SHEVS IFT specialises in fire, smoke and heat exhaust ventilation systems with emphasis on computational fluid dynamics simulations (CFD), design and build value engineering solutions (D&B), smoke control equipment applications, system testing and commissioning.

**Consultancy Services**
- Preliminary conceptual design for smoke control zones
- Detailed engineering of all smoke control applications
- Fire safety engineering / waiver application approaches for cost-effectiveness
- Computer fluid dynamics simulation modelling works by validated CFD softwares
- Office Buildings, Commercial Shopping Centres, Hotels, Factories, Warehouses, Basement Occupancies, Schools and Institutions, Churches, Auditoriums.

**Features and Benefits:**
- Cost-effective Solutions
- Advanced & Effective Equipment Applications
- Technically Compliant Design Schemes
- Minimal Service and Maintenance Costs

**Smoke and Heat Exhaust Ventilation Systems (SHEVS)**
- Empirical Calculations (BR186, BR258, BR368)
- Computational Fluid Dynamics Modelling (FDS)

**Smoke Control Equipment Selection and Application**
- Optimisation with Value Engineering
- Performance Specification (EN12101-Part 1-11)

**Testing and Commissioning**
- Cold/Hot Smoke Testing in accordance to AS4391:1999
- System Synchronisation and Integration
- Service and Maintenance Programs in compliance to Fire Regulations
Professional Engineering (Mechanical)
MIES, MiFireE, MASHRAE, MNFPA, M. Eng (Fire Safety)

With more than 20 years of experience as a smoke control specialist, SHEVS IFT is well-versed with the requirements for engineered smoke control systems in both prescriptive and performance based approaches in accordance to the local code of practice. SHEVS IFT is also one of the main editors for the Beijing Fire Code DBJ 01-623-2006 - Code for Design, Installation and Approval of Natural Ventilation System and Beijing Fire Code DB11/1025-2013 - Code for Design, Installation and Commissioning of Natural Smoke Ventilation System.

SHEVS’ expertise has been applied in the design for more than 100 projects in both local and overseas projects. Some of the prominent local commercial building projects include Causeway Point, Jurong Point, East Point Mall, Ion Orchard, Vivocity, Parliament House, Marina Square, Fusionpolis, Biopolis, Supreme Court, Paragon, Singapore EXPO, Singapore Sports Hub etc.

SHEVS IFT has been actively involved in design and build projects using established smoke control equipment brands for smoke curtains, natural smoke ventilators, mechanical smoke extraction system tested and certified to EN12101, BS7346, BR186, BR258, BR368 and relevant standards.

Registered Professional Engineering in Mechanical discipline combined with vast engineering experience background as a smoke control turnkey specialist, SHEVS IFT is exceptionally capable and efficient to deliver the most cost-effective smoke control system design in terms of value engineering.
Modelling of smoke movement has become increasingly sophisticated and the basis of our evaluation are:

- Computer based fire models
- Building airflow analysis models

SHEVS IFT typically prepares smoke movement models to evaluate or develop the design of a smoke control system prior to the actual building construction. These designs shall in turn form the basis to finalise the installation methods of the system through testing and commissioning. Through pre-construction modelling, cost-effective optimum system performance can be achieved prior to the procurement and installation of the equipment.

Time Squared ($t^2$) - Heat Release Rate (HRR) Curve

The $t$-squared (time squared) heat release rate (HRR) curve is commonly used to estimate transient fire growth for fire protection design purposes.

The $t$-squared parabolic growth equation is given by $Q = \alpha t^2$, where $Q$ is the HRR (kW), $\alpha$ is the fire growth coefficient (kW/s²), and $t$ is time (s).

Some commonly used fire growth coefficients are provided, or a custom coefficient can be specified. The $t$-squared fire ramp can be configured to grow until a specified HRR or time is attained. The output is a plot of the HRR vs. time.

Selection of Modelling Tool

The factors affecting the modelling method for a given building include:

- Type and Size of facility
- Complexity of the Smoke Control System Design
- Prescriptive and / or Performance based design approaches.

Modelling would include timed egress analysis which takes into account occupant travel speeds and the smoke logging impacts. In other words, studies would be made to assess the ASET (Available Safe Escape Time) and RSET (Required Safe Escape Time) values.

Modelling Evacuation Criteria

Several essential evacuation criteria used in the modelling includes:

- Tenable temperatures
- Tenable toxicity
- Visibility.

Temperature, smoke toxicity and visibility of the smoke layers are typically used to evaluate the smoke control systems to achieve life safety objectives.
SHEVS Checklist

Smoke ventilation ensures that smoke, heat and combustion gases can get out of the building from the moment the fire starts and is a means to limit the consequences of potential fires. Smoke ventilation thus contributes to:

- The safe evacuation of people.
- The fire fighting and rescue operations.
- The preservation of a building and its contents.

When deciding on the smoke ventilation required, however, the risks are considerably greater when one assumes standard condition instead of taking all individual circumstances into account.

The individual conditions affecting the design of a SHEVS can be divided into 10 independent criteria:

01. Objectives
02. Tenability Limits
03. Types of Smoke Control System
04. Design Fire Sizes (Sprinklered)
05. Smoke Reservoirs
06. Fire Compartmentation
07. Effects of Sprinkler System
08. ASET > RSET
09. Replacement Air Inlet
10. Wind Effects
1. Objectives

Generally, smoke control systems are used to improve life safety, aid firefighting or property protection. The system should be designed to be as simple and reliable as possible in line with the objectives of the smoke control system;

i. to improve tenability and visibility for firefighting and evacuation
ii. to limit smoke spread during phased evacuation
iii. to limit damages to equipment and furnishings caused by smoke.

2. Tenability Limits

All safe escape routes should be protected from the effects of fire by passive measures such as fire compartmented corridors or stairs or active systems such as smoke control systems or a combination of both.

Tenable conditions can be defined in terms of visibility and heat.

In terms of visibility limits, the escape routes should:

i. Maintain a smoke clear layer above eye level of at least 2.5m above floor level or
ii. Ensure that a minimum visibility of 10m through any smoke is maintained for occupants to see the exits and evacuate without undue hindrance.

In terms of heat, the smoke layer temperature should not exceed 200 degrees Celsius which is equivalent to a radiant heat flux of 2.5 kW·m⁻². Above such temperature, any escape below such hot smoke layer would be deemed untenable.

3. Types of Smoke Control System

Generally, there are 3 types of smoke control system;

i. smoke extraction within the room of fire origin
ii. smoke extraction in the common corridor or circulation space
iii. smoke extraction within the atrium spaces.

<table>
<thead>
<tr>
<th>Types and period of exposure</th>
<th>Effect</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation</td>
<td>Severe skin pain</td>
<td>200*</td>
</tr>
<tr>
<td>Conduction - metal (1 second)</td>
<td>Skin burns</td>
<td>60</td>
</tr>
<tr>
<td>Convection (30 minutes)</td>
<td>Hyperthermia</td>
<td>100</td>
</tr>
<tr>
<td>Convection (&lt; 5 minutes)</td>
<td>Skin/lungs burns by hot gases</td>
<td>120</td>
</tr>
<tr>
<td>Convection (&lt; 1 minute)</td>
<td>Skin/lungs burns by hot gases</td>
<td>190</td>
</tr>
</tbody>
</table>

*black-body: 2.5 kW·m⁻²

Critical temperature for different exposure conditions

SHEVS Checklist
1. Objectives    2. Tenability Limits
3. Types of Smoke Control System
4. Design Fire Sizes (Sprinklered)

For design purposes, the design fire size may be categorised into:

i. a growing fire

ii. a steady-state fire.

Note: In general, the use of a fixed fire size is deemed as the conservative solution (usually adopted in prescriptive fire codes).

It is commonly assumed that the fire stops growing when the sprinklers are activated. The design fire size is estimated to be the size the fire has grown to at the moment of sprinkler activation. For design purposes, the sprinkler activation time may be taken as the time for the activation of the 2nd ring of sprinklers.

With the sprinkler cooling effects, the hot smoke layer temperature will not exceed 200 degrees Celsius and it can be assumed that the fire will have a constant rate of heat release.

It has been found that after an initial incubation period, the heat release rate grows approximately as the square of the time, i.e:

\[
Q = \alpha t^2
\]

where \( Q \) is the heat release rate of the fire (kW), \( \alpha \) is a constant (kW·s\(^{-2}\)) and \( t \) is time (s)

<table>
<thead>
<tr>
<th>Fire class</th>
<th>Characteristic growth time, ( t_g ) (s)</th>
<th>Constant, ( \alpha ) (kW·s(^{-2}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra-fast</td>
<td>75</td>
<td>0.1876</td>
</tr>
<tr>
<td>Fast</td>
<td>150</td>
<td>0.0469</td>
</tr>
<tr>
<td>Medium</td>
<td>300</td>
<td>0.0117</td>
</tr>
<tr>
<td>Slow</td>
<td>600</td>
<td>0.0029</td>
</tr>
</tbody>
</table>

5. Smoke Reservoirs

Based on experimental testing limited to the size of test rig, typically, an area of 2000 to 3000 m\(^2\) has been adopted as the maximum smoke reservoir size to prevent excessive cooling of the hot smoke layer and the downward mixing of the smoke with the clear layer below.

In fire safety engineering for larger enclosures, such cooling and downward mixing of smoke may not occur until the fire has decayed. Therefore, larger smoke reservoirs may be feasible subject to further analysis and assessment through CFD modelling.
6. Fire Compartmentation

A fire will progress through various stages from ignition to fully developed unless action is taken to suppress or extinguish it.

Up to flashover condition, the rate of growth of a fire can be restricted by controlling flame spread, heat release and ease of ignition. However, once flashover has occurred, it is necessary to restrict the spread of fire by containment. Such containment of fire is known as compartmentation.

The ability of sprinklers to control fires means that the sprinklers have been used to justify the increase of the size of compartmentation and/or reducing the fire resistance requirements of the enclosing boundaries.

Prescriptively, compartment sizes have been allowed to be doubled with the provision of sprinklers. However, for fire safety engineering solution, the effective relationship between compartmentation and sprinklers should be developed accordingly.

7. Effects of Sprinkler System

As the smoke plume rises from a fire, it entrains air from the surroundings which causes the smoke plume to cool. The higher the ceiling, the lower will be the temperature of the smoke which reaches the sprinklers. The hotter the smoke, the more rapidly the sprinkler will activate.

The time to sprinkler operation depends on:

i. fire growth rate
ii. sprinkler location
iii. thermal sensitivity.

Thermal sensitivity of a sprinkler determines how fast it will heat up once immersed in a hot gas layer such as the ceiling jet plume from a fire. The thermal sensitivity is characterised by its Response Time Index (RTI). A smaller RTI value indicates a more thermally sensitive element.

The parameter used to describe sprinkler sensitivity is known as the response time index or RTI.

<table>
<thead>
<tr>
<th>Frangible Element Type</th>
<th>RTI Range (m²/s⁰.⁵)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Suppression Fast Response</td>
<td>26</td>
</tr>
<tr>
<td>Fast Response</td>
<td>50</td>
</tr>
<tr>
<td>Standard Response</td>
<td>105</td>
</tr>
</tbody>
</table>

Typical RTI values for sprinklers

A widely used computer program known as DETACT-T2 is able to predict sprinkler response times and corresponding fire sizes at sprinkler operation by combining the effects of fire growth, sprinkler location and sprinkler sensitivity. *DETACT-T2 has been developed by the (American) National Institute for Standards and Technology (NIST).*
8. **ASET > RSET**

Prescriptive codes require minimum exit widths and maximum travel distances with no mention of the time required to escape. In fact, during a fire scenario, the escape process is very time-related.

For any escape design to be successful, the time available for evacuation before untenable conditions occur must be greater than the minimum time required for escape.

In other words, \( \text{ASET} > \text{RSET} \)

- **ASET**: Available Safe Escape Time [the time from fire ignition to start of untenable conditions]
- **RSET**: Required Safe Escape Time [the time upon fire ignition till complete evacuation of the occupants to a place of safety]

9. **Replacement Air Inlet**

Replacement air is essential for any smoke control system to function effectively. The velocity of incoming air should be limited to a maximum of 5m/s in buildings. A powered inlet should not be used as it will create a push-pull effect as the fire size changes, resulting to turbulence of smoke layer causing smoke logging or even seriously affecting the opening or closing of fire escape doors.

10. **Wind Effects**

Very often, when a window breaks in a fire compartment during a fire situation, the effects of the wind can cause unpredictable and undesirable smoke movement in the building. For example, if the window on the windward side of the building breaks, the positive wind pressure can drive the smoke backwards into the building throughout the fire floor and even to the other floors, causing smoke logging and obstruction for the occupants to escape.

Therefore, wind analysis and studies are essential to ensure that the smoke control designs are functional and reliable under the effects of wind overpressures.

In any case that the adverse wind pressures cannot be overcome, a mechanical smoke extraction system may have to be used.
A fully integrated Engineered Smoke Control System (ESCS) shall comprise of several essential equipment such as smoke extraction fans, smoke ventilators, dampers and etc. The interfacing with AHUs, fire shutters, auto doors for air inlet etc must be coordinated accordingly.
**Waiver Application**

Prior to any performance-based solution approach, any non-compliance is usually submitted through the waiver application. In return, the fire authority may propose or recommend the non-compliance to be submitted through the performance-based plan submission.

**Key Stakeholders**

The key stakeholders involved in the performance-based plan submission process include:

1. Building Owner / Developer
2. Qualified Persons (QP)
3. Fire Safety Engineer (FSE)
4. Peer Reviewer (PR)
5. Registered Inspector (RI)
6. Fire Authority / Singapore Civil Defence Force (SCDF)

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**ESCWS Performance-Based (PB) Plan Approval Process**

- **Start**: Assume building design is to be based on prescriptive and PB approach

- **QP, FSE and relevant stakeholders to seek consultation with SCDF**

- **FSE submits FEDB to SCDF for in-principle agreement**

- **QP (FSE) prepares and certifies on plan for prescriptive and fire safety engineering works.**

- **OR**

  - **QP prepares the plans and certifies on prescriptive works while FSE certifies on fire safety reports, FER, O&M**

- **Peer reviewer prepares an assessment report on the plans and documents (FEDB, FER and O&M) relating to fire safety engineering works**

- **FSE addresses non-compliances / provides clarification to plans and documents and resubmit**

- **SCDF issues notice of non-compliance to QP (FSE) / QP and FSE**

- **End**: Yes

---

**Flowchart for performance-based plan submission**

**QP** (FSE): QP who is also a registered FSE

**FEDB**: Fire Safety Engineering Design Brief

**FER**: Fire Safety Engineering Report

**O&M**: Operations and Maintenance Manual

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SHEVS International Fire Technology
The outline of the plan submission process involving performance-based solutions is as follows:

1. **Engagement of Fire Safety Engineer (FSE)**

The building owner is required to engage an FSE for the preparation of performance-based solutions as part of the plan submission to the fire authority (SCDF).

2. **Preparation of Fire Safety Engineering Design Brief (FEDB)**

The FSE is responsible to prepare a preliminary report - Fire Safety Engineering Design Brief (FEDB) to be submitted to SCDF for in-principle agreement. The FEDB shall detail (i) Agreed Performance Criteria, (ii) Methodologies and Trial Designs, (iii) Design Objectives.

Note: The FSE should consult the fire authority (SCDF) on his FEDB proposal before formal submission.

3. **Assessment of FEDB, FER and O&M by the fire authority (SCDF)**

The FEDB will be assessed by SCDF. Upon the in-principle agreement of the FEDB, the FSE can proceed to prepare the following documents:

i. Revised FEDB, if conditional agreement is given
ii. Fire Safety Engineering Report (FER)
iii. Building Operations & Maintenance Manual (O&M)

In the event that the FEDB is rejected, the FSE will have to amend his FEDB accordingly and re-submit for SCDF’s consideration and agreement.

4. **Engagement of Peer Reviewer (PR)**

After the preparation of the FEDB, FER and O&M by the FSE, the owner is required to engage a Peer Reviewer (who is also a FSE) to assess the above documents & ensure that the performance-based solution is incorporated in the Building and M&E plans. The Peer Reviewer shall produce a report of his assessment in a Peer Reviewer’s report.

5. **Plans Submission by QP**

The Project QP is responsible for collating all the above documents for plans submission to SCDF. Plans containing the performance-based solution shall be endorsed by both the QP and the FSE. QPs who are also qualified FSEs may endorse in the capacity of both the QP and the FSE.

6. **Audit Checks by SCDF**

The submitted plans and documents may be selected by SCDF for subsequent audit checks.

7. **Engagement of Registered Inspector (RI)**

Upon completion of the fire safety works, the owner is required to engage a Registered Inspector who is an FSE to inspect the performance-based aspects of the fire safety works.

8. **Approval Processing Duration**

As performance-based solutions are usually unique and complex in nature, the time required to attain full approval can be excessively longer in comparison with prescriptive solutions. It is highly recommended to apply performance-based solutions at the earliest stage of the building design development.
**Documentation Requirements**

(a) Fire Safety Engineering Design Brief (FEDB)

Fire Safety Engineering Design Brief is a document summarizing agreed performance criteria and methods that will be used to evaluate trial designs. Generally, the FEDB would define:

i. Project Scope
ii. Stakeholders
iii. Design Objectives
iv. Performance Criteria
v. Design Fire Scenarios
vi. Trial Designs

Upon acceptance of the FEDB by SCDF, the FSE can proceed with the design that best meets the performance criteria.

(b) Fire Safety Engineering Report (FER)

The Fire Safety Engineering Report generally covers:

i. Expected hazards
ii. Risks
iii. System performance over the building life
iv. Commissioning and maintenance requirements

The FER should contain appropriate specifications and illustrations of the design, derived from the calculations and results within the report, so as to provide the basis for proper execution of the report recommendations.

(c) Building Operations and Maintenance (O&M) Manual

The O&M manual should contain:

i. Procedure for building operator to ensure that the fire safety systems of the PB solution are in good operating conditions at all times.

ii. Detailed instructions to the building operator on the restrictions imposed on the building, arising from the FSE’s assumptions during design and analysis. Such as:
   - critical fire load
   - building use and occupancy
   - reliability & maintenance programs.

Note: The O&M manual is to educate the tenants and occupants about the limitations and their responsibilities, to maintain the building as well as to serve as a guide for future additions and alterations of the building.

(d) Peer Reviewer’s Report

The Peer Reviewer’s Report should present his assessment of the FEDB, FER and O&M in terms of completeness and adequacy including:

i. An independent study of the proposed design solutions for the purpose of evaluating and determining its acceptability. Studies may include a separate fire or evacuation modelling using a different software.

ii. Objective comments on the assumptions, fire safety engineering approaches, methodologies, design parameters and software tools proposed by the FSE.
A. Community
- City Harvest Church
- Lighthouse Evangelism Church
- Marine Parade Community Centre
- National Library Board at Bras Basah
- Trinity Church
- Woodlands Regional Centre

B. Education
- Biopolis
- Catholic Junior College
- CET at Paya Lebar
- Civil Service College
- Fusionpolis
- Hwa Chong Junior College
- Lasalle SIA College
- Ngee Ann Polytechnic
- NUS Cultural Centre
- NUS Duke
- Raffles Junior College
- Raffles Institution
- Republic Polytechnic
- Singapore Arts School
- SIM
- SUTD
- Tanglin Trust School
- Temasek Polytechnic

C. Exhibition
- Conference Centres and Exhibition Halls
- Singapore Expo*

D. Health
- Hospitals
- Medical Centres
- Surgeries (doctor / dental) and pathology centres.
- Novena Medical Centre
- National Heart Centre*

E. Hotel
- Hotels
- Serviced Apartments
- Motels
- Hostels
- Other forms of tourist accommodation
- Amara Hotel
- Changi Meridian Hotel
- Crown Prince Hotel
- Meritus Mandarin Hotel
- Orchard Hotel
- Novotel Hotel "Apollo"
- Royal Scots Hotel

F. Industrial
- Factories
- Plants
- Workshops
- Warehouses
- Manufacturing and processing facilities
- Ang Mo Kio Industrial Park
- Bukit Batok Industrial Park
- C & P Mega Warehouse
- Eunos Technolink Park
- Halliburton Warehouse*
- Logistics Hub at Jalan Buroh
- L & C Chemical Warehouse
- Paya Ubi Industrial Park
- North Spring Bizhub
- NTUC Warehouse*
- Signature Building
- Sing Ming Autocare
- SPH Print Centre

G. Office
- Commercial
- Public Offices
- DBS
- IRAS Building I
- MITA Building
- Ocean Financial Centre
- Parliament House
- Supreme Court
- URA Building @ Maxwell
- 78 Shenton Way
H. Recreation
- Sporting Stadiums | Cinemas | Theme Parks | Tourist Attractions | Clubs | Pubs | Museums | Art Galleries
- Gardens
- Singapore Indoor Stadium
- Singapore History Museum
- Universal Studios Resort World Sentosa

I. Retail
- Shopping Centres | Supermarkets | Shops | Restaurants | Cafes
- AMK Hub
- Bugis Junction
- Capitol Development
- Causeway Point
- Century Square
- Compass Point
- City Square Mall*
- Central at Clarke Quay
- Cathay Building
- China Square
- Chinatown Point*
- Downtown East
- East Point Mall
- Esplanade Mall
- Funan Digitalife Mall
- Great World City
- Grandlink Square
- Ginza Plaza
- ION Orchard
- IMM Extension
- Lot One Shopper’s Mall
- Mustafa Centre
- Millenia Walk*
- Marina Square
- 268 Orchard Road*
- Novena Square
- North Point
- One Raffles Quay
- Orchard Cineleisure
- Ophir Development*
- People’s Park Complex
- Paradiz Centre
- Paragon
- Plaza Singapura
- Roxy Square
- Raffles City
- Seletar Mall
- Serangoon Central Mall
- Scotts Square
- Sembawang Shopping Centre
- Suntec City
- Tampines Mall
- Tanglin Mall
- Tekka Mall
- Ten Mile Junction
- Viva Vista
- Vivocity
- Westgate
- Whitesands
- Zhongshan Park

J. Transport
- Ports | Airports | Railways | Subways | Bus Terminals
- Changi Airport Terminal 1
- North East Line NEL - C773
- Qantas First Lounge, Terminal 1
- Seletar Aerospace Park
- Sengkang MRT Depot

K. Utilities
- Water & Sewerage Plants | Pipelines | Electricity & Telecommunications | power plants
- Changi Prison
- Senoko Power Station
- Tuas Incinerator
- Ulu Pandan Sewage
3.2 Provision of Compartment Walls and Compartment Floors

3.2.1 Any building other than a building of Purpose Group I which has -

(a) Any storey the floor area of which exceeds that specified as relevant to a building of that height in column (2) of Table 3.2A, or

(b) A cubic capacity which exceeds that specified as relevant in column (3) of Table 3.2A, shall be divided into compartments by means of compartment walls & compartment floors so that

(i) no such compartment has any storey the floor area of which exceeds the area specified as relevant to the building in column (2) of the Table, and

(ii) no such compartment has a cubic capacity which exceeds that specified as relevant in column (3) of the Table.

Table 3.2A Size Limitation of Building and Compartment

<table>
<thead>
<tr>
<th>Compartments</th>
<th>Maximum Floor Area</th>
<th>Maximum Cubical Extent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compartment below ground level. No compartment to comprise more than one storey.</td>
<td>2000m²</td>
<td>7500m³</td>
</tr>
<tr>
<td>Compartments between average ground level and a height of 24m. No compartment to comprise more than 3 storeys.</td>
<td>4000m²</td>
<td>15000m³</td>
</tr>
<tr>
<td>Compartments above a height of 24m from average ground level. No compartment to comprise more than one storey.</td>
<td>2000m²</td>
<td>7500m³</td>
</tr>
</tbody>
</table>

N.A. - Not Applicable
The atrium is open and unobstructed in a manner such that it may be assumed that a fire in any part of the space will be readily obvious to the occupants before it becomes a hazard; and

The building is fitted throughout with an automatic sprinkler system to comply with the requirements in Chapter 6; and

The building is fitted with an engineered smoke control system in accordance with Cl.7.6; and

Provision of openings and enclosures, and the planning of means of escape shall be subject to the approval of the Relevant Authority.

3.2.4 Compartmentation by Height

(a) In any compartment except those mentioned under sub-clause 3.2.4(c), up to a habitable height of 24m, no compartment shall comprise more than three storeys. This requirement can be relaxed for Atrium spaces provided the design of such spaces complies with the conditions stipulated under Cl.3.2.6.

(b) In any building which exceeds 24m in habitable height, no compartment shall comprise more than one storey for compartments at storey level exceeding 24m above average ground level, other than a compartment which is within a residential maisonette which may comprise two storey levels.

(c) Buildings under Purpose Group I may consist of more than 3 floors if they are occupied as a single household dwelling.

3.2.6 The Relevant Authority may consent to modify the requirements under Cl. 3.2.1 and 3.2.4(a) of this Code for the design of ‘Atrium spaces’ in a building provided the following conditions are complied with:

(a) The minimum plan area of the Atrium void shall be not less than 93m² and no horizontal dimension between opposite edges of the floor opening is less than 6m wide; and

(b) Occupancy within the floor space of the Atrium meets with the specification for low or ordinary hazard content; and

(c) The atrium is open and unobstructed in a manner such that it may be assumed that a fire in any part of the space will be readily obvious to the occupants before it becomes a hazard; and

(d) The building is fitted throughout with an automatic sprinkler system to comply with the requirements in Chapter 6; and

(e) The building is fitted with an engineered smoke control system in accordance with Cl.7.6; and

(f) Provision of openings and enclosures, and the planning of means of escape shall be subject to the approval of the Relevant Authority.
7.4 **Basement Smoke Control System**

7.4.1

(a) Where the total aggregate floor area of all basement storeys does not exceed 2000m², smoke vents in accordance with Cl.7.4.2 shall be provided.

(b) Where the total aggregate floor area of all basement storeys exceeds 2000m², engineered smoke control system that complies with the requirements stipulated in Cl.7.4.3 shall be provided for all parts of basement with the following exceptions:

(i) Where the basement or a portion of the basement is used as carpark, Cl.7.1.9 can be adopted to the carpark provided it is compartmented from rest of the basement;

(ii) Plant/equipment room with floor area not exceeding 250m² and compartmented from rest of the basement, and provided with two doors for better reach in fire fighting operation.

(iii) Plant/equipment room with floor area exceeding 250m² but not exceeding 2000m², smoke vents in accordance with Cl.7.4.2 or smoke purging system of at least 9 air-change per hour shall be provided.

(iv) Service areas such as storeroom and workshops (restricted to staff only) which are compartmented, smoke venting provision in accordance with Cl.7.4.2 or smoke purging system of at least 9 air-change per hour may be accepted for those areas in lieu of the engineered smoke control system. Automatic fire alarm/extinguishing system in accordance with Table 6.4A shall be provided where required.

7.4.2 Smoke vents shall be adequately distributed 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 openable in case of fire.

(c) The position of all vent outlets and the areas they serve shall be suitably indicated adjacent to such outlets.

(d) Where ducts are required to connect the vent to outlets, the ducts shall either be enclosed in structure or be constructed to give at least 1 hour fire resistance.

(e) Separate ducts and vent outlets shall be provided for each basement storey.
7.4.3 Where engineered smoke control system is required, it shall be provided as specified in Cl.7.6.

7.4.4 Smoke purging systems, where permitted under this Code in buildings for basement occupancies of plant/equipment room and service areas such as storeroom and workshops, shall conform to the following requirements:

(a) The purge rate shall be at least 9 air changes per hour.

(b) The smoke purging system shall be activated automatically by the building fire alarm system. In addition, a remote manual start-stop switch shall be located at fire command centre, or in the absence of a fire command centre in the building, at the main fire alarm panel on the first storey. Visual indication of the operational status of the smoke purging system shall also be provided with this remote control.

(c) Horizontal ducts shall be fabricated from heavy gauge steel (1.2mm thick).

(d) The exhaust fan shall be capable of operating effectively at 250°C for 2 hours and supplied from a secondary source of supply.

(e) Replacement air shall be provided and if it is supplied by a separate mechanical system, such a system shall be connected to a secondary source of power.

7.5 Smoke Control System

7.5.1 A smoke control system specified in Cl.7.6 shall be provided where:

(a) The requirements for compartmentation specified in Cl.3.2.1 and 3.2.4(a) and (b) are relaxed under the conditions in Cl.3.2.6 for ‘Atrium spaces’ in a building; and

(b) The total floor area of any compartment in a building or part of a building exceeds 5000m².

7.6 Engineered Smoke Control System

7.6.1 The engineered smoke control system shall be in the form of a smoke ventilation system by natural or mechanical extraction designed in accordance with:

(a) BR 186 - Design principles for smoke ventilation in enclosed shopping centres; and
7.6.2 The building to be provided with an engineered smoke control system shall be sprinkler protected.

7.6.3 Capacity of the engineered smoke control system shall be calculated based on the incidence of a likely maximum fire size for a sprinkler controlled fire as recommended in the following table:

<table>
<thead>
<tr>
<th>Occupancy (Sprinklered)</th>
<th>Fire Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heat Output (MW)</td>
</tr>
<tr>
<td>Shops</td>
<td>5</td>
</tr>
<tr>
<td>Offices</td>
<td>1</td>
</tr>
<tr>
<td>Hotel Guest Room</td>
<td>0.5</td>
</tr>
<tr>
<td>Hotel Public Areas</td>
<td>2.5</td>
</tr>
<tr>
<td>Assembly Occupancy with fixed seating</td>
<td>2.5</td>
</tr>
</tbody>
</table>

7.6.4 The capacity of an engineered smoke control system shall be capable of handling the largest demand for smoke exhaust from the worst case scenario.

7.6.5 The design smoke layer base shall be above the heads of people escaping beneath it. The minimum height shall be 2.5m.

7.6.6 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.
7.6.7 For cases where smoke is removed from the room of origin the smoke reservoir size for a smoke ventilation system shall not exceed:

(a) 2000m² for natural smoke ventilation system.
(b) 2600m² for mechanical smoke ventilation system.

7.6.8 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) 1000m³ for natural smoke ventilation system.
(b) 1300m³ for mechanical smoke ventilation system.

7.6.9 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 of not exceeding 1000m² (for natural ventilation system) or 1300m² (for mechanical ventilation system) or
(b) be subdivided such that smoke is vented to the circulation space or atrium only from part of the room with floor area not exceeding 1000m² (for natural ventilation system) or 1300m³ (for mechanical ventilation system) that are adjacent to the circulation space or atrium. However, the remainder of the room needs to be provided with an independent smoke ventilation system(s).

7.6.10 The maximum length of the smoke reservoir shall not exceed 60m.

7.6.11 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.

7.6.12 Owing to practical limitation, a smoke ventilation system shall have:

(a) a maximum mass flow not exceeding 175kg/s; and
(b) a minimum smoke layer temperature of 18°C above ambient.
7.6.13 Replacement air shall be by natural means drawing air directly from the external.

(a) The design replacement air discharge velocity shall not exceed 5m/s to prevent the escapees being hindered by the air flow.

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

(c) Replacement air shall be discharged at a low level, at least 1.5m beneath the designed smoke layer, to prevent “fogging” of the lower clear zone.

(d) Where the inlet cannot be sited at least 1.5m 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.

(f) Where the automatic roller shutters are used at replacement air inlets in the design and installation of engineered smoke control system, it shall be of perforated type having the required effective free area for the effective operation of the engineered smoke control system.

7.6.14 For cases where the smoke reservoir is above the false ceiling, the ceiling shall be of perforated type with at least 25% opening.

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

7.6.16 The smoke ventilation system shall be activated by smoke detectors located in the smoke control zone. Use of smoke detectors for activation must 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 must be avoided.

7.6.17 Provision of activating smoke detectors shall comply with SS CP 10.

7.6.18 A remote manual activation and control switches 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 main fire indicator board.
### 7.6.19
Except for ventilation systems in Cl.5.2.1(g) and (h), all other air-conditioning and ventilation systems within the areas served shall be shut down automatically upon activation of the smoke ventilation system.

### 7.6.20
Either a standby fan or multiple fans with excess capacity shall be provided for each mechanical smoke ventilation system such that in the event the duty fan or the largest capacity fan fails, the designed smoke extraction rate will still be met. The standby fan shall be automatically activated in the event the duty fan fails.

### 7.6.21
Fans shall be capable of operating at 250°C for 2 hours.

### 7.6.22
The fans and associated smoke control equipment shall be wired in protected circuits designed to ensure continued operation in the event of the fire.

### 7.6.23
The electrical supply to the fans shall, in each case, be connected to a sub-main circuit exclusive thereto after the main isolator of the building. The cables shall be of at least 1-hour fire resistance in accordance with SS 299.

### 7.6.24
Smoke ventilation ducts (both exhaust and replacement air ducts) shall be of at least 1 hour fire resistance. Where a duct passes through other fire compartment of higher rating, the duct shall be constructed to have the rating as that of the compartment. The rating shall apply to fire exposure from both internal and external of the duct or structure and the duct shall also comply with subcl. 7.1.1(j).

### 7.6.25
Fire damper shall not be fitted in the smoke ventilation system.

### 7.6.26
The time taken for the smoke ventilation system within a smoke zone to be fully operational shall not exceed 60 seconds from system activation.

<table>
<thead>
<tr>
<th>Compliance</th>
<th>N.A.</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Smoke extraction system with inpermeable ceiling</strong></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Fan</strong></td>
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<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Fire compartment wall (2 hour)</strong></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Smoke detector</strong></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Natural supply air</strong></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Supply air duct</strong></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Smoke extraction fan system</strong></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>1 hour fire rated duct</strong></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>2 hour fire rated duct</strong></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>Min 2.5m AFFL</strong></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
<td><img src="image.png" alt="Image" /></td>
</tr>
</tbody>
</table>
7.6.27 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.

7.6.28 Natural exhaust ventilation shall not be used together with powered smoke exhaust ventilation.

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

7.6.30 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.

7.6.31 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 design highest temperature.

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

7.7 Auditorium (used or intended for use as Cinema, Concert Hall, Performance Theatre) Smoke Control System

7.7.1 Provision of smoke vents having 2.5% of the floor area shall be provided to auditorium which is not sprinkler protected and to auditorium having floor area more than 500m², if sprinkler protected. The opening of the smoke vents shall be by automatic device.

7.7.2 In place of smoke vents, an engineered smoke control system would be considered as acceptable.
# Smoke Control Requirements for General Warehouse

<table>
<thead>
<tr>
<th>Location of Warehouse</th>
<th>Compartmet Size</th>
<th>Provision of Sprinkler System</th>
<th>Smoke Control Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above ground level</td>
<td>≤ 100m²</td>
<td>No</td>
<td>Not required</td>
</tr>
<tr>
<td></td>
<td>100m² &lt; Size ≤ 400m²</td>
<td>No</td>
<td>Smoke Vent (2.5% / 12m max.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Smoke Vent (6.0% / 15m max.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Smoke Vent (10.0% / 18m max.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Smoke Vent (15.0% / 21m max.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Smoke Vent (20.0% / 24m max.)</td>
</tr>
<tr>
<td></td>
<td>400m² &lt; Size ≤ Maximum cubical size</td>
<td>No</td>
<td>Smoke Vent (20.0% / 12m max.)</td>
</tr>
<tr>
<td></td>
<td>≤ 700m²</td>
<td>Yes</td>
<td>Not required</td>
</tr>
<tr>
<td></td>
<td>700m² &lt; Size ≤ 5000m²</td>
<td>Yes</td>
<td>Smoke Vent or purging system</td>
</tr>
<tr>
<td></td>
<td>&gt; 5000m²</td>
<td>Yes</td>
<td>Engineered Smoke Control System</td>
</tr>
<tr>
<td>Below ground level (Basement)</td>
<td>≤ 2000m²</td>
<td>Yes</td>
<td>Smoke Vent or purging system</td>
</tr>
<tr>
<td></td>
<td>&gt; 2000m²</td>
<td>Yes</td>
<td>Engineered Smoke Control System</td>
</tr>
</tbody>
</table>

Compliance

<table>
<thead>
<tr>
<th>N.A</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

Ineffective natural smoke exhaust under wind effect

CFD Simulation - Visibility Section
Root Objectives

R3.1 Prevent the untimely collapse of buildings due to the effects of fire that would affect the safe egress of the building occupants.

R3.2 Prevent spread of fire to adjacent properties due to the effects of a fire in the building.

R3.3 The building shall remain structurally stable to allow adequate time for fire-fighters to conduct their fire-fighting and rescue operations.

Sub Objectives

S3.1 Provision of elements of structure with appropriate fire resistance with respect to :

(i) the fire severity; and

(ii) fire fighting and rescue operations; and

(iii) the occupant evacuation time; and

(iv) enclosure characteristics and configurations; and

(v) the height of building; and

(vi) occupancy characteristics; and

(vii) different fire risk levels.

S3.2 The construction and use of building materials should be of the type and method appropriate to the intended performance.

S3.3 Provisions for reasonable and adequate measures to limit the development of fire.

S3.4 Provisions for prevention of spread of fire from and to high fire risk areas.

S3.5 Provisions for the protection of building fire systems to enable their proper functioning during a fire emergency.

S3.6 Provisions for prevention of spread of fire from storey to storey.

S3.7 Provisions for prevention of spread of fire to adjacent buildings.

S3.8 Provisions to minimise risk of fire initiation and limit fire and smoke spread in concealed spaces.

S3.9 Provisions for reasonable measures to prevent premature structural collapse of the building due to fire.
Chapter 7 - Mechanical Ventilation & Smoke Control System

**Root Objectives**

R7.1  Maintain tenable conditions for evacuation of occupants and protect them from injury arising from the effects of fire.

R7.2  Provide smoke management in the building for firefighting operations.

**Sub Objectives**

S7.1  Provisions for ventilation for life safety purposes such that, in the event of a fire, evacuation routes are maintained:

(i)  below thermal threshold for human tenability; and

(ii)  at visibility levels adequate for occupant evacuation; and

(iii) below toxicity threshold for human tenability for the period of time required for escape.

S7.2  Provisions for ventilation to maintain safe conditions in the means of escape for evacuees for the period of time required for escape.

S7.3  Provisions for adequate ventilation for the storage of flammable and explosive substances or equipment emitting flammable vapour, to prevent undesirable accumulation of such flammable vapour.

S7.4  The installation and operation of the mechanical ventilation systems shall

(i)  have minimal contribution to the spread of fire and smoke in the building; and

(ii)  have no adverse effects on the operation of other life safety or fire suppression systems.

S7.5  Provisions for appropriate and adequate ventilation to

(i)  rooms housing essential fire fighting facilities which are dependent on it for their continued operation; and

(ii)  fire command centre in which emergency personnel operate.
SHEVS International Fire Technology aims to adopt the most appropriate fire safety engineering approaches to protect both building and occupants at all times in compliance to both the local and the latest international code of practice. Integrated smoke control system solution implemented would as a standard include all or part of the following services unless otherwise advised:

- Natural Smoke Ventilation System
- Mechanical Smoke Ventilation System
- Automatic Smoke Curtain System
- Passive or Fixed Smoke Curtain System
- Automatic Smoke Detection System
- Automatic Replacement Air Inlet System
- Motorised Smoke Control Damper System
- Smoke Control Duct System

Due to the increasing complexity in building architecture, SHEVS IFT is also able to offer customised and special methods of smoke control installations to meet the fire safety, the day-to-day functionality as well as the aesthetical aspects.