European Guideline

CFPA-E No 35:2015 F

Smoke and Heat Exhaust Ventilation Systems Planning and Design

CFPA EUROPE
FOREWORD

The European fire protection associations have decided to produce common guidelines in order to achieve similar interpretation in European countries and to give examples of acceptable solutions, concepts and models. The Confederation of Fire Protection Associations in Europe (CFPA E) has the aim to facilitate and support fire protection work in European countries.

The market imposes new demands for quality and safety. Today, fire protection forms an integral part of a modern strategy for survival and competitiveness.

This guideline is primarily intended for those responsible for safety in companies and organisations. It is also addressed to the rescue services, consultants, safety companies etc. so that, in course of their work, they may be able to help companies and organisations to increase the levels of fire safety.

The proposals within this guideline have been produced by the Swissi AG and the author is Hans-Heinrich Wolfensberger from Switzerland.

This Guideline has been compiled by Guidelines Commission and adopted by all fire protection associations in the Confederation of Fire Protection Associations Europe.

These guidelines reflect best practice developed by the countries of CFPA Europe. Where the guidelines and national requirement conflict, national requirements must apply.

Copenhagen, 27 July 2015
CFPA Europe

Jesper Ditlev
Chairman

Madrid, 27 July 2015
Guidelines Commission

Miguel Vidueira
Chairman
Contents

1 Introduction .................................................................................................................... 4
2 Scope ................................................................................................................................ 4
3 Definitions ....................................................................................................................... 4
  3.1 SHEVS ...................................................................................................................... 4
  3.2 Smoke and heat extraction......................................................................................... 4
  3.3 Air supply ................................................................................................................. 4
4 Objectives and Conditions ............................................................................................ 5
  4.1 Objectives ................................................................................................................ 5
  4.2 Conditions ................................................................................................................ 5
5 Requirements .................................................................................................................. 5
  5.1 General .................................................................................................................... 5
  5.2 Smoke and heat extraction openings........................................................................... 5
  5.3 Smoke and heat extraction shafts and ducts.............................................................. 6
  5.4 Air supply openings................................................................................................... 6
  5.5 Control and activation................................................................................................ 6
  5.6 Power supply ............................................................................................................ 6
  5.7 HVAC Systems .......................................................................................................... 6
  5.8 Installation and maintenance ..................................................................................... 7
6 SHEVS concepts .............................................................................................................. 7
  6.1 Natural smoke and heat exhaust ventilation systems (N-SHEVS) ......................... 7
    6.1.1 Definition ........................................................................................................... 7
    6.1.2 General Information........................................................................................ 7
  6.2 Fire brigade operated smoke and heat exhaust ventilation systems (FB-SHVES) ...... 8
    6.2.1 Definition ........................................................................................................... 8
    6.2.2 General information............................................................................................ 8
    6.2.3 Air supply openings........................................................................................... 9
    6.2.4 Smoke and heat extraction openings.................................................................... 9
  6.3 Mechanical smoke and heat exhaust ventilation systems (M-SHEVS) .................... 10
    6.3.1 Definition ......................................................................................................... 10
    6.3.2 High temperature fans ...................................................................................... 10
    6.3.3 Air supply openings........................................................................................... 10
    6.3.4 Smoke and heat extraction openings................................................................... 10
7 SHEVS Concepts: Applicability ..................................................................................... 11
  7.1 Industry, Production and Storage Occupancies ....................................................... 11
  7.2 Business Occupancies .............................................................................................. 11
  7.3 Commercial Occupancies (under 2000 occupants) ................................................. 12
  7.4 High Occupancy Applications .................................................................................. 12
  7.5 Car parks .................................................................................................................. 12
8 Guidelines ..................................................................................................................... 15

Keywords:
Smoke, heat, SHEVS, extraction, ventilation, exhaust area
1 Introduction
Due to buoyancy effects, hot smoky gasses will tend to rise and spread rapidly, with the potential to cause both physical and financial damage. Without a properly designed smoke and heat exhaust ventilation system rooms can quickly fill a room with smoke making it untenable and causing a significant amount of damage. Smoke and heat exhaust ventilation systems (from here on out referred to as SHEVS) are designed to limit the spread of smoke and its damaging effects as well as ensuring a safe, smoke free zone is maintained in order to expedite egress. SHEVS can also be used to extract heat from a newly formed fire, which will simultaneously hinder the growth of the fire and spread of smoke; limiting the potential damage, reducing the temperature at ceiling level, aiding in safe evacuation and maintaining reasonable levels of visibility to help the intervening Fire Brigade better combat the fire.

2 Scope
The objective of this guideline is to provide a helpful tool in order to plan and design a SHEVS without the aid of computer simulation for the following scenarios:
- Industry, production and storage buildings
- Office buildings
- Supermarkets
- Rooms with a high number of people
- Car park

This guide is not intended for large fire compartments with volumes over 60,000 m$^3$ or rooms with more than 2,000 people.

Reference
All figures and examples are extracted from the 2014 technical bulletins of “Gebäudeversicherung des Kantons Zürich”.

3 Definitions

3.1 SHEVS
“Smoke and Heat Exhaust Ventilation Systems” includes all components used in a system that extracts smoke and heat from a fire and transports it to a safer area, such as outside. This also refers to any openings where the smoke may be extracted or air is supplied in order to avoid pressure issues.

3.2 Smoke and heat extraction
Smoke extraction refers to the system components of vents, openings, ducts and shafts where the air is designed to flow from the inside of the building to the outside, extracting any smoke or heat from the given area and depositing it in a relatively safe environment (e.g. openings in façades, roofs and including the shafts and ducts used to transport the air and smoke).

3.3 Air supply
Smoke extraction refers to the system components of vents, openings, ducts and shafts where fresh air is brought into the building in order to prevent pressure issues from occurring.
4 Objectives and Conditions

4.1 Objectives

SHEVS have the following objectives:

- To ensure that people can escape from a building without endangering themselves when leaving a fire compartment or the building and evacuating to a safe area.
- To maintain a level of smoke free environment so that fire brigade intervention is both practicable and as safe as possible.
- To protect the building and its contents via a controlled extraction of smoke and heat.
- To make certain there is rapid extraction of smoke once the fire has been extinguished.

4.2 Conditions

During the design process the following conditions must be considered and adhered to:

- Respect fire regulations, in particular those that handle the safe egress of occupants.
- The time for the fire brigade to respond and be ready to begin suppression actions will be estimated at 15 minutes from notification.
- If the SHEVS concept requires the use of smoke extraction fans or pressure nozzles during fire brigade intervention, the fire brigade must be informed so they can take the appropriate steps before and during the event.

5 Requirements

5.1 General

- SHEVS must comply with state of the art technology and be calculated, designed, installed and maintained in such a way that they are effective and are ready for operation at all times.
- The openings shall be arranged such that there is a clear and efficient flow of air from the supply point(s) to the exhaust points(s) in all regions of the fire compartment.
- All system components must be made of suitable materials and shall be, assembled and installed to be able to withstand all appropriate events.
- The specifications of the manufacturer and installer with regards to maintenance and inspection cycles must be considered during any design. The person or persons responsible for the inspection and maintenance of the system must be identified and informed of their responsibilities.

5.2 Smoke and heat extraction openings

- Extraction openings for the removal of smoke and heat must be arranged an aerodynamically efficient manner while still providing proper occupant and building safety.
- If extraction vents cannot be installed in the roof, the necessary openings can be installed in as logically and uniform as possible on opposite façades as to provide the same coverage as if installed in the roof.
- In large fire compartments, the ceiling/roof should be divided at ceiling/roof level into smoke reservoirs in order to limit the spread of smoke.
5.3 Smoke and heat extraction shafts and ducts
- Smoke and heat extraction shafts and ducts must be designed and installed in such a way that they are able to withstand the stresses inherent during smoke and heat extraction.
- During the planning and implementation process the designer must look at the requirements for the selected ducts in the event of a fire.
- It must be expected that there may be some deformation and swaying of the ducts during the extraction process and therefore appropriate measures must be taken to limit the impact this will have.
- Plastic anchors for the installation of power cables are not allowed and power cables must conform to the necessary fire resistance levels when passing through walls.

5.4 Air supply openings
- During planning installation of SHEVS, it is assumed that smoke can only be extracted if there is an aerodynamically equivalent opening from which fresh air is supplied into the fire compartment.
- Air supply openings (e.g. openings in walls/façades, doors, windows) must be planned as to have as low height as possible. The air supply openings must be able to supply fresh air at least the same rate as the hot air and smoke is extracted.
- For the smoke removal with mechanical SHEVS, air supply velocities of a maximum of 5 m/s are permissible at the air supply opening in areas where low occupancy can be expected (e.g. Industry or Storage Occupancies), otherwise a maximum velocity of 3 m/s is suggested.
- The pressure ratios must be such that the egress is not hampered (e.g. higher pressures in a room can make doors difficult or even impossible to open).

5.5 Control and activation
- Generally, fixed SHEVS are strongly recommended to be automatically activated (e.g. activation by sprinklers or fire/smoke detection).
- The activation of SHEVS must also be able to be controlled manually from a safe location by the fire brigade. There should be a control station that labels each of the possible situations in a clear and recognizable manner (e.g. on/open, off/closed, error).

5.6 Power supply
SHEVS must have a source of power that is independent to the main power of the building (Note: Consult local codes and guidelines for specifics).

5.7 HVAC Systems
The use of HVAC installations (e.g. ventilation and air conditioning) as a SHEVS is permitted only if the HVAC installations fulfil the requirements set forth for SHEVS.
5.8 Installation and maintenance

- All system parts must be made of approved materials and shall be designed and installed to withstand severe conditions.
- The parts used in the systems such as fans, heat and smoke vents, etc. have been tested and approved in accordance with the EN 12101-ff series of standards and have the corresponding certificate.
- The specifications for all components within the SHEVS must be made available to all relevant parties, including the inspection and maintenance requirements. Those responsible for maintaining proper working order must be identified and informed.
- The full schematic of the SHVES must be documented and provided to the relevant parties and a test carried out in order to verify the functionality.

6 SHEVS concepts

There are three options when designing a SHEVS concept: Natural, Mechanical and Fire Brigade driven. It should be noted that only mechanical SHEVS concepts can be used as a method to increase occupant safety. Natural SHEVS concepts are useful in offering further protection for the goods and building structure, whereas the Fire Brigade SHEVS concepts should only be considered as an efficient method of smoke removal.

6.1 Natural smoke and heat exhaust ventilation systems (N-SHEVS)

6.1.1 Definition

Natural smoke and heat exhaust ventilation systems (N-SHEVS) refers to a system of smoke and heat extraction using the natural buoyancy of hot, smoky gasses to drive both the extraction of the smoke from the building and the introduction of fresh air into the building.

6.1.2 General Information

- N-SHEVS are ineffective in protecting underground areas.
- Production areas using N-SHEVS, are required to have the ventilation area cover 0.65% of the floor’s aerodynamic area \((A_{\text{aerodyn}}) = 0.65 \%\) for the given fire compartment.
- Smoke and heat vents must be installed at the highest reasonable point in the building, such as in the roof or at the highest point of a façade. The corresponding air supply openings must be placed as close to floor level of the fire compartment as possible.
- N-SHEVS must be able to function at the designed level of performance under all circumstances, independent of the weather conditions.
- If the smoke and heat vents cannot be installed in the roof, then it is permissible to install them at the highest point of two opposing façades. The fire brigade must be able to open and close the vents independently of each other.
- It should be noted that the efficiency of N-SHEVS can be negatively influenced by weather conditions (temperature, wind direction), fire scenario (size of the fire, smoke temperature) and smoke logging degree.
- In larger fire compartments it may be necessary to introduce smoke barriers to ensure proper directional air flow from the supply points to the exhaust openings.
The geometric surface area of a wall opening can be determined as follows:

\[ A = \frac{A_{aerodyn}}{c} \]

- \( A \): Geometric surface area (wall opening) \([\text{m}^2]\)
- \( A_{aerodyn} \): Aerodynamic effective area \([\text{m}^2]\)
- \( c \): Flow Coefficient (see table below)
- \( \alpha \): Opening Angle

**Table – aerodynamic flow coefficients (c) for different opening types**

<table>
<thead>
<tr>
<th>Type of Opening</th>
<th>Opening Angle ((\alpha \pm 5^\circ))</th>
<th>Flow Coefficient (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completely opened surface</td>
<td></td>
<td>0.65</td>
</tr>
<tr>
<td>Jalousies (shutters)</td>
<td>90°</td>
<td>0.65</td>
</tr>
<tr>
<td>Side-hung window</td>
<td>(\geq 60^\circ)</td>
<td>0.5</td>
</tr>
<tr>
<td>Side-hung window</td>
<td>(\geq 45^\circ)</td>
<td>0.4</td>
</tr>
<tr>
<td>Side-hung window</td>
<td>(\geq 30^\circ)</td>
<td>0.3</td>
</tr>
</tbody>
</table>

(Table from DIN 18232-2:2003-06, Appendix C, Table C.1)

**6.2 Fire brigade operated smoke and heat exhaust ventilation systems (FB-SHVES)**

**6.2.1 Definition**
- Fire brigade operated smoke and heat exhaust ventilation systems (FB-SHVES) refers to a concept (as opposed to a system) that includes potential air-flow directions in order to assist the fire brigade in suppressing the fire as well as pushing/extracting the smoke and hot gasses out of the building. FB-SHVES concepts are cost effective method in quickly removing smoke and hot gases from a fire compartment but shall only be applied if approved by local national codes and guidelines.

**6.2.2 General information**
- FB-SHVES concepts are not applicable to those fire compartments that are further than one level underground or include complex geometries.
- If smoke removal via the fire brigade is desired, it must be included in the fire brigade intervention concept.
- The fire brigade responsible for the intervention in a building must use the appropriate fans (e.g. if the concept calls for a fan rated at 50,000 m³/hour, the fire brigade must adhere to these requirements).
- The simultaneous use of multiple smoke vents requires a specific concept. In particular, it must make sure that the flow of air and smoke is properly directed to the openings. If this is not done correctly, it is possible that the smoke may not be transported to the openings and an effect similar to plug-holing will take place.
6.2.3 Air supply openings

- The efficiency of the FB-SHEVS hinges on the assumption that air supply openings are readily available and arranged such that there is an efficient flow of air.
- The FB-SHEVS must be placed 3-4 meters away from the air supply opening in order to ensure the entire opening is used in blowing the air into the building.
- SHEVS should be installed in such a way that they directly or indirectly (e.g. via a staircase and/or a corridor) blow air into the fire room. Potential pressure losses must be considered in any concept.

If a direct air supply into the fire compartment is not possible, the air can be supplied via the fire brigade using pressure hoses and nozzles.

Below is a list of typical volumetric flow rates:

- Standard smoke fan 30,000 m³/hour (combustion engine, electrical motor or water power unit)
- Standard smoke fan 50,000 m³/hour (combustion engine, electrical motor or water power unit)
- Large smoke fan 250,000 m³/hour (on trailer or motor vehicle)

(These volumetric flows have been calculated without pressure loss)

6.2.4 Smoke and heat extraction openings

- The aerodynamically effective smoke exhaust area should be at least 1.3 m², which corresponds to a geometric opening of 2 m².
- In corners or larger enclosed areas additional openings must be introduced to avoid areas where the smoke and heat can accumulate. This arrangement must be designed in an aerodynamically logical fashion.
- Extraction openings must always be installed at the highest point of the fire compartment, whether that be the roof, ceiling or points on a façade.
- Extraction openings must be able to be controlled from a safe area and be operational in the event of a power failure.
6.3 Mechanical smoke and heat exhaust ventilation systems (M-SHEVS)

6.3.1 Definition
Mechanical smoke and heat exhaust ventilation systems (M-SHEVS) refers to a system of smoke and heat extraction using mechanical devices, such as fans, to drive or extract the smoke and hot gasses from the building. Air supply may be naturally or mechanically provided. This system is also sometimes referred to as a “Driven” or “Automatic” SHEVS.

6.3.2 High temperature fans
- M-SHEVS high temperature fans are allowed only when approved by a recognised testing laboratory.
- M-SHEVS must be guaranteed to operate for 60 minutes at a temperature of 600 °C.
- In the event lower that temperatures of smoky gases can be reasonably expected, the temperature resistance of the fans can be reduced to 200 °C (e.g. in sprinkler covered areas).

6.3.3 Air supply openings
Air supply openings (e.g. doors, gates, and windows) must be installed as close to floor level as reasonable. They must be designed so their surface area can supply the necessary volumetric flow while not allowing the incoming air to exceed the maximum velocity as per the design. The fire brigade should be informed as to the arrangement and be given access to the control systems in the event of an emergency. The openings should be arranged so that there is a well-directed flow of air within the compartment.

6.3.4 Smoke and heat extraction openings
Extraction openings should be placed just under the ceiling and arranged in order to produce a well-directed flow of air within the compartment.
7 SHEVS Concepts: Applicability
For all tables below the following conditions apply:

- \( n_e \): non-essential
- \( - \): not practical
- \( o \): limited applicability
- \( + \): suggested

Sprinkler protected buildings

### 7.1 Industry, Production and Storage Occupancies

<table>
<thead>
<tr>
<th>Concept</th>
<th>Smoke control applicability with regards to compartment size (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(incl. intermediate floors and mezzanines)</td>
</tr>
<tr>
<td></td>
<td>Enclosed rooms</td>
</tr>
<tr>
<td></td>
<td>Rooms with openings (e.g. windows)</td>
</tr>
<tr>
<td></td>
<td>Up to 3200 m²</td>
</tr>
<tr>
<td>N-SHEVS</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>( n_e )</td>
</tr>
<tr>
<td>FB-SHEVS</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>( n_e )</td>
</tr>
<tr>
<td>M-SHEVS</td>
<td>+</td>
</tr>
</tbody>
</table>

1) Not practical for underground applications

### 7.2 Business Occupancies

<table>
<thead>
<tr>
<th>Concept</th>
<th>Smoke control applicability with regards to compartment size (m²) and number of stories (incl. intermediate floors and mezzanines)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fire compartment</td>
</tr>
<tr>
<td></td>
<td>one or two floors</td>
</tr>
<tr>
<td></td>
<td>Up to 4800 m²</td>
</tr>
<tr>
<td>N-SHEVS</td>
<td>( o )</td>
</tr>
<tr>
<td></td>
<td>( n_e )</td>
</tr>
<tr>
<td>FB-SHEVS</td>
<td>( + )</td>
</tr>
<tr>
<td></td>
<td>( n_e )</td>
</tr>
<tr>
<td>M-SHEVS</td>
<td>( + )</td>
</tr>
</tbody>
</table>

1) Not practical for underground applications

Number of required air changes for FB-SHEVS and M-SHEVS:
The number of air changes is in function of the height of the fire compartments

- Height < 5.0 m: 8 air changes per hour
- Height > 5.0 – 7.5 m: 6 air changes per hour
- Height > 7.5 m: 4 air changes per hour
7.3 Commercial Occupancies (under 2000 occupants)

<table>
<thead>
<tr>
<th>Concept</th>
<th>Smoke control applicability with regards to compartment size (m²) and number of stories (incl. intermediate floors and mezzanines)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Up to 2400 m² single storey</td>
</tr>
<tr>
<td>FB-SHEVS ¹)</td>
<td>+</td>
</tr>
<tr>
<td>FB-SHEVS ¹)</td>
<td>-</td>
</tr>
<tr>
<td>M-SHEVS</td>
<td>+</td>
</tr>
<tr>
<td>M-SHEVS</td>
<td>-</td>
</tr>
</tbody>
</table>

¹) Not practical for underground applications

The number of required air changes for M-SHEVS is 8 per hour.

7.4 High Occupancy Applications

<table>
<thead>
<tr>
<th>Concept</th>
<th>Smoke control applicability with regards to occupant count</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Up to 2000</td>
</tr>
<tr>
<td>M-SHEVS</td>
<td>+</td>
</tr>
</tbody>
</table>

The number of required air changes for M-SHEVS is 8 per hour.

7.5 Car Parks

<table>
<thead>
<tr>
<th>Concept</th>
<th>Smoke control applicability with regards to compartment size (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(incl. intermediate floors and mezzanines)</td>
</tr>
<tr>
<td></td>
<td>Enclosed rooms</td>
</tr>
<tr>
<td></td>
<td>Up to 3600 m²</td>
</tr>
<tr>
<td>N-SHEVS ¹)</td>
<td>+</td>
</tr>
<tr>
<td>N-SHEVS ¹)</td>
<td>-</td>
</tr>
<tr>
<td>FB-SHEVS ²)</td>
<td>-</td>
</tr>
<tr>
<td>M-SHEVS</td>
<td>+</td>
</tr>
<tr>
<td>M-SHEVS</td>
<td>-</td>
</tr>
</tbody>
</table>

¹) Not practical for underground applications

²) Not practical in underground applications past the first level

The number of required air changes for FB-SHEVS and M-SHEVS is 8 per hour.
Example 1
FB-SHEVS, Parking, first basement floor
Example 2
M-SHEVS, Supermarket, open and multistorey
8 Guidelines

Fire

Guideline No. 1:2015 F - Fire protection management system
Guideline No. 2:2013 F - Panic & emergency exit devices
Guideline No. 3:2011 F - Certification of thermographers
Guideline No. 4:2010 F - Introduction to qualitative fire risk assessment
Guideline No. 5:2003 F - Guidance signs, emergency lighting and general lighting
Guideline No. 6:2011 F - Fire safety in care homes for the elderly
Guideline No. 7:2011 F - Safety distance between waste containers and buildings
Guideline No. 8:2004 F - Preventing arson – Information to young people
Guideline No. 9:2012 F - Fire safety in restaurants
Guideline No. 10:2008 F - Smoke alarms in the home
Guideline No. 11:2005 F - Recommended numbers of fire protection trained staff
Guideline No. 12:2012 F - Fire safety basics for hot work operatives
Guideline No. 13:2015 F - Fire protection documentation
Guideline No. 14:2007 F - Fire protection in information technology facilities
Guideline No. 15:2012 F - Fire safety in guest harbours and marinas
Guideline No. 16:2008 F - Fire protection in offices
Guideline No. 17:2015 F - Fire safety in farm buildings
Guideline No. 18:2013 F - Fire protection on chemical manufacturing sites
Guideline No. 19:2009 F - Fire safety engineering concerning evacuation from buildings
Guideline No. 20:2012 F - Fire safety in camping sites
Guideline No. 21:2012 F - Fire prevention on construction sites
Guideline No. 22:2012 F - Wind turbines – Fire protection guideline
Guideline No. 23:2010 F - Securing the operational readiness of fire control system
Guideline No. 24:2010 F - Fire safe homes
Guideline No. 25:2010 F - Emergency plan
Guideline No. 26:2010 F - Fire protection of temporary buildings on construction sites
Guideline No. 27:2011 F - Fire safety in apartment buildings
Guideline No. 28:2012 F - Fire safety in laboratories
Guideline No. 29:2013 F - Protection of paintings: Transport, exhibition and storage
Guideline No. 30:2013 F - Managing fire safety in historical buildings
Guideline No. 31:2013 F - Protection against self-ignition and explosions in handling and storage of silage and fodder in farms
Guideline No. 32:2014 F - Treatment and storage of waste and combustible secondary raw materials
Guideline No. 33:2015 F - Evacuation of people with disabilities
Guideline No. 34:2015 F - Emergency power supplies
Guideline No. 35:2015 F - Smoke and heat exhaust ventilation systems. Planning and design
Natural hazards
Guideline No. 1:2012 N - Protection against flood
Guideline No. 2:2013 N - Business Resilience – An introduction to protecting your business
Guideline No. 3:2013 N - Protection of buildings against wind damage
Guideline No. 4:2013 N - Lightning protection
Guideline No. 5:2014 N - Managing heavy snow loads on roofs

Security
Guideline No. 1:2010 S - Arson document
Guideline No. 2:2010 S - Protection of empty buildings
Guideline No. 3:2010 S - Security system for empty buildings
Guideline No. 4:2010 S - Guidance on key holder selections and duties
Guideline No. 5:2012 S - Security guidelines for museums and showrooms
Guideline No. 6:2014 S - Emergency exit doors in non-residential premises