence is needed prior to installation that the system will meet prescriptive requirements and/or perform as intended.

In many cases this can be demonstrated simply by provision of design drawings, specifications and calculations. For some systems, particularly those designed to assist fire-fighting access or protect means of escape, additional verification of performance might be needed. For further detail see Annex A.

15.1 Zone modelling

Where a zone model is used to determine the likely conditions within a car park the designer should ensure that the model is suitable for the purpose and provides full details of the model used, the inputs to the model, modelling assumptions including simplifications to the geometry and the objectives of the modelling in quantifiable terms.

Care should be taken to ensure that the model is used within its capabilities. Zone models are based on empirical relationships and therefore careful consideration should be given when extrapolating the model beyond its established limits.

In all cases the use of zone models to model complex geometries might not give reliable results where flows of smoke and heat are complex.

15.2 CFD modelling

CFD modelling can be used to model the movement of heat and smoke in complex geometries and if used appropriately can give both designers and regulators confidence that the installed system will achieve its objectives.

As a minimum a report should be prepared stating the CFD code used and its version, the boundary conditions (inputs), geometry layout and simplifying assumptions, grid specification, sensitivity analysis, results and the modelling objectives.

The CFD model should present temperatures and smoke spread. Smoke may be represented as smoke concentration/optical density or visibility inside the car park. Results should, as a minimum, show in the horizontal plane smoke spread and temperatures at 1700 mm from the finished floor level.

When investigating the smoke flows within the car park using CFD, it is essential that the geometry of the car park is modelled as accurately as practicable including all significant down-stand beams and obstructions, etc. Depending on a number of issues, such as the height, area and geometry of the car park, the presence of cars could therefore affect the results.

The modelling should be based on the worse case scenarios. The modelling should investigate the car park both when it is empty of cars and when it is full of cars corresponding to the number of car parking spaces available.

15.3 Selection of verification method

COMMENTARY ON ***15.3***

The choice of verification method is up to the designer and it is therefore incumbent on them to demonstrate to the approving authority''s satisfaction, that the approach and model to be used are appropriate in the circumstances of the case.

In general systems based on air change rates are relatively simple and can be verified by simple calculations.

Those systems intended to provide specific conditions, whether for means of escape or fire-fighter access, based on the dilution of smoke or the provision of a clear area might need to be verified prior to installation using computer modelling techniques.

Where computer modelling is the preferred route for pre-installation verification it is suggested that agreement is reached as to the conditions to be modelled between the designer and approving authorities prior to commencing modelling.

16 Interaction with other fire protection systems and other building systems

16.1 General

Smoke and heat control systems described in this standard need to co-exist with mechanical, electrical and other fire protection systems within the building.

16.2 Sprinkler systems

Where a sprinkler system is to be installed, the location of the sprinkler heads and jet fans should be co-ordinated to ensure that the effect of the jet fans on the spray pattern of the sprinklers is minimized.

16.3 Other ventilation systems

COMMENTARY ON ***16.3***

It might be the case that day-to-day environmental engine exhaust fume control is provided by a system other than the smoke and heat control system. In the event of fire it is important that the fire provisions take precedence. It is also important that any components common to both fire and environmental systems are able to meet the requirements of the fire, smoke and heat control systems. The following recommendations apply.

a) Wherever the vehicle exhaust fume ventilation is provided by a system independent of the smoke and heat control system, that system should close down in the event of the smoke and heat control system being initiated.

b) Any ducts or openings which form a part of the non-fire protective ventilation system and which penetrate between storeys or fire compartments should be closed at the boundary between storeys or fire compartments using fire-rated smoke dampers.

c) All smoke control dampers in that part of the HVAC system corresponding to the affected smoke control zone should move into their fire operational positions simultaneously with the HVAC fans.

d) The functions described in a) to c) should be tested after the system has been installed by simulating a fire detection signal in accordance with Clause **17**.

e) If parts of the HVAC system are used in the smoke and heat control system, those parts of the HVAC system which are incorporated into the smoke and heat control system should follow all appropriate recommendations in this standard.

f) All smoke control dampers should be capable of being opened and closed by powered devices.

16.4 Lighting, signage, public address and voice alarm systems

In view of the importance of rapid evacuation of car park occupants for several of the smoke control systems detailed in this standard, consideration should be given to optimizing lighting, signage and public address and voice alarm systems in the car parks.

Sound levels of public address and voice alarm systems, and of the car park smoke control systems, should be such that when the car park smoke control systems are activated, messages are clearly audible and intelligible. The designers of the car park smoke control systems, public address and voice alarm systems should consult each other at the design stage to optimize the performance of the combined systems. For further discussion see Annex B.

16.5 Pressure differential systems

COMMENTARY ON ***16.5***

One or more of the protected stairwells connected to the car park may be equipped with a pressure differential system. If the storey is more than 10 m below ground level, and the stairwell is a fire-fighting shaft, then the stairwell would usually be pressurized.

The dynamic pressure head due to the stairwell door intercepting the air flow from a jet fan might adversely affect the pressure difference across the storey-exit door.

The jet fan system should not have an adverse effect on the performance of the pressurization system.

16.6 External/ground level escape routes

*COMMENTARY ON **16.6***

All smoke and heat control systems need to eject smoky gases to the exterior, at or above ground level. Care needs to be taken to ensure that this smoke does not create unacceptable hazards to people in the surrounding areas.

The location of smoke exhaust outlets for the smoke and heat control systems should be selected to minimize the risk of smoke adversely affecting people or vehicles in the surrounding area, taking wind effects into account.

Air inlets for the smoke and heat control system should not be located where smoky gases being exhausted by the same smoke and heat control system could be drawn in with the incoming air.

16.7 Security systems

*COMMENTARY ON **16.7***

Smoke control measures and building security might conflict unless the needs of both are taken into account during the design of the building. Smoke control measures, for example, often require openings for replacement air to enter the building whereas security against unauthorized entry requires that openings are impassable to people.

Security measures such as CCTV can be very useful in preventing arson, and/or as an adjunct to fire detection systems or when giving directed messages using the public address system.

Security systems should not adversely affect the operation of the smoke and heat control system. For example, where doors are recommended to act as air inlets, and can be closed off for part of the day, they should open automatically when the smoke and heat control system is activated.

Where CCTV is monitored by a control room, the operators of that control room should have the capability, that is the facilities and training, to monitor the fire detection system as well.

Where CCTV is monitored by a control room, and there is a public address system, the control room operators should be trained to give directed messages as needed.

16.8 Fire safety management

The design of the smoke and heat control systems should take into account the needs of the fire safety manager during the building''s operating lifetime.

The design, installation, and subsequent management of the fire protection measures should conform to the requirements of BS 5588-12, except where specific exceptions are detailed in this standard.

17 Commissioning

All parts of a smoke ventilation system used within a car park should be inspected, tested, demonstrated and verified at the completion of installation. Table 2 provides a suggested checklist of the major components of the system. Any additional features included in a system, such as remote system monitoring, should be tested and demonstrated.

Table 2 **Checklist for commissioning of major components of a smoke and heat control system or SHEVS**

Component	**Installed** [tick]	**Tested** [tick]
Natural systems		
Check that adequate openings are provided		
Check suitable distribution of openings		
All mechanical systems		
Provide full set of as installed drawings, written system description, calculations and cause and effect chart for system in all modes of operation		
Verify that the main extract fans are providing the specified volumetric performance		
Verify that supply fans, where present, are providing the specified volumetric performance		
Ensure no leakage at flexible connectors		
Ensure free and correct operation of non-return dampers, where fitted to main fans		
Ensure correct installation and operation of fire/smoke dampers		
Ensure correct operation of system under simulated mains failure		
Ensure correct operation of extract system in case of failure in one part		
Carry out cable survey and check certification		
Confirm certification of fan to appropriate standards		
Check functionality of fire service override switch		
Verify an adequate source of replacement air is provided		
Conventional mechanical system		
Verify correct air extract rates to each ducted extract point		
Demonstrate the automatic operation of the system by the selected method of system activation		
Confirm correct selection and installation of all fixtures and fittings used in the installation of ducting allowing for compliance with all relevant regulations and standards		
Confirm certification of ducting being suitably fire rated		
Impulse smoke dispersal		
Confirm all jet fans operating and in correct direction		
Demonstrate the automatic operation of the system by the selected method of system activation		
Check jet fans are operating at correct speed according to the agreed design strategy Demonstrate air movement in all parts of the car park under daily ventilation and fire conditions		
Confirm certification of jet fan to appropriate standards		
Impulse system for fire-fighter access and/or means of escape		
Demonstrate automatic operation of the system as specified in the design strategy for each smoke control zone		
Where considered necessary by the approving authorities demonstrate the control of the smoke flow in line with the declared system design for each smoke control zone using an appropriate methodology (for example smoke testing)		
All systems		
Check the interaction between the car park ventilation system and all other detection, alarm, smoke control or any other life safety system Ensure that all systems respond in the appropriate manner		

18 Documentation to be supplied with heat and smoke control system

18.1 General design recommendations

18.1.1 Documentation indicating that the design philosophy and calculation meet one, or a combination, of the design objectives given in **4.1** should be provided. This should be made available to the owner of the car park where the smoke and heat control system is installed and/or to the user of the system.

This documentation should comprise all of the information necessary for clear identification of the installed system, e.g. drawings, description, list of components, certification of installation act, test certificates of components, details of calculations made.

Where a car park is altered, updated documentation on the smoke and heat control system should be provided and made available for the owner and/or user of the car park.

18.1.2 Fire-fighting

Where the car park employs a system that is designed to assist fire-fighting it is imperative that sufficient information is provided to enable attending fire-fighters to understand the system and operate any override controls as necessary.

In the case of smoke clearance systems a simple plan with a description of the system, override controls and their location in the building will normally suffice.

For systems designed to assist fire-fighting or to protect means of escape, suitable plans showing the extract points and fans should be provided for each level of the car park, together with a brief description of the system''s function. Additionally, where jet fans are employed, their location should be indicated on the plan and information should be provided to identify the preferred fire-fighting access point and direction of approach for a car fire in any particular fire alarm/smoke control zone that is activated.

This information can be provided in the form of plans for fire service use, held at a suitable location accessible to the fire service 24 h per day. Alternatively for more complex systems an electronic graphical representation could be provided adjacent to the fire alarm panel showing the zone involved and the preferred access stair core/direction etc.

Further information on plans for fire service use is given in BS 5588-12:2004, Annex Q.

18.2 Detailed recommendations

18.2.1 System design documentation

Where appropriate, the documentation should include the following. a)

A justification for the choice of design fire.

b) Where design calculations explicitly include wind pressure forces and/or wind pressure coefficients, identification of all zones of overpressure and suction on the building''s surface.

c) The locations of all exhaust ventilator outlets and replacement air openings in the building.

d) Assumptions and input parameters used in calculations of the external environment of the building.

e) Wind load, snow load, and low ambient temperature assessments for any ventilators.

f) Relative positions of the exhaust outlets and unprotected openings in neighbouring buildings, pedestrian areas and vehicle roadways in the neighbourhood of the building.

NOTE This may be done by the provision of plan, elevation and section drawings complete with the relevant design information from a) to e).

g) full details of all the inlet air provisions, locations and their method of operation;

h) for mechanical systems, the total volume of air to be provided;

i) the calculated air flow speed at the inlets for this air.

18.3 Installation, maintenance and testing documentation

The frequency and level of periodic testing and maintenance should be documented and conform to BS 5588-12, including details of the following:

- commissioning;
- routine, periodic testing;
- operating and maintenance manuals.

18.4 Computer control software

Where relevant, a comprehensive description of the control software should be provided to the building owner and/or his site agent by the system designer, together with documentation of all changes made to the system after installation.

When changes are made to the control software or associated computer system, the results of a full check of the smoke and heat control system operation in accordance with Clause **17** should be included.

19 Maintenance and safety

The responsible person in the car park owner''s management chain (see BS 5588-12) should ensure that all components of a smoke and heat control system are maintained and regularly tested in accordance with the requirements of BS 5588-12 as well as in accordance with any suppliers'' recommendations.

NOTE Attention is drawn to the need to include the replacement air provisions within the maintenance regime.

Annex A (informative) Computer-based models

A.1 General

Computer-based models might simplify the task of calculations as a part of the design process, or (in the case of CFD analysis) can allow calculations to be made where there are no reliable correlation formulae on which to base a zone model.

A.2 Computer-based zone models

A.2.1 Where computer-based zone models are used to carry out the calculations recommended in this standard as part of the design process, all mathematical formulae used in those models, assumptions made, and values of input parameters should be explicitly included in the documentation made available to the owner of the building and the relevant approval authorities.

A.2.2 In addition, information concerning validation of the computer-based zone models, and justification for any extrapolation beyond established limits used in the design needs to be included in the documentation. Where such validation information exists in the publicly available literature, appropriate references may be cited.

A.3 Computational fluid dynamics models

A.3.1 Where computational fluid dynamics (CFD) models are used to carry out the calculations recommended in this standard, care needs to be taken not only to confirm validation of the CFD model itself, but also to ensure that the boundary conditions, mesh size, design size, grid size, geometry and presence of vehicles are appropriate to the scenario being modelled.

NOTE For a more comprehensive discussion of the use of CFD models see Annex A of PD 7974-2.

A.3.2 A full description of the model, including its boundary conditions, confirmation of the choice of mesh size and of convergence onto a solution, needs to be included in the documentation made available to the owner of the building.

Annex B (informative) Lighting, signage, public address and voice alarm systems

B.1 Lighting and signage

Cars are often effectively soundproofed. This makes the visual signage in a car park even more important than usual. With the exception of SHEVS designs, the smoke control methods discussed in this standard will all allow a greater or lesser degree of smoke logging even close to the floor, over all or a part of the car park storey affected by fire and smoke.

It follows that there is an advantage in using flashing lights in an emergency to alert people in cars, and to draw their attention to written signs. These signs will point the way to the nearest exit for evacuation on foot. It is also important that these signs are not too far apart where smoke might be present. It is also important that in a SHEVS design the signs are located below the design smoke layer base.

It is good practice for signs to instruct people in the event of fire to turn off their engines, leave their cars and evacuate on foot.

Where car parks are associated with shopping centres and other occupancies where large numbers of persons are present, it would be useful to provide similar signs instructing people (whether on foot or in cars) not to enter the car park when a fire is detected.

Where judged appropriate, automated exit barriers can be designed to open during a fire emergency.

Where considered appropriate any evacuation signal can be supplemented by flashing lights in order to attract the attention of people in cars.

B.2 Public address and voice alarm systems

Sound levels of public address, voice alarm and the smoke and heat control systems can be adjusted so that when the smoke and heat control system is activated in the event of a fire, the resulting messages are clearly audible and intelligible above the noise produced by the smoke and heat control system (e.g. extract fans and jet fans).

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