MALAYSIAN STANDARD

MS 1780:2005

SMOKE CONTROL SYSTEM USING NATURAL (DISPLACEMENT) OR POWERED (EXTRACTION) VENTILATION

ICS: 13.220.01

Descriptors: smoke control, natural ventilation, powered ventilation, engineered smoke control system

DEPARTMENT OF STANDARDS MALAYSIA

DEVELOPMENT OF MALAYSIAN STANDARDS

The **Department of Standards Malaysia (DSM)** is the national standardisation and accreditation body.

The main function of the Department is to foster and promote standards, standardisation and accreditation as a means of advancing the national economy, promoting industrial efficiency and development, benefiting the health and safety of the public, protecting the consumers, facilitating domestic and international trade and furthering international cooperation in relation to standards and standardisation.

Malaysian Standards are developed through consensus by committees which comprise of balanced representation of producers, users, consumers and others with relevant interests, as may be appropriate to the subject in hand. These standards where appropriate are adoption of international standards. Approval of a standard as a Malaysian Standard is governed by the Standards of Malaysia Act 1996 (Act 549). Malaysian Standards are reviewed periodically. The use of Malaysian Standards is voluntary except in so far as they are made mandatory by regulatory authorities by means of regulations, local by-laws or any other similar ways.

The Department of Standards appoints **SIRIM Berhad** as the agent to develop Malaysian Standards. The Department also appoints SIRIM Berhad as the agent for distribution and sale of Malaysian Standards.

For further information on Malaysian Standards, please contact:

Department of Standards Malaysia
Level 1 & 2, Block C4, Parcel C
Federal Government Administrative Centre
62502 Putrajaya
Malaysia

Tel: 60 3 88858000
Fax: 60 3 88885060
http://www.dsm.gov.my

Email: central@dsm.gov.my

OR

SIRIM Berhad
1, Persiaran Dato' Menteri
P.O. Box 7035, Section 2
40911 Shah Alam
Selangor D.E.

Tel: 60 3 5544 6000
Fax: 60 3 5510 8095
http://www.sirim.my

CONTENTS

Committee representation

The Fire Safety and Prevention Industry Standards Committee (ISC M) under whose authority this Malaysian Standard was developed, comprises representatives from the following organisations:

Association of Consulting Engineers
Chemistry Department Malaysia
Construction Industry Development Board Malaysia
Department of Chemistry, Malaysia
Department of Standards Malaysia
Fire and Rescue Department Malaysia
Forest Research Institute of Malaysia
General Insurance Association of Malaysia
Malaysian Fire Protection Association
Master Builders Association Malaysia
Pertubuhan Akitek Malaysia
Public Works Department Malaysia
Real Estate Housing Developers' Association Malaysia
The Institution of Engineers, Malaysia
The Institution of Fire Engineers (UK) Malaysia Branch
Universiti Kebangsaan Malaysia
Universiti Putra Malaysia

The Technical Committee on Smoke Management which developed this Malaysian Standard consists of representatives from the following organisations:

Association of Consulting Engineers Malaysia

Federation of Malaysian Manufacturers

Fire and Rescue Department Malaysia

Malaysia Fire Protection Association

Public Works Department

The Institution of Engineers, Malaysia (IEM)

Universiti Putra Malaysia

FOREWORD

This Malaysian Standard was developed by the Technical Committee on Smoke Management under the authority of the Fire Safety and Prevention Industry Standards Committee.

Compliance with a Malaysian Standard does not of itself confer immunity from legal obligation.

SMOKE CONTROL SYSTEM USING NATURAL (DISPLACEMENT) OR POWERED (EXTRACTION) VENTILATION

1. Scope

This Malaysian Standard describes smoke control by means of natural (exhaust) ventilation, powered (exhaust and depressurisation) ventilation or a combination of both.

Smoke control by means of pressurisation is described separately under the MS 1472.

2. Normative references

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

BS 7346:1990, *Components for smoke and heat control systems*

MS 1471:1999, *Vocabulary on fire protection*

MS 1472:1999, *Code of practice for fire precautions in the design of buildings – Smoke control in protected escape routes using pressurization.*

UBBL:1984, *Uniform Building By Law*

3. Definitions

For the purpose of this Malaysian Standard, the definitions given in MS 1471 shall apply.

4. Design concepts

4.1 Smoke obscures visibility and can also contribute fatalities in a fire incident. It is therefore increasingly realised that occupant safety in a fire can be greatly improved by providing an efficient smoke extraction system. Moreover, such systems can limit property damage, both directly by reducing the spread of smoke, and indirectly by providing better visibility and thus easier access to the seat of the fire for fire fighters.

4.2 Smoke extraction is one of the tools, which the fire safety engineer may use to ensure adequate fire safety within a building. As such it should not be considered in isolation, but as an integral part of the total package of fire safety measures designed for the building. Thus the need for smoke extraction in any building should be designed in conjunction with the means of escape, compartmentation and active suppression systems.

Smoke extraction should be considered under the following circumstances:

a) Smoke extraction for life safety

Smoke extraction for life safety purposes is of benefit in buildings where means of escape to open air cannot be achieved within a short period of time and in which the means of escape could be severely contaminated with smoke and become impassable.

Examples include shopping malls, atrium buildings and high rise buildings with phased evacuation i.e. when a proportion of the occupants are expected to stay in the building throughout the duration or part of the duration of the fire.

b) Smoke extraction for fire fighter access

Smoke extraction for fire fighter's access is desirable when:

i) fire brigade access is difficult, e.g. basements and high rise buildings; or

ii) rapid attack on fire is necessary to reduce fire spread and property damage e.g high value warehouses.

Buildings where smoke clearance by natural means may be difficult (e.g. basements, windowless buildings and buildings without openable windows) a powered smoke purging/dilution system is required.

5. Method of smoke control

The efficiency of the smoke control system may be adversely affected by wind or outside temperatures. Pressures generated by wind may affect operation of the extraction of smoke by providing a positive pressure at the point of extraction. Internal climatic conditions may also affect the movement of smoke particularly in spaces with large volumes, such as atriums. This is because forced air circulation may prevent the smoke of low buoyancy from reaching initially the point of detection. The stack effect in tall buildings and temperature inversion may also need to be considered.

The various techniques commonly used for smoke control are as described below.

5.1 Smoke containment (passive method)

Smoke containment relies on physical barriers to limit the spread of hot smoky gases from one compartment in a building to another. Passive compartmentation such as doors, walls and floors can be used to provide some protection against smoke ingress. The extent to which smoke will leak through these barriers will depend on the size and shape of leakage paths and the pressure differentials across the paths.

5.2 Smoke dilution

Smoke dilution describes any method of mixing the smoky gases with enough clear air to increase the available visibility and to reduce the threat from toxic products of combustion. Application includes car parking area where the low ceiling height and exhaust ductwork configuration may makes the smoke reservoir principle impractical.

5.3 Smoke reservoir exhaust ventilation (see also Clause 6 and Clause 7)

This is a method that provides a separation between an upper layer of smoke and a lower layer of relatively clear air. This is achieved by continuously extracting smoke from the buoyant smoke reservoir (or layer), using either natural extract ventilators or powered smoke exhaust fans.

This air is then replaced by outdoor air, which re-enters the space below the base of the smoke layer.

5.4 Depressurisation

Depressurisation involves the control of smoke using pressure differentials in which the air pressure in the space containing the fire is reduced below that in the adjacent spaces requiring protection. Examples of application are internal rooms or office floors having an area exceeding 1 000 m^2 and where the introduction of low level replacement air is impractical.

5.5 Pressurisation

Smoke control using pressurisation method is specified in MS 1472.

6. Engineered smoke control system

Engineered smoke control system should provides the following:

a) The system will safely control the movement and spread of smoke within the building.

b) The system is designed to remove smoke produced by a fire type and risk associated with a specific building use.

c) The control and removal of smoke will enhance the conditions inside the building for purposes of safe evacuation from the building and ingress for search and rescue operation.

d) The contained and designed movement of the smoke will enhance the operational effectiveness of the sprinklers.

e) The containment of the smoke within the smoke reservoir will minimise the spread of smoke throughout the building and thus reduce the costs associated with smoke damage to the building fabric, stock and capital items.

f) The control and removal of smoke will maintain clearer and safer conditions for people to evacuate the premises. This is done by keeping the movement level of people clear from smoke and hot toxic gases and increasing the visibility levels to aid safe escape.

7. Smoke reservoirs/zones

7.1 A smoke reservoir will prevent the spread of hot smoke and gases throughout the whole area of the building. It will also assist in keeping the smoke as hot as possible and therefore maintain maximum buoyancy and movement towards the extraction point.

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)

7.3 Smoke reservoir creates a single position from which the smoke can be extracted.

7.4 For natural smoke ventilation, the limit of each reservoir/zone should be 2 000 m^2 (refer to 8.8).

7.5 For powered smoke ventilation, the limit of each reservoir/zone should be 2 600 m^2 (refer to 8.8).

7.6 The maximum length of a smoke reservoir/zone should be in the region of 60 m unless proven otherwise by engineered calculation.

7.7 The amount of smoke extraction from the reservoir should be sufficient to prevent the smoke layer from building down to below the design head height clearance.

7.8 The rate of extraction (natural or powered) shall be sufficient to meet the design requirement, in that it shall be capable of extracting the amount of smoke which is entering the base of the smoke layer.

7.9 For any ventilation system to work effectively there shall be an adequate supply of make up fresh air (replacement air) to balance the system.

7.10 The replacement air shall be introduced at the lowest possible level (at least 0.5 m below the base of the smoke layer). This is to ensure that the smoke layer is not disturbed by the flow of air into the building. The air velocity should be minimised to a value not exceeding 5 m/s.

7.11 The preference is for the replacement air to be introduced naturally, via louvres, doors, roller shutters, windows, ventilators, all of which shall open automatically so that the supply of fresh air is guaranteed.

7.12 Powered replacement air should not exceed 75 % or be less than 50 % of the extracted air volume.

8. Applications

8.1 Basement smoke control system

8.1.1 Where the total aggregate floor area of all basement storeys does not exceed 1000 m^2 smoke vents in accordance with 8.1.3 may be provided in lieu of engineered smoke control system.

8.1.2 Where the total aggregate floor area exceeds 1000 m^2 engineered smoke control system that complies with the requirements stipulated in 8.1.4 shall be provided for all parts of basement with the following exceptions:

a) Where the basement or a portion of the basement is used as car park, 8.1.4 can be adopted for the car park provided it is compartmented from the rest of the basement.

b) Plant/equipment room with floor area not exceeding 250 m^2 and compartmented from the rest of the basement and provided with two doors for better reach in fire fighting operation.

c) Plant/equipment room with floor area exceeding 250 m^2 but not exceeding 1 000 m^2 smoke vents in accordance with 8.1.3 smoke purging/dilution system of at least ten air changes per hour shall be provided.

d) Service areas such as laundries, office storeroom and workshops (restricted to staff only) which are compartmented, smoke venting provision in accordance with 8.1.3 or smoke purging/dilution system of at least ten air changes per hour may be accepted for those areas in lieu of the engineered smoke control system.

8.1.3 Smoke vents shall be uniformly distributed to induce and enhance cross ventilation adequately along perimeter of basement and their outlets shall be easily accessible during fire fighting and rescue operations. Installation shall comply with the following requirements.

a) The number and their sizes shall be such that the aggregate effective vent openings shall not be less than 2.5 % of the basement floor area served.

b) The vent outlets if covered under normal conditions shall be breakable/openable in case of fire.

c) Breakable covers should be capable of being opened by the fire service from outside the building and permanent notice identifying the area they serve should be provided on or adjacent to the covers.

d) The vent outlets are sited not less than 5 m away from exits.

e) Where ducts are required to connect the vents to outlets, the ducts shall be constructed to give at least 1 h fire resistance rating.

f) Separate ducts and vent outlets shall be provided for each basement storey.

8.1.4 Where powered ventilation system is required for car parking areas in basements with total floor area exceeding 1 000 m^2, a smoke purging/dilution system which is independent of any system serving other parts of the building shall be provided to give a purging/dilution rate of not less than ten air changes per hour. Installation shall comply with the following requirements.

a) The smoke purging/dilution system shall be activated automatically by the building fire alarm system. In addition, a remote manual start-stop switch shall be located at the fire command centre, or at the main fire alarm panel. Visual indication of the operation status of the smoke purging/dilution system shall also be provided with this remote control switch.

b) Supply air shall be drawn directly from the external and its intake shall not be less than 5 m from any exhaust discharge openings.

c) Where there is natural ventilation for such basement car park based upon openings equal to not less than 2.5 % of the floor area of such storey, such natural ventilation may be considered as a satisfactory substitute for the replacement air of the smoke purging/dilution system for that storey.

d) Exhaust air shall be discharged directly to the external and shall not be less than 5 m from any air intake openings.

e) Separate duct or equivalent arrangements such as sub-ducts shall be provided for each compartmented basement level.

8.1.5 Where engineered smoke control system is required, it shall be provided as specified in 8.8.

8.2 Smoke control system for above ground premises

8.2.1 Where the total, aggregate floor area within the same fire compartment exceeds 1 000 m^2 or the volume exceeds 7 000 m^3, smoke control system shall be provided.

8.2.2 Where natural smoke ventilation is provided, the smoke vents shall be in accordance with 8.2.5.

8.2.3 Where powered smoke control system is provided, this comply with 8.2.6.

8.2.4 Where engineered smoke control system is provided, this shall comply with the requirement specified in 8.8.

8.2.5 Smoke vents shall be positioned at high level above the smoke layer base and conform to the requirement as specified below:

a) the number and their sizes shall be such that the aggregate effective vent openings shall not be less than 2.5 % of the floor area served and the minimum height clearance shall comply with 7.2;

b) the vent outlets shall be of the permanently opened type or open automatically under a fire mode condition without human intevention;

c) replacement air shall be by means of natural ventilation; and

d) conformance to Clause 7.

8.2.6 Engineered smoke control system design shall be applicable only for ceiling heights exceeding 2 m (see Clause 7) for the smoke reservoir principle to be effective.

Below 2 m (see Clause 7) ceiling heights, powered smoke purging/dilution system of at least ten airchanges per hour shall be provided to suit the concepts adopted. Make up or replacement air shall be provided in the following manner:

a) For smoke depressurisation concept, it is not necessary to provide air, however pressure differential between depressurised zone and the adjacent zone shall be maintained at between 10 Pa to 50 Pa.

b) For smoke dilution concept, replacement air may be introduced at any level but, if powered, shall be limited to not less than 50 % and not greater than 75 % of the exhaust air volume.

8.3 Smoke control system for fire fighting access lobby

8.3.1 Fire fighting access lobby where not mechanically pressurised, shall be smoke vented in compliance with the requirements specified below:

a) the openable area of windows or area of permanent ventilation shall not be less than 25 % of the floor area of the lobby, and

b) for ventilation by means of openable windows, additional permanent ventilation having a free area of 464 cm^2 shall be provided.

8.3.2 A smoke lobby shall be treated as a protected stairway as described in 8.4.

8.4 Smoke control system for protected stairway

8.4.1 Protected stairway where not mechanically pressurised should be provided with either:

a) openable windows at each upper storey or landing level having a clear openable area not less than 5 % of the cross sectional area of the stairway; or

b) an openable vent outlet at the top having a clear area of not less than 1 m^2.

8.5 Smoke control of hotel internal corridors

8.5.1 Where internal corridors in hotels are not mechanically pressurised, such corridors shall be smoke purged/diluted at a purging/dilution rate of not less than ten air changes per hour.

8.5.2 Engineered smoke control system may be applied only for corridors exceeding 2 m height (see Clause 7).

8.5.3 Natural ventilation is permissable only if induced cross ventilation is available and the aggregate effective vent openings of not less than 2.5 % of the floor area served can be provided.

8.6 Smoke control for auditorium (cinemas, theatres, etc)

Smoke vents with effective openings of not less than 2.5 % of the floor area served shall be provided for auditoria which is not sprinkler protected and to auditoria having floor area more than 500 m^2 if sprinkler protected.

Where engineered smoke control systems is preferred, it shall conform to 8.8.

8.7 Atrium smoke control system

8.7.1 Where the requirement for compartmentation specified in the UBBL are relaxed for atrium spaces in a building, a smoke control system shall be provided for a sterile tube atrium type as specified below:

a) Where the height of the atrium is 17 m or less and the volume of the atrium is 17 000 m^3 or less, the smoke exhaust rate shall be 19 m^3 /s or six air changes per hour, whichever is greater.

b) Where the height of the atrium is 17 m or less and the volume of the atrium is more than 17 000 m^3, the smoke exhaust rate shall be 19 m^3 per second or four air changes per hour, whichever is greater.

c) Where the height of the atrium is more than 17 m, the smoke exhaust rate shall be at a minimum of four air changes per hour.

d) Where engineered smoke control system is preferred, it shall be provided as specified in 8.8.

8.7.2 For a non-sterile tube atrium type, engineered smoke control system complying with the requirement as stipulated in 8.8 shall be adopted.

8.7.3 The smoke control system shall be activated by:

a) smoke detectors located at the top of the atrium and adjacent to each return air-intake from the atrium or beam detectors at the appropriate levels;

b) the automatic sprinkler system serving the atrium zone(s);

c) automatic detector system (but not the manual call point); or

d) manual controls readily accessible to the fire brigade.

8.8 Engineered smoke control system

8.8.1 Engineered smoke control system shall be in the form of a smoke ventilation system by natural or powered extraction designed in accordance with acceptable engineering standard and design guide.

8.8.2 The building provided with engineered smoke control system shall not have a smoke layer temperature exceeding 250 °C. Where exceeding 250 °C, other form of fire engineering analysis shall be carried out to validate the smoke performance and behaviour.

8.8.3 Capacity of the smoke ventilation system shall be calculated based on the incidence of a likely minimum fire size for a sprinkler controlled fire as specified in the Table 1.

8.8.4 The capacity of a smoke ventilation system shall be capable of handling the largest demand for smoke exhaust from the worst case scenario.

8.8.5 The design smoke layer base shall be above the heads of people escaping beneath it. The minimum height shall be as described in Clause 6.

8.8.6 Smoke reservoirs to prevent the lateral spread of smoke and to collect smoke for removal shall be of non-combustible construction capable of withstanding smoke temperatures.

Table 1. Fire size

Occupancy (Sprinklered)	Fire Size	
	Heat output (MW)	Perimeter of fire (m)
Shops	5.0	12
Offices	1.5	12
Hotel guest room	0.5	6
Hotel public areas	2.5	12
Assembly occupancy with fixed seating	2.5	12
Warehouse	10	18
Basement service area (lorry parks)	7	15
Car parks	1.5	13.5

8.8.7 For cases where smoke is removed from the room of origin, the smoke reservoir size for a smoke ventilation system shall not exceed:

a) 2 000 m^2 for natural smoke ventilation system; and

b) 2 600 m^2 for powered smoke ventilation system

8.8.8 For cases where smoke is removed from the circulation space or atrium space the smoke reservoir size for a smoke ventilation system shall not exceed:

a) 1 000 m^2 for natural smoke ventilation system of the circulation atrium space; and

b) 1 300 m^2 for powered smoke ventilation system of the circulation atrium space.

8.8.9 For cases where smoke is removed from the circulation space or atrium space, the rooms discharging smoke into the circulation space/atrium spaces shall either:

a) have a floor area not exceeding 1 000 m^2 (for natural ventilation system) or 1 300 m^2 (for powered ventilation system) of the circulation atrium space; and

b) be subdivided such that smoke is vented to the circulation space or atrium only from part of the room having a floor area not exceeding 1 000 m^2 (for natural ventilation system) or 1 300 m^2 (for powered ventilation system) provided with an independent smoke ventilation system (s) unless proven otherwise by engineered calculation.

8.8.10 The maximum length of the smoke reservoir shall not exceed 60 m unless proven otherwise.

8.8.11 Adequate arrangement(s) shall be made in each smoke reservoir for the removal of smoke in a way that will prevent the formation of stagnant regions.

8.8.12 Replacement air shall be drawn directly from the external or adjacent spaces as follows:

a) The design replacement air discharge velocity shall not exceed 5.0 m/s to prevent the escapees being affected by the air flow.

b) Replacement air intake shall be sited at least 5 m away from any exhaust air discharge.

c) Replacement air shall be discharged at a low level, at least 0.5 m beneath the designed smoke layer, to prevent "fogging" of the lowest clear zone.

d) Where the inlet cannot be sited at least 0.5 m below the smoke layer, a smoke curtain or a barrier shall be used to prevent replacement air distorting the smoke layer.

e) Where replacement air is taken through inlet air ventilators or doorways, devices shall be incorporated to automatically open such inlet ventilators and doors to admit replacement air upon activation of the smoke ventilation system.

8.8.13 For cases where the smoke reservoir is above the false ceiling, the ceiling shall be of perforated type or evenly distributed air inlets with at least 10 % openings.

8.8.14 The smoke ventilation system shall be provided with secondary source of power supply.

8.8.15 In conjunction with 8.7.3, the smoke ventilation system shall be activated by smoke detectors located in the smoke control zone. Use of smoke detectors for activation shall be carefully designed so that accidental or premature activation of smoke detectors on a non-fire zone due to smoke spills or spread from other areas is avoided.

8.8.16 A remote manual activation and control switch as well as visual indication of the operation status of the smoke ventilation system shall also be provided at the fire command centre and where there is no fire command centre, at the main fire indicator board.

8.8.17 Except for ventilation systems for escape routes and smoke lobbies, all other air conditioning and ventilation systems within the areas served shall be shut down automatically upon activation of the smoke ventilation system.

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

8.8.19 The fans and associated smoke control equipment shall be wired in protected circuits designed to ensure continued operation in the event of the fire.

8.8.20 The electrical supply to the fans shall be by means of cables of at least 2 h fire resistance.

8.8.21 Smoke ventilation ducts (both exhaust and replacement air ducts) passing through another fire compartment shall be constructed to have the same rating and/or as that of the compartment.

8.8.22 Non-motorised fire dampers shall not be fitted in the smoke ventilation system.

8.8.23 The time taken from the smoke ventilation system within a smoke zone to be fully operational shall not exceed 60 s from system activation.

8.8.24 For natural smoke ventilation system the natural ventilators shall be:

a) in the "open" position in the event of power/system failure; and

b) positioned such that they will not be adversely affected by positive wind pressure.

8.8.25 Natural exhaust ventilation shall not be used together with powered replacement air or powered smoke exhaust ventilation.

8.8.26 All smoke curtains where required, unless permanently fixed in position, shall be brought into position automatically to provide adequate smoke-tightness and effective depth.

8.8.27 Smoke curtain or other smoke barrier at any access route forming part of or leading to a means of escape shall not in their operational position obstruct the escape of people through such route.

8.8.28 Where glass walls or panels are being used as smoke screens to form a smoke reservoir or as channelling screens, they shall be able to withstand the highest designed smoke temperature.

8.8.29 All smoke control equipment (including smoke curtains) shall be supplied and installed in accordance with the accepted standards e.g BS 7346.

8.8.30 To minimise the phenomena of plugholing, multiple inlets should be (calculated or modelled) used for powered smoke extraction system. The maximum mass flow rate through each exhaust inlet shall be limited to suit the depth of smoke layer below the exhaust inlet.

8.8.31 The ceiling jet produced when the smoke plume hits the ceiling can impact the effectiveness of a powered smoke venting system. To contain this impact, smoke exhaust should be designed for a minimum smoke layer depth of 10 % of the floor to ceiling height.

9. Testing and commissioning procedures

9.1 Smoke control systems are designed for use during a fire condition with temperatures produced by the fire are significantly higher than ambient temperature conditions. Therefore, the use of cold smoke tests does not reflect the efficient operation of the smoke control system as designed. What it will do, is to show the air flow patterns that will be potentially induced by the smoke extract equipment. Cold smoke tests are sometimes used for the acceptance testing of smoke ventilation systems. Whilst this cold smoke can be used to operate the smoke detection system and therefore activate all the components of the smoke ventilation system, it should be noted that since the smoke itself is cold it should not have the buoyancy that smoke in a true fire condition should have, and cannot therefore adequately test the ventilation efficiency of the system". This is particularly relevant in high buildings where smoke produced by a 'fogging machine' at floor level, has very little temperature in itself to rise quickly to the point of extraction.

9.2 Design utilising the technique of smoke dilution and incorporating low level exhaust (e.g car parks) can be adequately tested with cold smoke (fogging machine). During such test, the smoke spill fan(s) should be allowed to activate under its automatic mode and visibility should be maintained for evacuation purposes at all times.

9.3 There have been real fire tests using full size fires to assess the effect and efficiency of the equipment and parameters for design. However, such tests, if necessary, should be limited to project of high complexity.

9.4 The system should be tested thoroughly and the activation on receipt of the appropriate signalling device (from whichever detection method is chosen and approved) is required. The ability of the system to fail safe to the design position should also be checked.

9.5 The main fire alarm should provide the correct information and operational sequence and the interfaces with other allied systems should be checked.

9.6 All test data shall be recorded and witnessed by the client's representative and this information also logged in the operation and maintenance manual. A full set of as-built drawings, system sequence control, schematic and servicing data shall also be part of the operation and maintenance manual.

Acknowledgements

Dr Ow Chee Sheng (Chairman)	Institute of Engineers, Malaysia
Puan Siti Mariam Rahmat (Secretary)	SIRIM Berhad
Ir Chen Thiam Leong	Association of Consulting Engineers Malaysia
Encik Ong Tek Wei	Federation of Malaysian Manufacturers
Encik Madzlan Hashim/ Encik Wan Zaidi Wan Isa	Fire and Rescue Department Malaysia
Ir Tan Chew	Malaysian Fire Protection Association
Encik Ishak Abbas/ Encik Abd. Rahim Ahmad	Public Works Department
Dr Nor Mariah Adam	Universiti Putra Malaysia