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PERINTAH TETAP KETUA PENGARAH BILANGAN TAHUN 2015

GARIS PANDUAN PENGGUNAAN SISTEM *JET FAN* SEBAGAI PEPASANGAN KESELAMATAN KEBAKARAN AKTIF UNTUK SISTEM PENGURUSAN ASAP DI RUANGAN LETAK KERETA

1. TUJUAN

Garis panduan ini bertujuan untuk memberikan penjelasan berhubung penggunaan sistem *jet fan* sebagai pepasangan keselamatan kebakaran aktif untuk sistem pengurusan asap di ruangan letak kereta bawah tanah dan di atas paras akses perkakas bomba.

2. LATARBELAKANG

2.1 Pada permulaaannya sistem *Jet fan* telah digunakan untuk menyediakan sistem pengudaraan dan pengeluaran asap di dalam terowong sahaja. Walaubagaiman pun mulai tahun 2009 ianya telah mula digunakan sebagai sistem pengurusan asap di ruangan letak kereta di dalam bangunan.

2.2 Sistem *Jet Fan* ini membolehkan kadar ketumpatan asap dikurangkan (*smoke density*) iaitu berasaskan jarak penglihatan lebih dari 10 meter, tanpa toksid dan suhu (*temperature*) asap kurang daripada 60°C dalam masa kurang dari 30 minit. Oleh itu ini membolehkan pelepasan diri atau ~~pengeluaran kenderaan~~ dari ~~kawasan yang terbakar~~ bebas dari bahaya kebakaran. ~~Juga~~ membolehkan pasukan bomba menjalankan operasi kebombaan dengan ~~lebih efektif dan~~ berkesan.

2.3 Pada tahun 2010 satu garispanduan penggunaan sistem jet fan sebagai pepasangan keselamatan kebakaran untuk kawalan asap di ruangan letak kereta telah dikeluarkan oleh Jabatan Bomba Dan Penyelamat Malaysia (JBPM). Garispanduan tersebut menjurus ~~kepada penambahbaikan pepasangan sistem *jet fan* sedia pada masa itu, supaya dapat~~ memenuhi objektif sebenar sebagai kawalan terhadap *smoke clearance, smoke dilution, evacuation* ~~*time (Availabel Safety Evacuation Time)*~~ dan operasi penyelamatan dan melawan kebakaran.

3 ASPEK PENGURUSAN ASAP (SMOKE MANAGEMENT)

3.1 Pengurusan asap merupakan aspek yang penting dalam sesuatu bangunan untuk membolehkan pelepasan diri berlaku dalam keadaan selamat dan membolehkan kerja-kerja penyelamatan dan melawan kebakaran dijalankan dengan lebih efektif dan berkesan oleh pasukan bomba.

3.2 Aspek pengurusan asap ini telah dijelaskan di dalam Undang-Undang Kecil Bangunan Seragam (UBBL) 1984, Malaysian Standard (MS) dan British Standard seperti berikut. :-

3.2.1 Undang-Undang Kecil Bangunan Seragam (UBBL)1984.
Undang-undang Kecil 249, UBBL 1984 menyatakan "Dalam bangunan tanpa tingkap, struktur bawah tanah dan kilang yang luas kawasannya, kemudahan pengeluaran asap hendaklah disediakan bagi penggunaan tempat keluar dengan selamat.

3.2.2 Malaysian Standard (MS) 1780:2005
"Smoke Control System Using Natural (Displacement) or Powered (Extraction) Ventilation".

3.2.3 British Standard (BS) 7346- Part 7:2013
"Compenent for Smoke and Heat Control-Code of Practice of on functional recommendation and culculation methods for smoke and heat control system for covered car park".

4 KETETAPAN JABATAN

4.1 Bagi tujuan merekabentuk sistem *Jet fan* di ruangan letak kereta perlulah mematuhi keseluruhan kriteria rekabentuk yang dinyatakan di dalam piawaian seperti berikut:-

4.1.1 Malaysia Standard (MS) 1780 - *"Smoke Control System Using Natural (Diplacement) or Powered (Extraction) Ventilation".*

4.1.2 British Standard (BS) 7346- Part 7:2013 - *"Compenent for Smoke and Heat control-Code of Practice of on functioinal* *recommendation and culculation methods for smoke and heat control system for covered car park".*

4.2 Ketetapan Am

4.2.1 Rekabentuk, pemasangan, pengujian dan simulasi *Computational Fluid Dymamics (CFD)* sistem *jet fan* hendaklah mematuhi UBBL 1984, (MS) 1780 dan BS 7346: Part 7-2013.

4.2.2 Penggunaan sistem *Jet fan* dibenarkan kepada ruangan letak kereta yang tertutup dan mempunyai sistem semburan automatik (sprinkler system) serta sistem pengesan jenis *addressable.*

4.2.3 Penggunaan sistem *Jet fan* tidak dibenarkan di tempat letak kereta terbuka/separa terbuka.

4.2.4 Penggunaan sistem *jet fan* tidak dibenarkan pada ruangan tempat letak kereta bawah tanah yang menggunakan sistem meletak kereta secara mekanikal *(mechanical car racking system)* .

4.2.5 Pengunaan sistem *jet fan* hanya dibenarkan dalam ruangan tempat letak kereta dengan tetulang struktur *flat slab.*

4.2.6 Penggunaan sistem *jet fan* tidak dibenarkan bagi ruangan tempat letak kereta yang mempunyai tetulang struktur beam yang terkeluar.

4.2.7 Pihak PSP disyaratkan mengemukakan simulasi *CFD* modeling yang disediakan oleh pihak *Fire Safety Engineer* bagi pengunaan sistem jet fan di ruangan tempat letak kereta yang mempunyai keluasan zon asapnya (*smoke control zone)* melebihi $2000m^2$. *CFD* modeling yang dikemukakan itu hendaklah berasaskan kepada dua (2) senario kebakaran.

4.2.8 Jika zon kawalan asap yang kurang $2000m^2$ jumlah keluasannya dalam satu pemetakan, *CFD* modeling tidak diperlukan.

4.2.9 *CFD* modeling dan analisa laporan *CFD* daripada syarikat pembuat *CFD* tidak dibenarkan.

4.2.10 Penentuan saiz "*car fires*" hendaklah berdasarkan kepada Klausa 5.1 Table 1, BS 7346:2013 seperti di lampiran 1.

4.2.11 Penentuan *"Smoke control zones"* atau *"Smoke Reservoir Size"* hendaklah berdasarkan kepada Klausa 10.1.15, BS 7346:2013 seperti di lampiran 1.

4.2.12 Penentuan rekabentuk "*smoke layer base*" adalah merujuk kepada Klausa 7.2, MS 1780 : 2005 dan kadar tukaran *intake* adalah 10 *airchange* seperti di lampiran 2.

4.2.13 Penentuan suhu ketahanan sistem *jet fan* perlu merujuk kepada Klausa 8.8.18, MS1780:2005 seperti di lampiran 2.

4.2.14 Semua pendawaian sistem *jet fan* perlu di dalam konduit logam atau menggunakan kabel dari jenis *fire resistance* yang diluluskan.

4.2.15 Penyelengaraan dan ujian terhadap keberkesanan sistem *jet fan* hendaklah diuji menggunakan kaedah *hot smoke test.*

4.2.16 Sekiranya sistem jet fan gagal berfungsi semasa ujian dijalankan, kajian semula dalam aspek rekabentuk, pengiraan, *CFD* Modeling, pemasangan dan aspek-aspek lain yang berkaitan perlu dilakukan.

5. TARIKH KUATKUASA

5.1 Pemakaian Perintah Tetap ini berkuatkuasa dari tarikh ianya ditandatangani.

5.2 Secara automatik ia membatalkan Arahan Keselamatan Kebakaran Bilangan 1 Tahun 2010, Garis Panduan Penggunaan Sistem Jet Fan Sebagai Pepasangan Keselamatan Kebakaran Untuk Kawalan Asap Di Ruangan Letak Kereta.

6. PEMAKAIAN

6.1 Perintah Tetap ini terpakai di seluruh Malaysia termasuk Sabah dan Sarawak.

6.2 Garispanduan ini hendaklah dibaca bersama *MS 1780:2005 dan BS 7346-Part 7:2017.*

7. PENUTUP

Ketua Pengarah adalah berhak untuk membuat pindaan atau penambahan pada perintah tetap ini dari masa kesemasa. Perintah Tetap ini hendaklah dijadikan garispanduan bagi penggunaan sistem *Jet fan* sebagai pepasangan keselamatan kebakaran untuk kawalan asap di ruangan letak kereta dalam aspek:-

7.1 Merekabentuk sistem tersebut,

7.2 Semasa proses semakan dan kelulusan pelan Mekanikal & Elektrikal, dan

7.3 Pemeriksaan dan ujian system tersebut bagi tujuan *"Certificate Compliance dan Completion"* (CCC) dan "*Occupancy Permit*" (OP).

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(DATUK WIRA HAJI WAN MOHD NOR BIN HAJI IBRAHIM)

Ketua Pengarah,

Jabatan Bomba dan Penyelamat Malaysia.

Tarikh :

1 Scope

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

NOTE 1 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 be revised in a future edition of this standard if 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 those who manage the fire safety of car parks.

It gives 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 the 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. Following the BRE fire tests on car stacker systems, it also includes recommendations for fire sizes and fire suppression in these types of installations.

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

NOTE 2 Guidance on loading bays and coach parks can be found in the FETA publication, Design of smoke ventilation systems for loading bays and coach parks – a guide for system designers *[5].*

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

[SOURCE: BS 7346-4:2003, 3.1.2]

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

3.4 car stacker system
vehicle stacking arrangement which allows cars to be parked more efficiently per unit area of car park space – usually a mechanical device which stores vehicles either above or beneath another (in a tiered or multi-tiered configuration)

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 7346-4:2003, 3.1.11.

3.7 computational fluid dynamics (CFD) model
computer simulation model where the fundamental equations of heat and mass transfer are solved using numerical methods

[SOURCE: PD 7974-2:2002, 3.8]

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 a smoke and heat control system

NOTE Adapted from BS 7346-4:2003, 3.1.14.

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 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.

3.13 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.

3.14 extract 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

3.15 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

[SOURCE: BS 7346-4:2003, 3.1.16]

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

3.17 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, 3.10.

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

[SOURCE: BS 7346-4:2003, **3.1.17**]

3.19 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

[SOURCE: BS 4422:2005, 3.369]

3.20 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

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

3.22 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

3.23 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.

3.24 impulse fan
axial, centrifugal or mixed-flow fan designed to induce air movement by thrust

NOTE An impulse fan is also known as a jet fan.

3.25 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 car park storey.

3.26 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

[SOURCE: BS 476-20:1987, **2.9**]

3.27 jet fan
fan used for producing a jet of air in a space and unconnected to any ducting

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

3.28 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

3.29 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 or car park storey.

3.30 multi-criteria fire detection
fire detection system with detector heads monitoring two or more fire phenomena

3.31 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 or car park storey.

3.32 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

3.33 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

NOTE Adapted from BS 7346-4:2003, 3.1.32.

3.34 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

3.35 replacement air
clean air entering a building to replace smoky gases being removed by the smoke and heat control system

NOTE Adapted from BS 7346-4:2003, 3.1.34.

3.36 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.

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

[SOURCE: BS 7346-4:2003, 3.1.37]

3.38 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

[SOURCE: BS 7346-4:2003, 3.1.39]

3.39 **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.

3.40 **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).

[SOURCE: BS 7346-4:2003, **3.1.42**]

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

3.42 **stagnant area**
area in which there is little or no air movement resulting in an undesirable build up of contaminated air

3.43 **steady-state design fire**
design fire based on the largest fire with which a smoke control system is expected to cope

3.44 **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

3.45 **thrust**
force created at the discharge of an impulse fan

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

3.46 **time-dependent design fire**
design fire based on the most severe fire growth rate with which a smoke control system is expected to cope

3.47 **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.

[SOURCE: BS 7346-5:2005, **3.1.51**]

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 spreads 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 should choose one of the following design objectives.

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

b) Creating and maintaining a relatively 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.

c) 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.

NOTE The techniques available to achieve these objectives are:

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

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

c) 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 system

4.2.1 Where the objective is solely to achieve clearance by horizontal cross-flow through the car park storey one of the following should 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 impulse 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 fire-fighters with a clear air access path to the car or other combustible material on fire, the following methods should 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.

Recent research has shown that the widespread use of plastics in body panels has resulted in cars containing a higher fire load (see BRE report, Fire spread in car parks *[1]) and there is the potential for fire to spread to adjacent cars, even across an empty parking bay. 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 (see* Natural fires in closed car parks *[6]).*

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 has been shown to slow or prevent fire spreading to the adjacent vehicle (see BRE report, Fire spread in car parks *[1]). See* ***9.1.16*** *and* ***16.2*** *for recommendations to reduce the risk of interaction between sprinklers and impulse fans.*

The capacity of car parks can be increased by the use of stackers, where mechanical systems can place one car closely above another. This arrangement could allow rapid fire spread from one car to another. However, experiments have shown that this spread can be significantly controlled by a suitably designed and installed sprinkler system (see BRE Report 256618 [7]).

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.

Other suppression systems might be an acceptable alternative to sprinklers.

5.1 Car fires

For steady-state design methods, the design fire should either use the appropriate value of heat release rate and other parameters from Table 1 or 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 should be used as justification.

Table 1 **Steady-state design fires**

Fire parameters	Indoor car park without sprinkler system	Indoor car park with sprinkler system	2 car stacker with sprinklers
Dimensions	5 m × 5 m	2 m × 5 m	2 m × 5 m
Perimeter	20 m	14 m	14 m
Heat release rate	8 MW	4 MW	6 MW

NOTE It is not practical within this British Standard to give guidance on a suitable design fire size for stacker systems where sprinklers are not installed or where they exceed two cars high.

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 should be used as justification.

5.2 Stores and storage within car parks

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 should 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 account:

a) the type of combustible materials stored;

b) the amount and disposition of the fire load;

c) the degree of fire resisting enclosure if provided;

d) the provision of sprinklers;

e) the size of the store/compartment involved.

6.4 Mechanically ventilated car parks

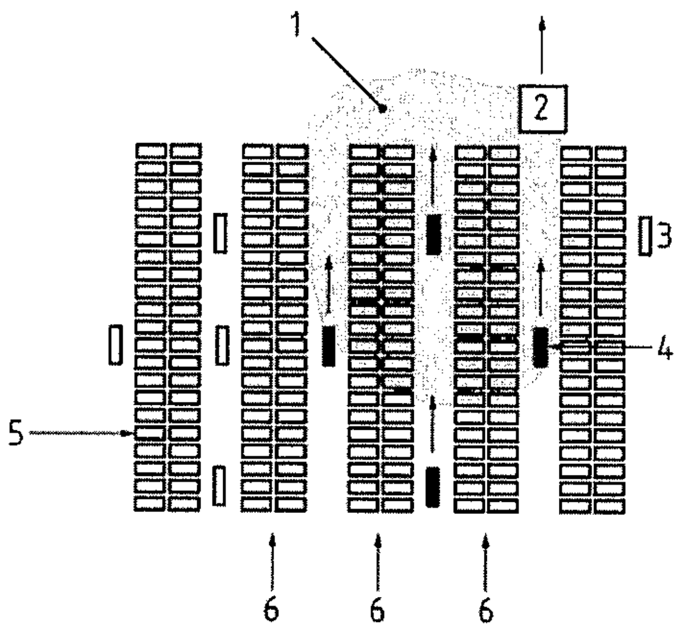
For basement or enclosed car park storeys, mechanical ventilation should be provided to at least six air changes per hour. In addition, wherever it is possible for cars to queue in the building with engines running, e.g. at exits and ramps, provision should be made for a local ventilation rate of at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

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.

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



Key

1	Controlled smoke flow	4	Operational impulse fans
2	Extract	5	Parking bays
3	Inoperative impulse fans	6	Supply air

NOTE Only impulse fans coloured black are operating.

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, which illustrates the way in which, with the selective activation of the impulse fans, the flow of smoke can be controlled.

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 Following any delay considered appropriate (see **10.1.20**), the impulse fans will operate and move smoke and heat more rapidly than by natural means, therefore 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 criteria detailed in **10.2** should also be used here.

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.

The provision of power supplies should be in accordance with BS EN 12101-10.

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 an additional part of any option a) to d).

A manual fire service switch should not be used as the only form of initiation for systems designed to assist fire-fighting access and/or protect means of escape.

14.2.2 The design cause and effect should be made available to all parties very early in the process to allow procurement, installation and commissioning.

14.2.3 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.

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

14.2.5 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 minimize adverse effects from air movement caused by the environmental ventilation system.

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

14.2.6 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.

14.2.7 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.

14.2.8 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. Fire service override switches should be finished in the colour compliant with current fire service requirements and all switches should be labelled for fire-fighter use only and its purpose should be identified.

14.2.9 The fire service switch should not be located within the body of the car park itself.

14.2.10 The manual arrangements for re-setting the smoke extract system to normal after it has been activated automatically should be clearly separate from and not affected by the facilities for re-setting the fire alarm system after it has been operated.

14.2.11 No switch should be incorporated in the fire alarm system which can isolate the automatic operation of the smoke extract systems in the triggering of the alarm (e.g. for use when periodically testing the alarm system) unless a non-mutable audible warning is given in a position under regular observation whilst the smoke extract systems are isolated.

14.2.12 Any arrangements for interconnection of the smoke extract system with a building management system (BMS) should be such that any fault developing on the processing system, or any change from its normal operation including when it is being maintained, will not jeopardize the operation of the smoke extract systems.

14.3 Computerized control systems

COMMENTARY ON 14.3

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

14.3.1 Where computerized 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.

14.3.2 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 9999).

14.3.3 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**.

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

14.4 Power supplies

14.4.1 General

14.4.1.1 The electrical distribution system should be designed and installed by a competent person as defined in BS 7671.

14.4.1.2 The electrical arrangements should conform to BS 7671 and the relevant parts of BS EN 60947.

14.4.1.3 To maintain the operation of the life safety and fire-fighting systems, a secondary power supply, e.g. an automatically started standby generator or an alternative utility supply from another external substation, should be provided in accordance with BS 8519.

14.4.2 Dual circuits/diverse routes

Both the primary and the secondary supplies should be protected against fire and water damage and separated from each other by adopting diverse cable routes.

The diverse cable routes for the power supplies should be separate from any non-life safety/fire-fighting system circuits that could be detrimental to the operation of the life safety and fire-fighting system circuits.

Where the diverse routes come together in the same area, they should be separated from each other by a partition with a fire resistance period of at least 1 h.

NOTE This does not apply within the room containing the automatic change over device.

14.4.3 Fire protective enclosures for equipment

Any electrical substation or enclosures containing any of the following equipment should be separated from the remainder of the building by construction protected against fire and water damage for a period of at least 1 h:

- distribution boards;
- motor control panels;
- smoke control plant; and
- automatic changeover devices, with their associated switchgear.

NOTE A smoke control plant does not usually require separation from the car park it protects.

14.4.4 Automatic changeover devices

Changeover devices should conform to BS EN 60947-6-1 and BS EN 60947-6-2.

14.4.5 Control panels

Control panels serving the appropriate life safety and fire-fighting circuits should be protected to IP54 classification as specified in BS EN 60529:1992.

14.4.6 Cable selection

The cables selected for smoke ventilation installations should be fire-resistant cables meeting the requirements of BS 8519.

Cables selected for use with an automatic fire detection system should comply with BS 5839-1.

14.4.7 Cable installation practice

When installing cables that are required to maintain circuit integrity under fire conditions, the resistance to fire of the cable fixings, cable containment system and any joints should be at least equivalent to the survival time required for the cable.

Joints in cables, other than those contained within the enclosures of equipment, should be avoided wherever practicable.

Where fire-resistant cables have by their method of construction adequate mechanical protection (e.g. cables tested in accordance with BS 8491), they should either be fixed directly to the building structure, or be installed such that they are enclosed in or carried upon cable management or containment systems. If the cables are fixed directly to the building, the fixings should provide adequate support in the presence of the potential hazards (see Introduction).

Where fire-resistant cables require additional mechanical protection, they should be enclosed in or carried upon cable management or containment systems. Such systems should provide adequate support and maintain necessary mechanical protection in the presence of the potential hazards. The systems and their supports should be sized to cater for the reduction in the tensile strength of steel when directly exposed to a fire temperature.

14.4.8 Cable support systems

The support system should have a fire survival time equal to that of the cables it supports and for the same defined fire conditions.

When sizing the support brackets for containment routes, which are intended to support fire-resistant cables in a fire condition and where the circuits are to maintain their integrity for a pre-determined period, the drop rods and hangers should be sized to take into account the fact that the tensile strength of steel will be significantly reduced in a fire situation.

14.4.9 Inverters

Power supplies for systems derived from frequency inverters in order to vary the speed of the motor should be equipped with a fail-safe fire mode. The fire mode should effectively disable the motor protection function to enable, if necessary, the inverter/motor to run to destruction.

Where the smoke and heat control system is provided with speed control using frequency inverters, each 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.

If the ventilation system is required to have multiple speeds in fire mode, in order to perform the required duty, each speed should be separately hard-wired and initiated from the individual fire alarm interface modules.

14.4.10 Area of special risk

Smoke ventilation system cables installed within the car park should be installed to avoid locations above parking places as far as is practicable.

NOTE In the cable fire test rig in BS 8491, the maximum temperatures developed are approximately 850 °C but higher temperatures might be experienced directly above a burning car or van.

15 Pre-installation verification

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 should be verified prior to installation (see **10.1.17**).

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

CFD modelling should be carried out in accordance with Annex B.

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

16 Interaction with other fire protection systems and other building systems

16.1 General

The smoke and heat control systems described in this standard should work in conjunction with mechanical, electrical and other fire protection systems within the building.

16.2 Interaction of impulse fans and sprinklers

Where sprinklers are installed within a car park fitted with an impulse ventilation system, the distribution of the impulse fans should be co-ordinated with the sprinkler installation in order that the jet stream from the impulse fan creates minimum interference with the sprinkler pattern.

NOTE 1 At the time of publication, little research has been carried out into the impact that the installation of impulse fans has on the performance of a sprinkler system.

NOTE 2 The performance of impulse fans is achieved in the creation of a high speed jet of air discharged from the fan outlet which induces into the jet stream. It is the high speed jet of air and the air movement that it creates that has the greatest impact on the activation of sprinkler heads and the disturbance of the sprinkler pattern.

Where impulse ventilation is designed to work in conjunction with sprinkler installations all impulse fan motors and terminal boxes should have a rating of IP55.

The effectiveness of sprinklers in controlling the spread of fire within a car park depends on the activation of the sprinkler heads located above the vehicle(s) on fire; therefore the distribution of the impulse fans, where possible, should be focused in the roadways.

NOTE 3 This has two benefits; the impulse fans will have a reduced impact on the activation of the sprinklers and the sprinkler pattern and secondly, as the impulse fans will be located in the roadway instead of above parked vehicles, they might benefit from improved performance.

16.3 Other ventilation systems

16.3.1 General

16.3.1.1 Where separate systems are installed for environmental/pollution control and smoke control

a) In the event of a fire, the environmental/pollution control system should close down. Any ducts or openings that form part of this ventilation system and which penetrate fire compartment boundaries (walls and floors) should have these penetrations protected using fire dampers manufactured to BS EN 15650 with a classification period to match the compartment boundary. All such fire dampers should close under the control of the signal from the smoke/fire alarm system.

b) The separate smoke control system should be immediately activated.

c) The system should be demonstrated to function reliably at commissioning and details should be given in accordance with Clause 17.

16.3.1.2 A combined system that is used for day-to-day environmental and fume control, but which functions as a smoke control system in the event of a fire

a) The whole system should be designed as a smoke control system. It should only use smoke control components classified to the BS EN 12101 series. There should be no fire dampers in the system, which could close and prevent the system from working correctly.

b) The selection of the products to be used should follow the recommendations given in Clause 13.

c) As the system is started or changed over, the dampers should move to the positions required to allow the smoke to be exhausted.

d) The smoke extract fans should be started immediately.

e) This should be demonstrated to function reliably at commissioning and details given in accordance with Clause 17.

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 C.

16.5 Interaction with other smoke ventilation systems

COMMENTARY ON 16.5

If not properly co-ordinated with lobby doors that link to access routes from the building above, impulse fans can have an adverse effect on the performance of other smoke ventilation systems within the building.

For example, protected stairwells connected to the car park might 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 an impulse fan might adversely affect the pressure difference across the storey-exit door.

To avoid the risk of impulse fans having an adverse effect on other smoke ventiliation systems within the building, the discharge of the impulse fans should be positioned so that the jet stream from the fans does not create adverse airflow conditions in the area of the lobby doors.

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 if this forms part of the fire strategy for the building.

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 if this forms part of the overall fire strategy for the building.

17 Commissioning

All parts of a car park ventilation system should be inspected, tested, demonstrated and verified at the completion of installation.

At an early stage in the project all relevant documents relating to the system design should be submitted to the appointed regulatory authorities. These documents include:

- system design criteria;
- design objectives;
- system overview and performance;
- calculations to support the design;
- schematics;
- product specification;
- drawings;
- cause and effect chart; and
- CFD modelling report (where applicable).

Table 2 provides an example checklist covering the major components of the ventilation system. The system should be demonstrated to perform in day-to-day ventilation mode as well as for smoke clearance or smoke control.

Table 2 Example checklist for commissioning of a smoke and heat control system

Component	Installed ✓ [tick]	Tested ✓ [tick]
Natural ventilation systems		
Check that adequate openings are provided		
Check that openings are suitably distributed		
Check that openings will not be liable to obstruction		
All mechanical systems		
Provide full set of as installed drawings, written system description, calculations and cause and effect chart		
Verify by measurement that the extract fans are providing the correct rate of extract		
Verify by measurement that the supply fans are providing the correct airflow rate		
Check that there is no excess leakage through flexible connectors or ductwork		
Check free and correct operation of gravity operated non-return dampers		
Demonstrate the correct operation of fire/smoke dampers		
Demonstrate the correct operation of the system in the event of mains failure		
Demonstrate the correct operation of the system in the event of one fan failure		
Carry out a cable survey and check cable rating		
Confirm fans conform to BS EN 12101-3		
Check operation of fire service override switch		
Check that local isolators to all fans are suitably fire rated		
Verify that an adequate source of make up air is available		
Ducted mechanical system		
Verify airflow rates through each duct extract point		
Demonstrate the automatic operation of the system by the selected method of activation		
Confirm correct selection and installation of all fixtures and fittings used in the installation of ducting in compliance with relevant regulations and standards		
Confirm certification of ducting		
Impulse smoke clearance system		
Confirm operation of all impulse fans and operation in the correct direction		
Demonstrate the automatic operation of the system by the selected method of activation		
Check impulse fans are operating at the correct speed according to the agreed design strategy		
Demonstrate air movement in all parts of the car park in daily ventilation and smoke clearance mode		
Confirm impulse fans conform to BS EN 12101-3		
Impulse ventilation system for fire-fighter access and/or means of escape		
Demonstrate the correct activation and operation of the system by automatic means and compliance with the declared design for each zone		
Using cold smoke generation, demonstrate the control of airflow for each zone		
All systems		
Check the interaction between the car park ventilation system and all other detection, alarm, smoke control or any other life safety system		
Confirm that all other ventilation systems linked to the car park will shut down in the event of fire being detected in the car park		
Confirm calibration of carbon monoxide monitoring system		
Confirm free and correct movement of motorized dampers		

18 Documentation to be supplied with smoke and heat control system

18.1 General design recommendations

18.1.1 General

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 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 safety management

The design should consider all aspects of access for maintenance and regular testing. The following information should be handed over on completion:

a) all details of the design (cause and effect);

b) the as installed information;

c) how to run the system;

d) how to maintain the system;

e) how to test the system and how often (see also BS 9999);

f) what records to be kept on maintenance and testing;

g) information for fire-fighters; and

h) product, installation and maintenance details of all fire and smoke safety components.

18.1.3 Fire-fighting

Where the car park employs a system that is designed to assist fire-fighting, sufficient information should be 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 should be provided.

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 impulse 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.

Suitable plans showing the extract points and fans, as well as the location of any manual override controls for fire-fighters (for example, control panels and/or switches) should be provided for each level of the car park.

NOTE 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 9999:2008, Annex M.

18.2 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 might 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 relevant sections of Table 2 should be used to confirm that the installed system has not developed faults or deteriorated and remains compatible with the original design intent.

A regular maintenance and test programme should be carried out in accordance with the installers'/manufacturers' operating and maintenance instructions.

In addition, the following items, where applicable, should also form part of an ongoing and regular maintenance regime.

a) Examine for any corrosion associated with the smoke ventilation equipment.

b) Check for water ingress.

c) Check that fire resistance enclosures associated with the kit remain intact.

d) Check that any separate compartments remain sealed.

e) Inspect fixings and support for deterioration.

f) Check for any modifications to the car park that might impact on the performance of the ventilation system.

g) Confirm interactions with other recently installed smoke venting installations.

h) Check the correct functioning of fire doors and that they maintain their integrity.

i) Check operating instructions and labelling are still intact and replace as necessary.

j) Carry out lubrication of equipment as necessary.

k) Check for the reliability and correct function of fan failure provisions.

l) Check for the reliability and correct function of mains failure provisions.

m) Check that all grilles and guards remain intact, affective and clear of debris.

18.4 Computer control software

Where relevant, a comprehensive description of the control software should be provided to the building owner and/or the 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 continuing reliability of the ventilation system should be ensured in accordance with BS 9999 and any suppliers' manuals. Any alteration to the building or smoke control system might compromise the original design intent and, consequently, all design and installation documentation should be included in a handover manual on completion of the installation so that the impact of any changes to the building can be properly evaluated.

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

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7.2 A reservoir is the collection point for the smoke. The design should ensure that the smoke reservoir is maintained above head height, thereby ensuring maximum conditions for breathing and visibility (and minimising conditions for panic). The minimum smoke layer base (head height clearance) shall be as follows:

a) For lowest floor or single: 2.75 m (natural displacement ventilation) 2.00 m (powered extraction ventilation)

b) Upper storey:

3.00 m (natural displacement ventilation) 2.00 m (powered extraction ventilation)

8.8.18 Fans shall be capable of operating at 250 °C for 2 hours.