REHVA

Fire safety in buildings-
Smoke Management Guidelines

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Introduction to Fire Safety in Buildings

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Fire Safety in Buildings

Smoke Management Guidelines

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Introduction to Fire Safety in Buildings

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Introduction to Fire Safety in Buildings

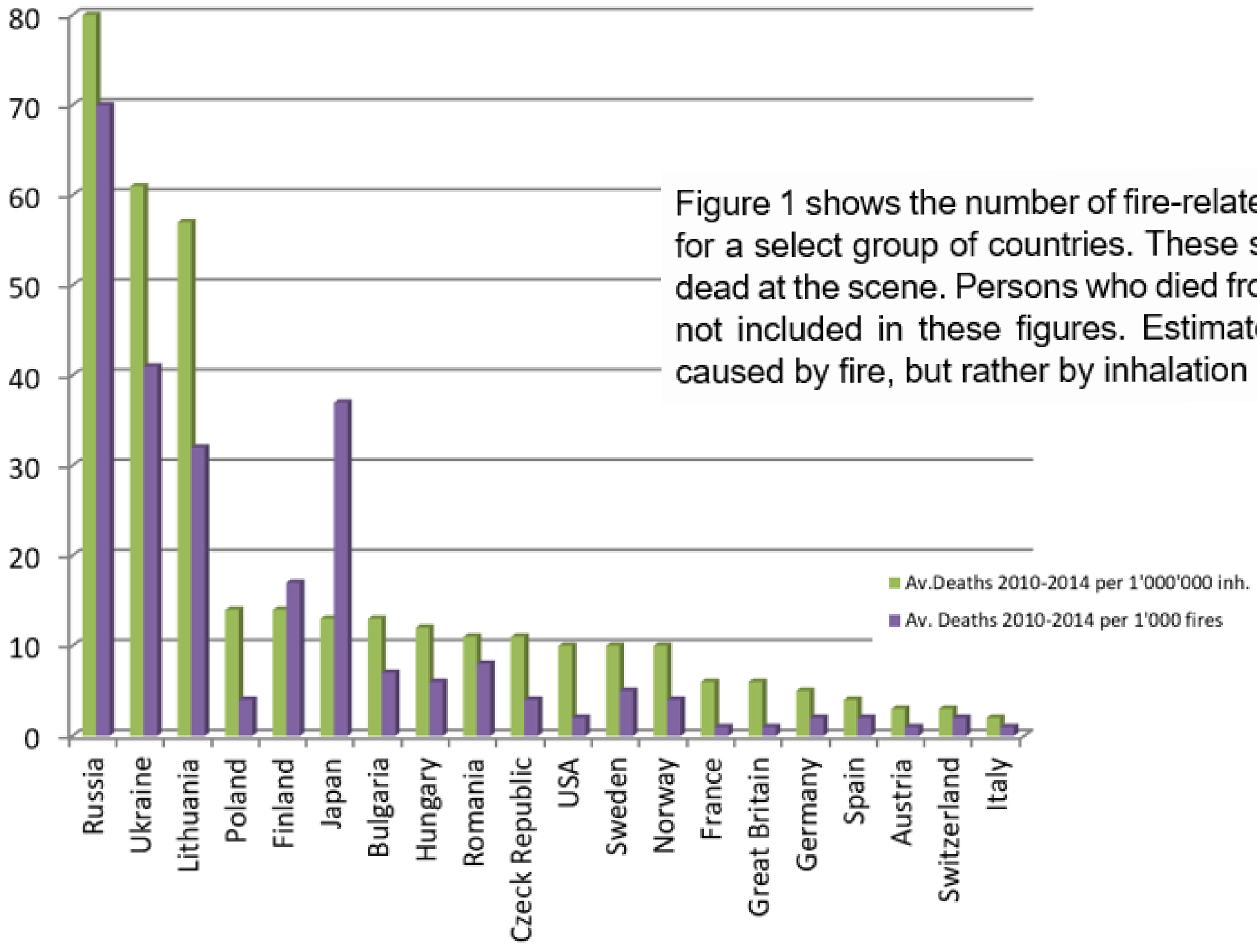


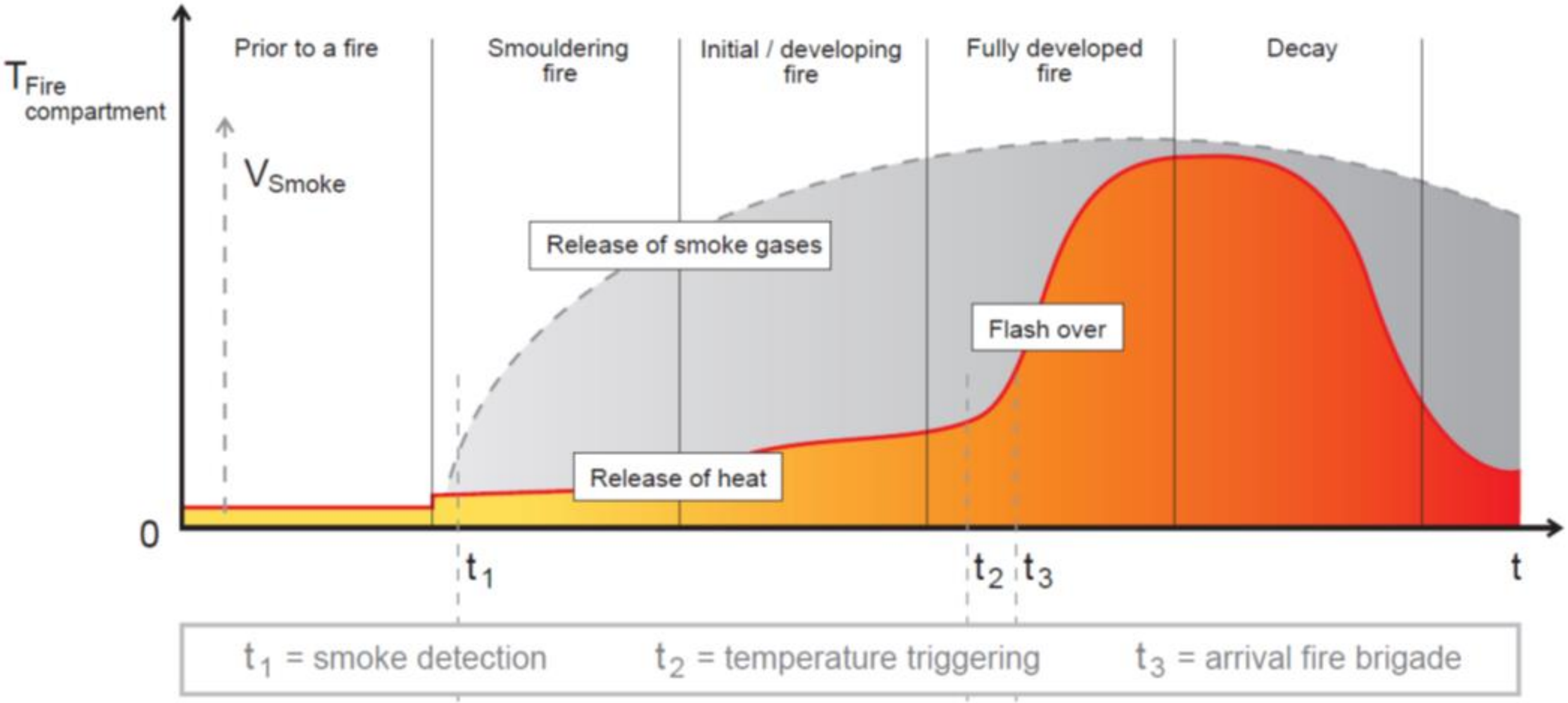
Figure 1 shows the number of fire-related deaths by country in relation to population and number of fires for a select group of countries. These statistics generally only account for victims who were recovered dead at the scene. Persons who died from fire-related injuries after removal from the scene are generally not included in these figures. Estimates indicate that more than 90% of fire-related deaths are not caused by fire, but rather by inhalation of toxic fire gases (smoke).

Figure 1: International statistics on fire-related deaths

Content… (1)

Content

Basics…



T Fire compartment
V Smoke
Prior to a fire
Smouldering fire
Initial / developing fire
Fully developed fire
Decay
Release of smoke gases
Flash over
Release of heat
0
t1
t2
t3
t
t1 = smoke detection
t2 = temperature triggering
t3 = arrival fire brigade

What...

4 Smoke control systems

4.1 Natural smoke and heat exhaust ventilation (NSHEV)

Figure 15: Principle of natural smoke extraction

The differences in function of natural smoke and heat exhaust ventilation (NSHEV) and smoke and heat exhaust ventilation systems (SHEVS) have already been pointed out. As concerns the flow-mechanical processes, the main components of NSHEV are the natural smoke and heat exhaust ventilation equipment (NSHEV or smoke vents) in the roof or upper wall area of the room – or, ideally, supply air surfaces near the floor. The smoke extraction and/or flow of the room is based on the pressure differentials resulting from varying temperatures between the room and the environment. Dimensioning such systems essentially involves the task of determining the size of the NSHEV and supply air surfaces.

4.2 Smoke and heat exhaust ventilation system (SHEVS)

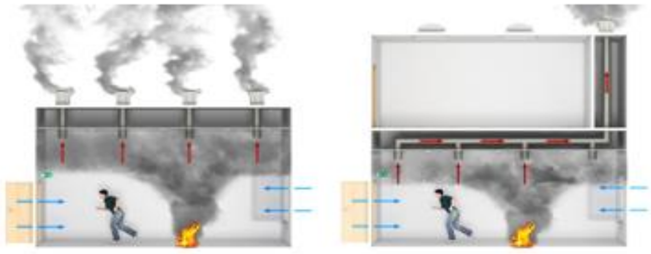


Figure 16: Examples of mechanical smoke extraction

In the case of smoke and heat exhaust ventilation systems, smoke is extracted by means of smoke control fans installed in the room's ceiling. There may be additionally mounted smoke control ducts between a fan and individual extraction points in the room and motor-driven smoke control dampers for targeted guidance and efficient control of the fire gases. The designing of smoke and heat exhaust ventilation systems is primarily about determining the fan data with respect to the conveyed volume flow, the necessary increase in pressure as well as the temperature class of the smoke control fan and the size of the required supply air surface.

4.3 Pressure differential systems (PDS)

Pressure differential systems (PDS) are installed to prevent the inflow of smoke in safety staircases, their lobbies as well as in fire-brigade lift shafts and their lobby areas.

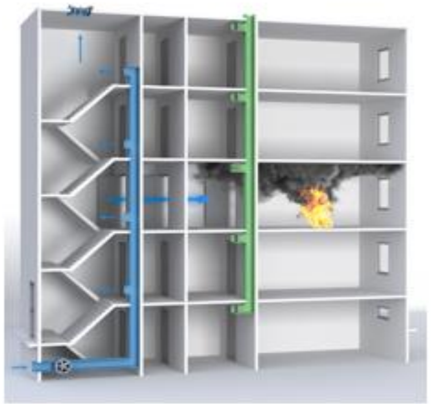


Figure 17: Principle shows smoke control by pressure differential systems

The typical spread of smoke across lobby doors, which connect the corridor of a floor of origin to a stairwell, is shown in Figure 18. In the upper door area, smoke flows from the corridor into the stairwell, while air from the stairwell is conveyed to the corridor at floor level. This is caused by the temperature difference between the two room areas. The intensity of such exchange flow increases as the temperature differential rises.

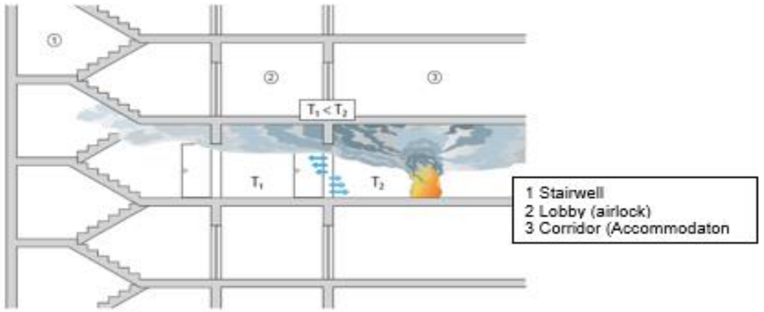


Figure 18: Spreading of smoke from a floor into the stairwell with open lobby doors, without PDS (schematic outline)

Dilution…

Dilution

As concerns the room conditions, smoke control is characterised by dilution due to largely homogeneous areas of concentration of temperature (and smoke). This air flow condition of the room is mainly shaped by the room's air intake, which is influenced substantially by the size and position of the air supply surfaces. Particularly small air supply surfaces, located in the upper area of the room, create supply air streams with relatively high flow speeds. The induction effect of the supply air streams creates a flow that fills the room, causing smoke to be distributed virtually evenly throughout the entire room volume in the event of a fire.

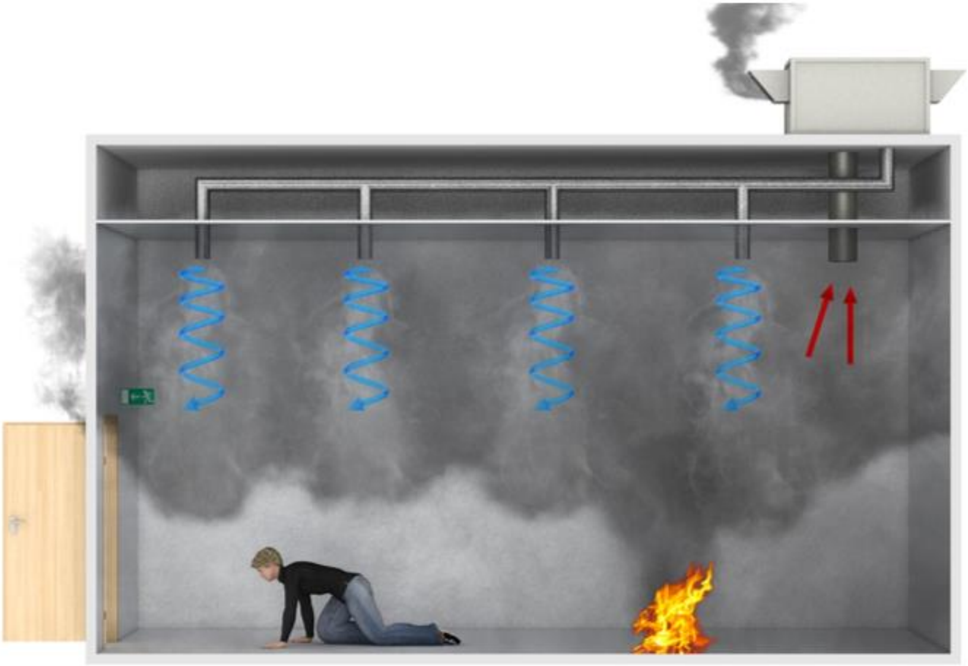


Figure 4: *Dilution of fire gases (smoke)*

Layering…

Layering

An essential element of smoke extraction through layering is a low-impulse air supply in the lower section of the room. In this case, the supply air speeds are so small (typical values $\leq 1\,m/s$) that the supply air does not trigger a room-filling flow. The air flow is then primarily defined by the plume forming above the source of the fire. This plume transports the combustion products created by the fire and the heat flow convectively released to the upper section of the room. They will be extracted and discharged from the room naturally – ideally, through vents in the ceiling – or mechanically by means of fans. Two gas layers on top of each other form in the room under such conditions.

Figure 8: Layering of smoke gases (for example, in case of a mechanical smoke extraction system)

Pressure differential system…

Pressure differential systems (PDS)

Ideally, escape routes are kept free of smoke for a sufficient amount of time in the event of a fire. Smoke control by pressurezation systems have proved to be a qualified method of displacement. This involves a fan that creates excess pressure for the escape route, thus preventing smoke penetration. The approach is based on vent surfaces in the area affected by the fire and/or in upstream airlocks. Through special air discharge vents, the pressure differential is controlled in such a manner that doors to the escape route can still be opened. Small amounts of smoke that might have spread into the escape route can be discharged. In addition, the temperature in the escape route is also decreased by blowing in fresh air. In the event of fire, users will be alerted quickly and can escape, or be rescued, without any risk. This facilitates the fire-brigade's fire-extinguishing access.

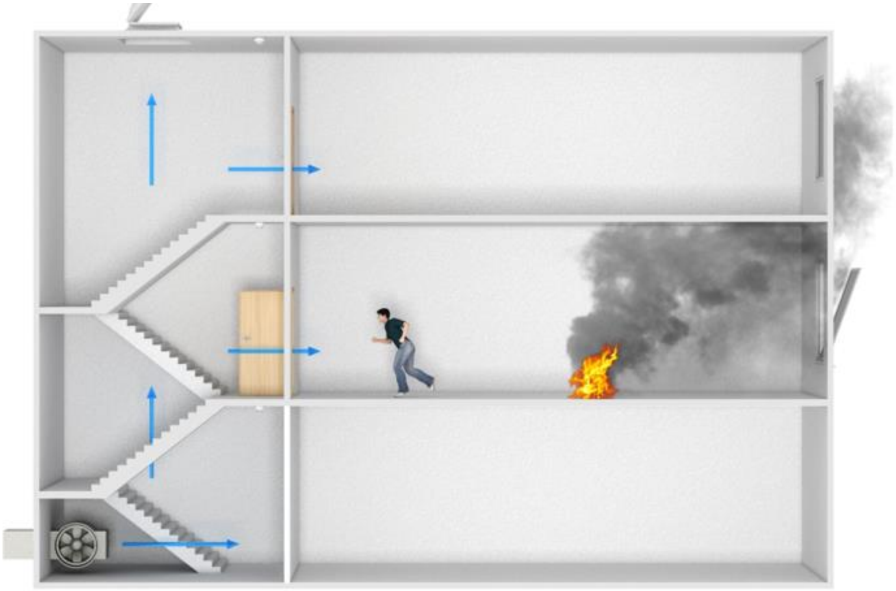


Figure 9: Displacement of smoke gases (for example, through pressure differential systems)

Specific application…

Creation of smoke compartments by isolation or displacement

In many cases, it is useful to divide fire compartments into smoke compartments. Smoke compartments prevent or contain the spread of smoke in the building. In ideal circumstances, it allows for smoke to be extracted at the source, thus keeping escape routes usable for a sufficient amount of time. Smoke compartments can be created through structural (e.g., smoke curtains) or equipment-specific measures.

A special type of creating a smoke compartment is vortex smoke extraction. This method uses special extraction elements (vortex hoods). They allow for a constant, linear capture of the smoke across the width of the smoke compartment. In addition, they create a high negative pressure near the extraction point.

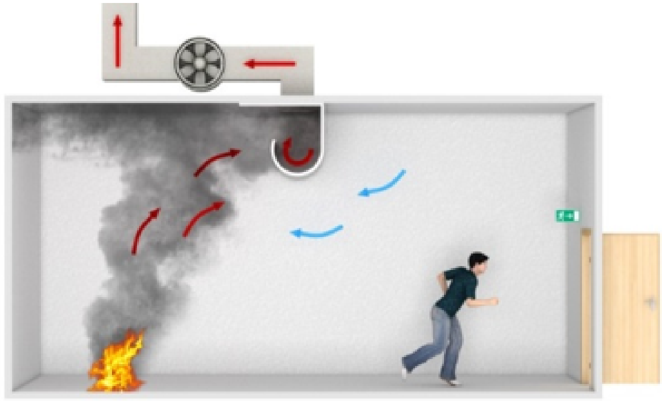


Figure 10: Principle of vortex smoke extraction

Specific application…

Jet fans are often used in underground parking and tunnels that move the smoke in a specific direction depending on the situation. As a rule, additional supply air and mechanical smoke control fans for the extraction are necessary. Jet fans destroy the smoke layering in the direction of the extraction. This is why jet fans should be activated only once the self-rescue of people in the affected area has been completed.

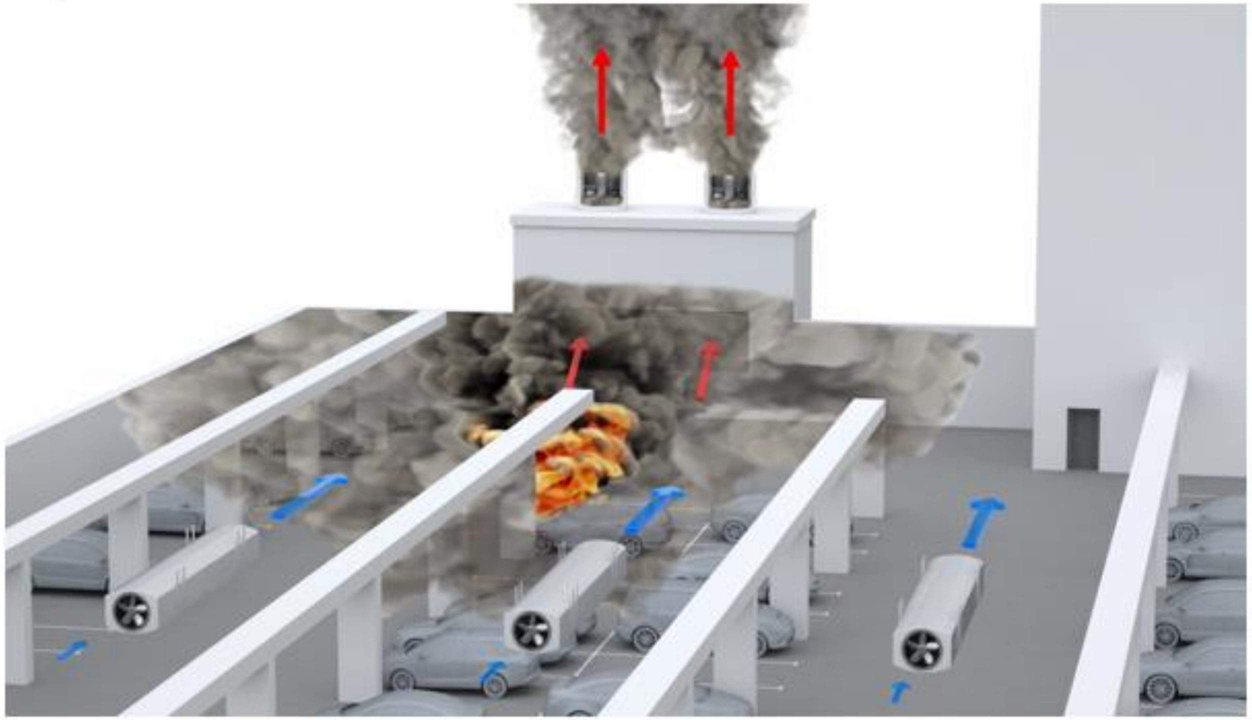


Figure 12: Displacement of smoke gases (e.g., through jet fans)

Dimensioning...

Dimensioning methods and how these are applied to systems

Dimensioning methods

General

The dimensioning of systems for smoke control is generally based on the protection objective to maintain a low-smoke layer, the height of which is relative to the height of the building and/or utilisation. Essentially, three methods are used for dimensioning in this context:

- Zone models,
- CFD models (field models),
- Model experiments.

Especially the first two methods are available to users today as computer programs. Thanks to modern graphical user interfaces, they are easy to use. But this ease of handling comes at the risk that application conditions may be ignored and/or application limits exceeded.

The engineering methods for dimensioning smoke control systems are all derived from the flow-mechanical conservation equations for mass

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u_x)}{\partial x} + \frac{\partial(\rho u_y)}{\partial y} + \frac{\partial(\rho u_z)}{\partial z} = 0, \qquad (1)$$

pulse (only the x component is stated here; the equations for the y and z components are obtained through simple index permutation)

$$\frac{\partial(\rho u_x)}{\partial t} + \frac{\partial(\rho u_x^2)}{\partial x} + \frac{\partial(\rho u_x u_y)}{\partial y} + \frac{\partial(\rho u_x u_z)}{\partial z} = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} + g_x \rho \qquad (2)$$

and (thermal) energy

Content view… (2)

Components...

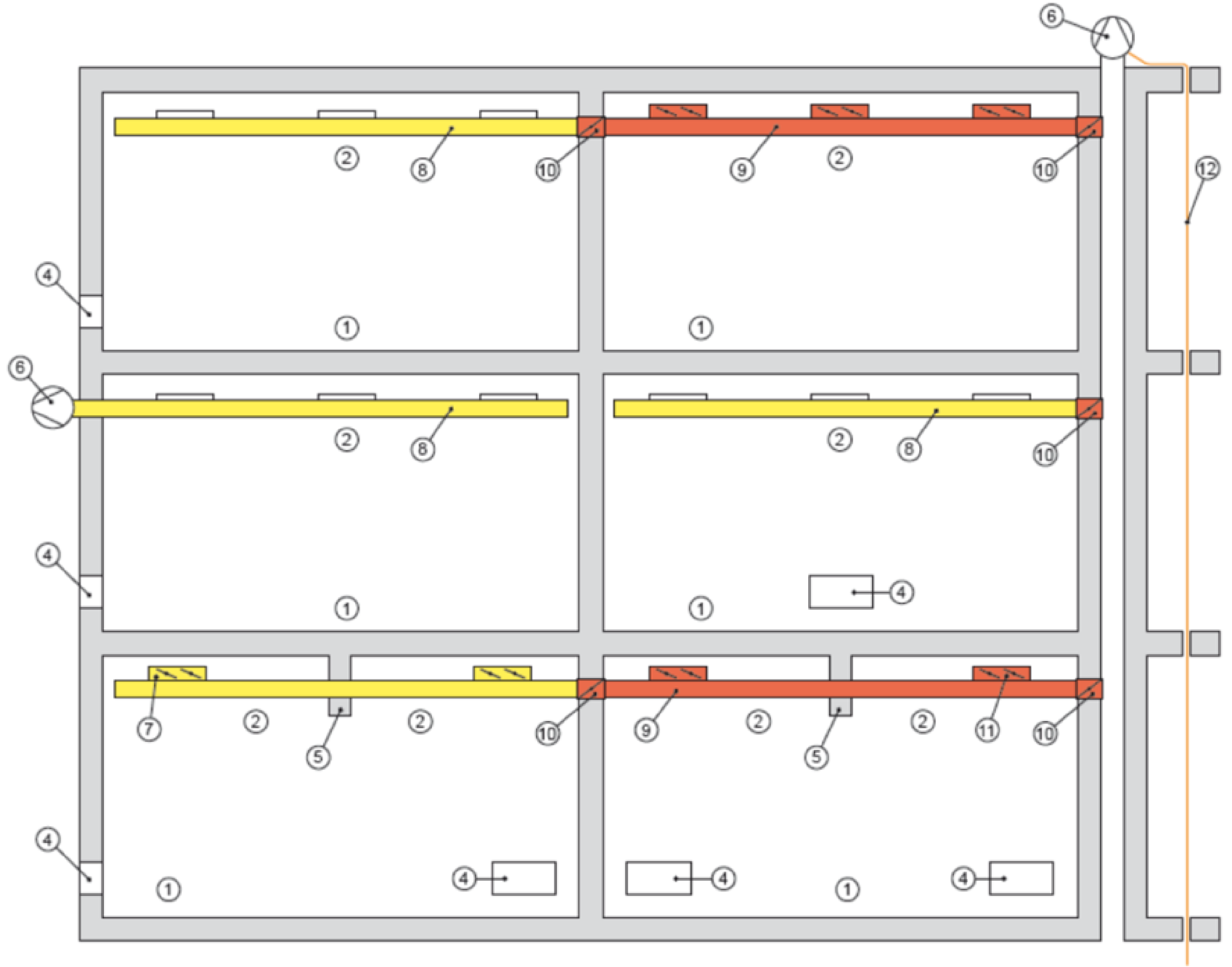


Figure 41: Example for mechanical smoke and heat extraction (EN 12101-8)

Components…

Overview of smoke control dampers

Controls	Single Compartment	HOT 400	Multi Compartment
Automatic activation (AA) Fire test: OPEN Command after 30 s	 - 600°C Damper with actuator - Actuator without thermal protection	- per definition, this damper does not exist	 - Standard temperature curve (fire curve) with actuator - Actuator without thermal protection
Manual intervention (MA) Fire test: OPEN Command after 25 min. HOT 400: Cycling at 400 °C	  - 600°C damper with actuator - Actuator with thermal protection	 - Fire damper modified as HOT 400 damper - Actuator with thermal protection	  - Standard temperature curve (fire curve) damper with actuator - Actuator with thermal protection

Figure 46: Examples of different classifications and possible designs

View into content… (3)

Fire alarm concept…

The fire alarm concept indicates the setup of a fire alarm system, such as the one shown in Figure 54.

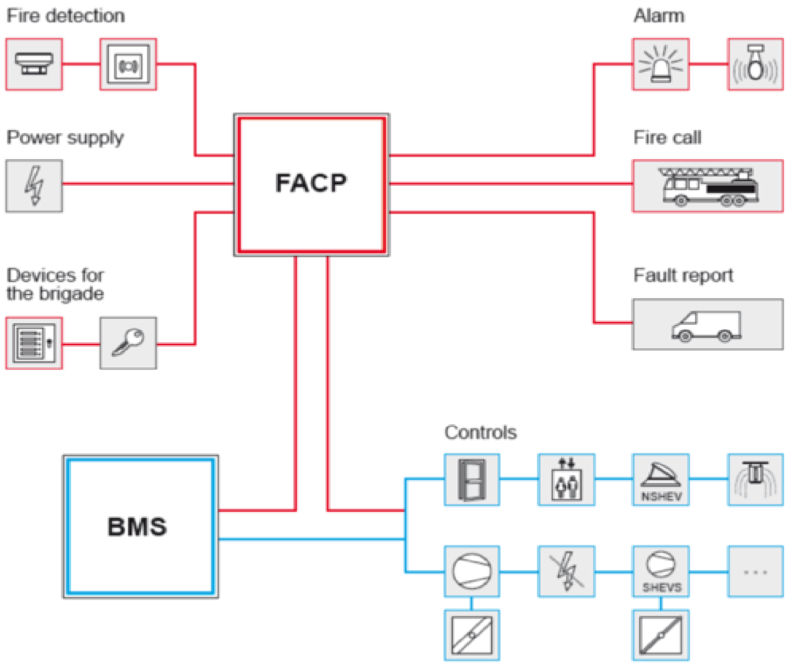


Figure 54: Setup of a fire alarm system

Activation of fire protection devices

The activation of fire protection devices, frequently referred to as fire control, includes, for example, the reliable triggering and/or activation of:

- Automatic fire extinguishing systems
- Smoke control systems

Risk analyses…

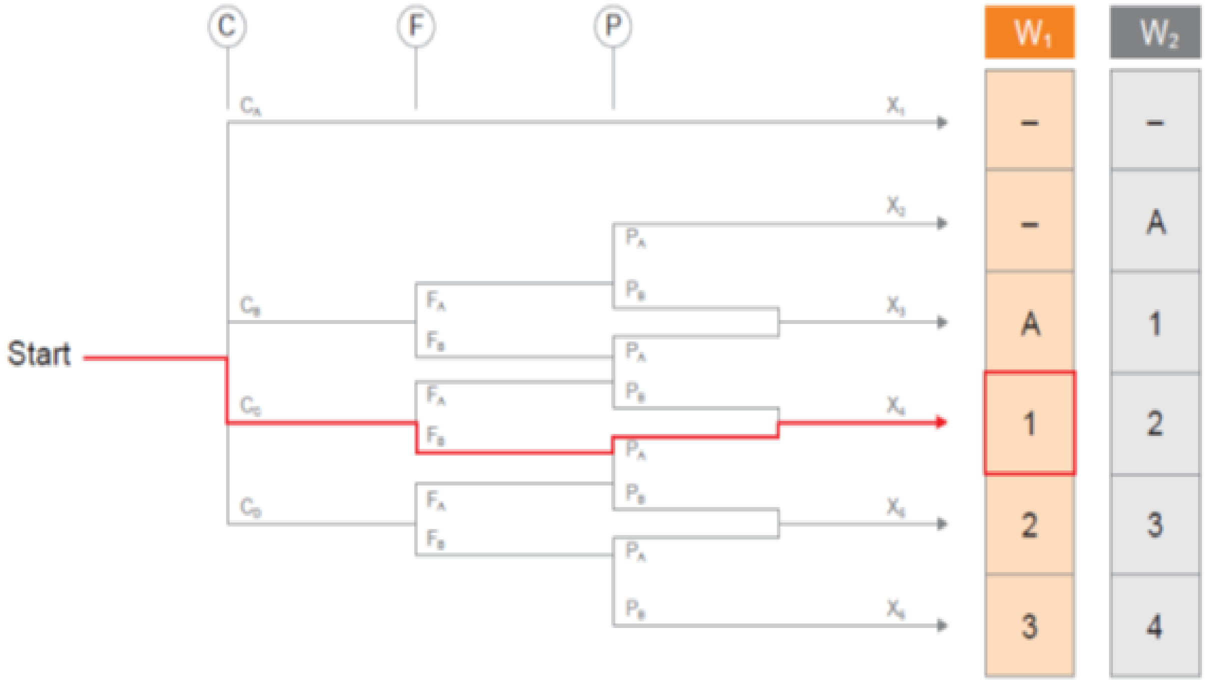


Figure 56: Example of a risk graph

Wiring concepts…

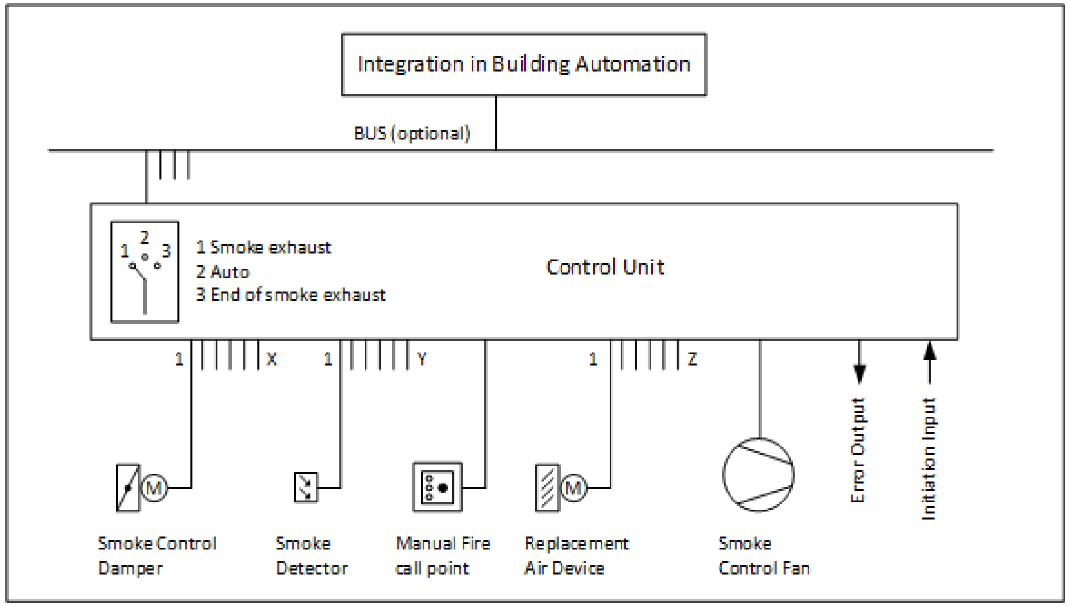


Figure 58: Conventional control and activation (principle)

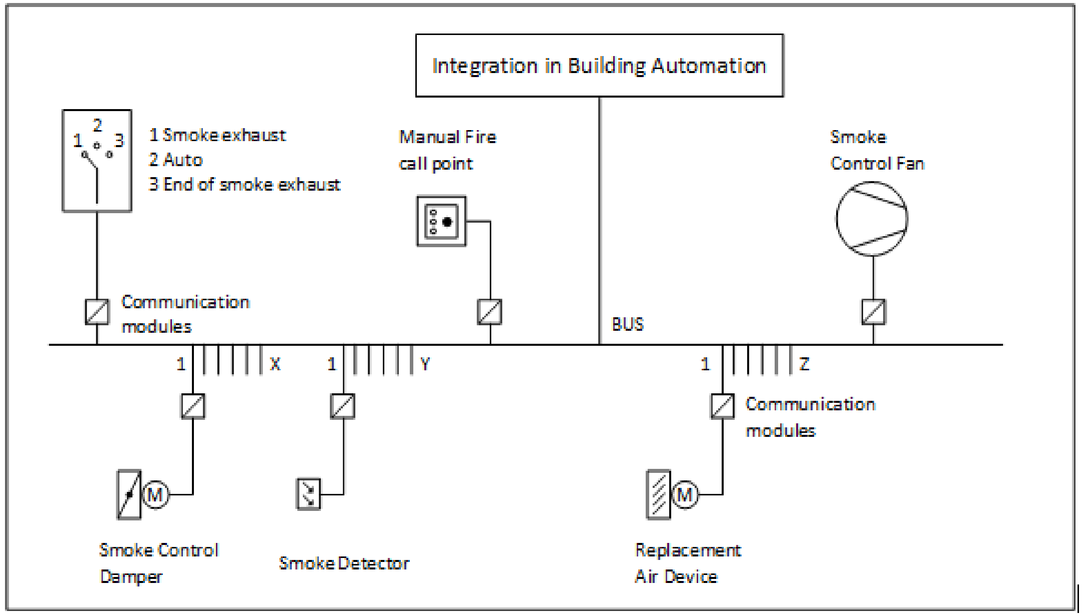


Figure 59: Control in bus technology (principle)

..view into the content... (4)

Annexes...

Pressure differential systems (PDS) – additional information

Pressure differential systems (PDS) are installed to prevent the inflow of smoke in safety staircases, their lobbies as well as in fire-brigade lift shafts and their lobbies.

The typical spread of smoke across lobby doors, which connect the corridor of a floor of origin to a stairwell, is shown in Figure 61. In the upper door area, smoke flows from the corridor into the stairwell, while air from the stairwell is conveyed to the corridor at floor level. This is caused by the temperature difference between the two room areas. The intensity of such exchange flow increases as the temperature differential rises. The mean flow speed of the smoke in the door cross-section can be estimated by

$$\bar{u}_R = 1{,}98 \sqrt{h_T \left(1 - \frac{T_V}{T_F}\right)} \qquad (84)$$

with

$\bar{u}_R$	being the mean flow speed of the smoke in m/s in the door cross-section,
h_T	being the clear door height in m,
T_F	being the mean temperature in K in the corridor,
T_V	being the mean temperature in K in the lobby.

Annexes…

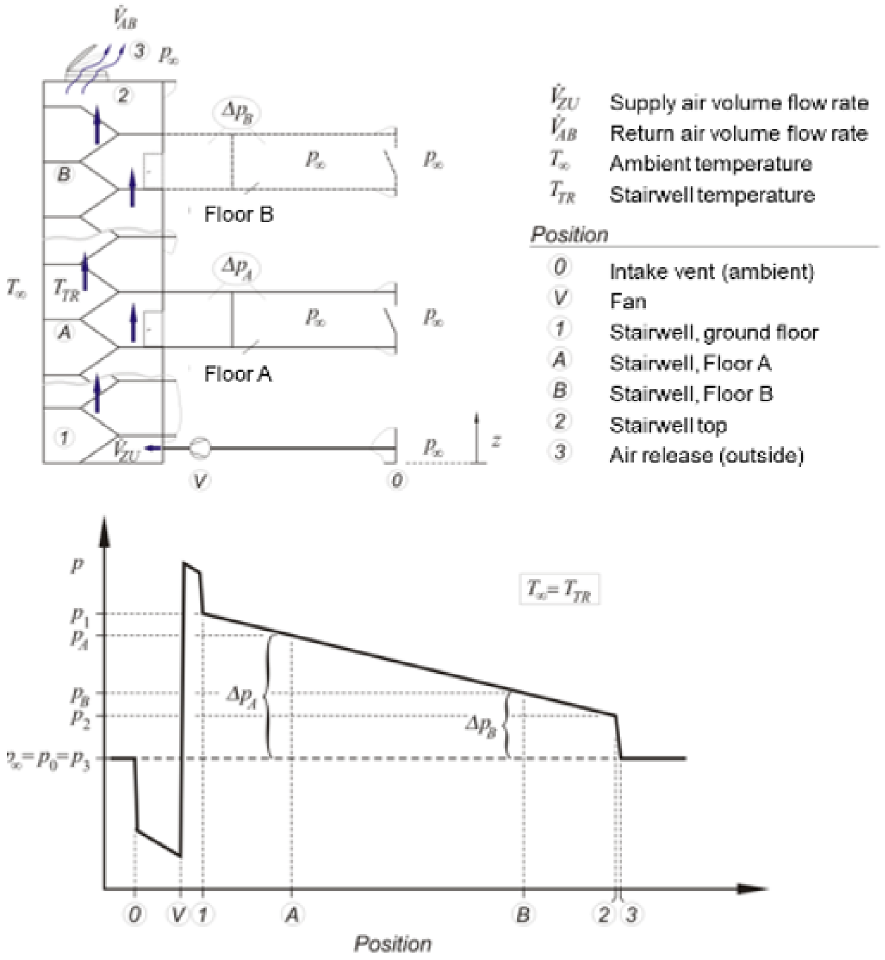


Figure 68: *Pressure gradient in a stairwell when operating a PDS, neglecting any leakage losses (isothermal conditions)*

Annexes…

Pedestrian flow movement during fire evacuation

General principal of travel speed analysis

The main indicator of motional activity of a crowd moving simultaneously on the same route in the same direction as its reaction to the conditions of the environment is the speed of the human flow[21] [22]. It is well-known that the velocity of the human flow (V) depends on the type of routes (j), the density of flow (D) and the level of emotional state (e). In other words, the velocity is the function of these factors and its value at the i section of the route can be represented as $V^{e}_{j,Di}$. The purpose of the field observations and these experiments is to establish the relation between the human flow velocity and other multiple factors. The flow velocity is defined by the mean values of individual travel speed V_n of N people moving on a particular section of route, i.e.:

$$V^{e}_{j,Di} = \sum_{1}^{n} V_n / N \qquad (92)$$

Annexes…

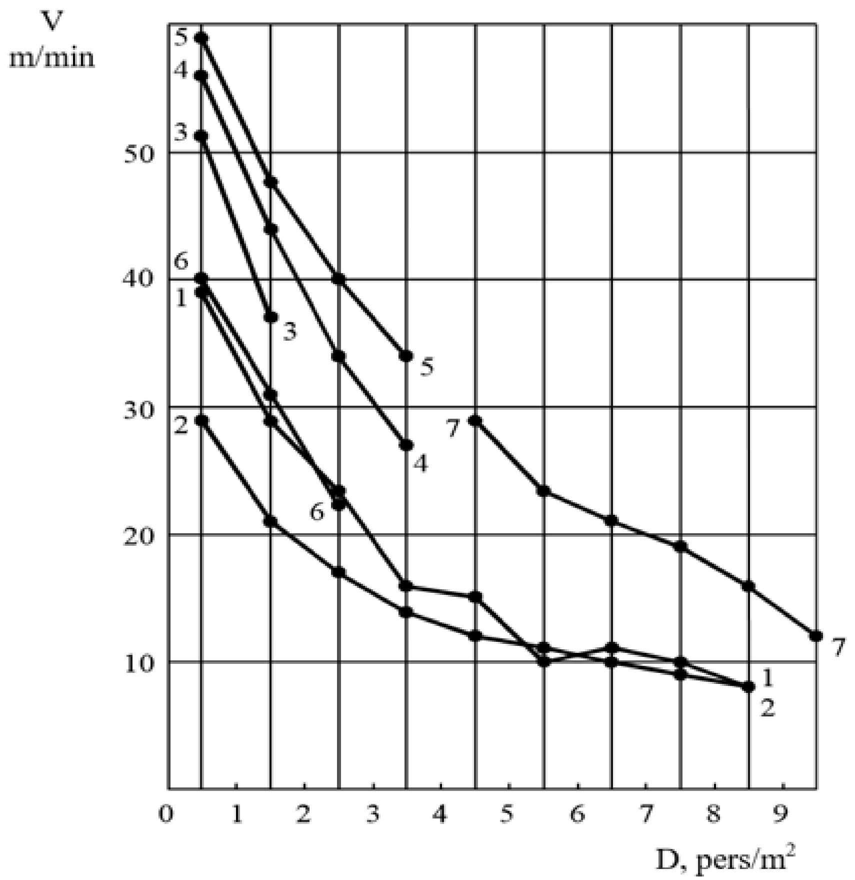


Figure 73: Empirical relationships between travel speed of human flow and density, which were obtained at the end of the 1970s (stairs upwards)

How to use this guidebook

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Target groups…

- consulting engineers
- building authorities
- fire officers
- contractors
- facility managers
- students
- fire fighters
- interested parties in fire protection (in general)

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