



TLT-Turbo GmbH

Am Weinberg 68 · D-36251 Bad Hersfeld / Germany
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TLT-TURBO GMBH STANDARD FAN PRODUCTION PLANT AT BAD HERSFELD

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TLT standard fan production plant at Bad Hersfeld

Our Bad Hersfeld facility has a history going back to 1874, when Benno Schilde and August Büttner founded their factories here.

The “exhausters” traditionally made of cast iron could be built much lighter and cheaper through the use of steel sheet.

At Büttner the focus was initially on blowers for tubular boilers and dryers, then shifted to heavy-duty industrial fans as required specifically in power plant de-dusting applications. Schilde, meanwhile, stepped up its research and development of light-duty ventilating fans and medium-duty industrial blowers. Numerous patents and registered designs testify to a steady flow of engineering breakthroughs. With the erection of its series production facility at Bad Hersfeld, dedicated mainly to the cost-effective production of roof fans, the Babcock-BSH Group gained a leading market position both in Germany and abroad. The Turbo-Lufttechnik GmbH (TLT) – Bad Hersfeld site - was newly esta-

blished in June 1995, now integrating Babcock-BSH's Air and Thermal Engineering division.

The “TLT-Turbo GmbH”, newly established in March 2003 as a company in their own rights, belongs to AG Kühnle, Kopp & Kausch, Frankenthal.

TLT now is one of the world's leading fan manufacturers and our competence is expressed in mature and very economical products. Our two R&D centres at Zweibrücken and Bad Hersfeld guarantee a continuing process of always adapting all TLT products to the latest demands of the market.



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SMOKE (FUME) EXHAUST FANS FUNDAMENTALS

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3.0 Basic considerations

Some recent fires have reminded us of the vast potential for destruction, injury and loss of life that fire may have. Its perils lie in the blaze that forms the core of the disaster and in its products such as smoke and heat, both of which are at their most hazardous form in a "captive" state, i.e., within an enclosed building. Practical experience has shown that the smoke is much more dangerous to human beings than the heat (flames). According to fire statistics, two-thirds of all deaths due to fire result from suffocation and smoke poisoning, while one-third is caused by burns and collapsing buildings. These observations confirm the dominant role of smoke as a threat to human beings in the event of a fire. Moreover, hot smoke and combustion gases, in conjunction with thermal buoyancy effects, may literally "pre-heat" those building areas to which the flames themselves have not yet spread, thus paving the ground for their propagation.

These conditions and hazards impose a whole set of requirements for an effective preventive fire protection strategy. The main objectives can be summarized thus:

- **Smoke extraction**
- **Smoke dilution**
- **Keeping escape routes and rescue accessways clear of smoke so as to facilitate the fire-fighting effort.**

To prevent the fire from spreading, the heat of combustion must be removed from the building along with the smoke. In modern building services engineering, mechanical smoke and heat exhaust systems have therefore become a standard feature since they effectively protect lives and property. The heart of such a smoke and heat exhaust system are the smoke exhaust fans.

4.0 History of TLT smoke exhaust fans

In the early '70s, a fire in a PVC film manufacturing shop devastated the production facilities of Kalle AG in Wiesbaden, a leading manufacturer of packaging film. Presumably, an overheated bearing had ignited a small quantity of PVC and caused a local smouldering fire that nevertheless released clouds of billowing smoke. The damage was assessed at several millions DM.

The high loss was caused by the hydrochloric acid vapours which inevitably form in the combustion of PVC. These gases attacked all unprotected metal surfaces of the film making line, which had to be scrapped as a result. Kalle's works fire department contacted the Hersfeld-based BSH company, their traditional fan supplier, and requested the development of a fan that would be able to extract smoke, fumes and toxic matter via the roof. Starting out from their standard roof fan range, BSH (now TLT) set out to develop a roof-mounted smoke exhaust fan rated for "higher temperatures". Following extensive in-house testing, the unit was finally classified for 400°C service for a duration of 120 minutes.

Thus, the "smoke exhaust fan" was born, although a market warranting volume production or even promising significant sales revenue had yet to be identified. At the time, stationary smoke exhaust fans were virtually unknown as a preventive fire protection solution. Through word of mouth in the fire-fighting and consulting experts' community and an intense information and sales promotion effort directed by BSH at fire authorities, building supervision offices, architects and specifiers, the potential of smoke/fume exhaust fans was soon established. In addition to the roof-mounted fan versions, the market soon demanded diverse other designs since smoke and fumes cannot always be extracted via the building roof. Thus, BSH began to develop smoke exhaust fans for wall installation and floor-mounted units for use inside buildings. Today, Turbo-Luft-

technik GmbH of Bad Hersfeld supplies a complete range of smoke and fume exhaust fans for virtually any application. Needless to say, each model is fully tested and certified according to the latest European standards and regulations. And it all began with that "small fire" at Kalle AG in Wiesbaden.





5.0 Legal basis

Although in Germany the conference of the Ministers of Urban Planning, Housing and Construction (ARGEBAU) has imposed a model building code (MBO) for reference by the federal states, building law has in essence remained the responsibility of the latter.

As a result, applicable building law is enshrined in the State Building Code (LBO) of each federal state. It follows that fire protection requirements vary regionally.

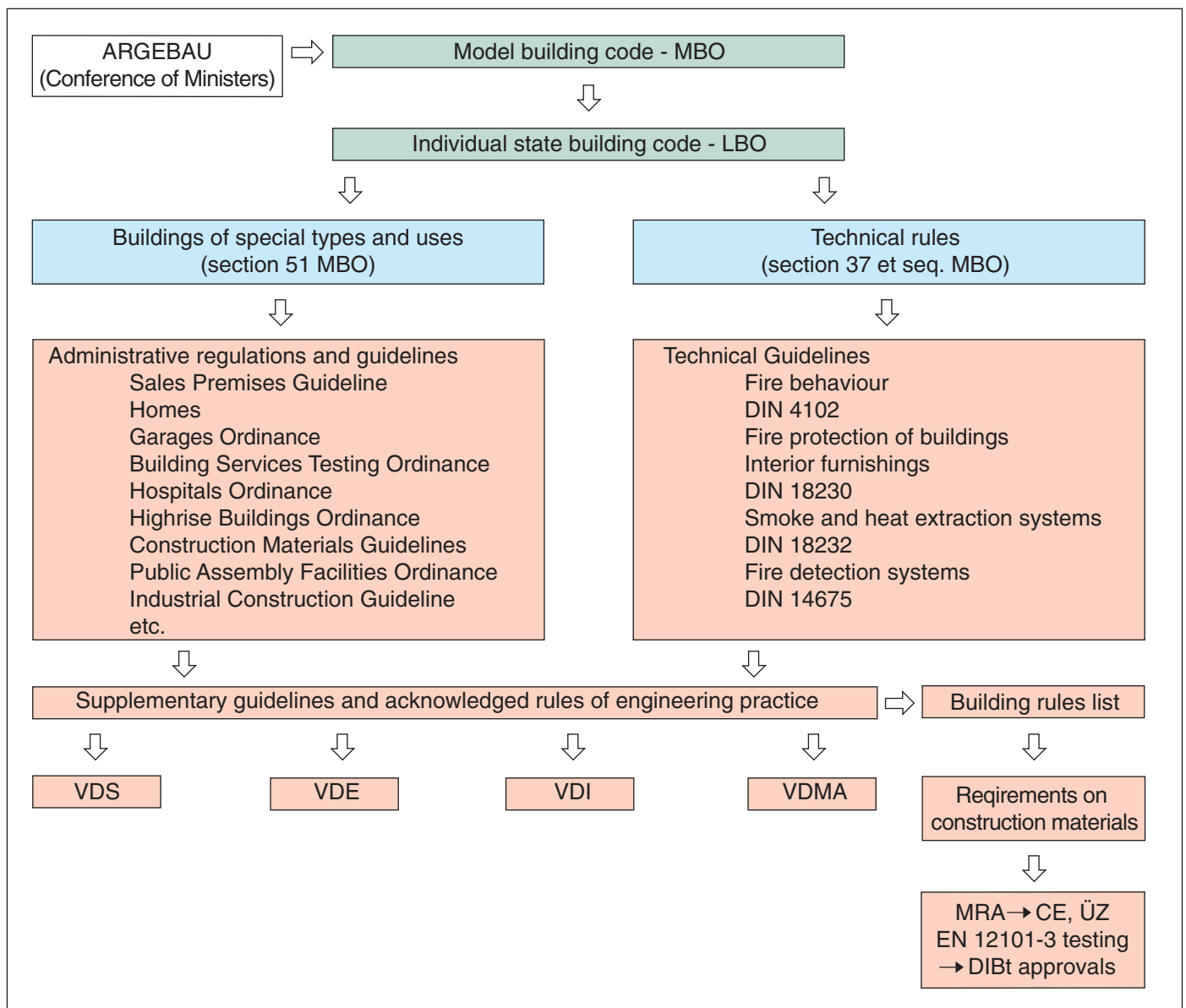
However, each LBO code applies to all construction activities and equipment. It is supplemented by building law standards for classified construction materials, components, and special components.

A review of the building codes for the various federal states with regard to fume and smoke extraction reveals a common principle that features in all German building regulations. Referring to smoke and heat control, section 17(1) contains the following provision:

"Structures shall be designed such that the outbreak of fire and the propagation of flames and smoke are effectively prevented, and that human beings and animals can be rescued and an effective fire-fighting effort can be launched should a fire nevertheless occur."

Considering this being a general formulation, the aim of the efforts can be seen clearly though.

Laws, regulations and codes





5.1 Objectives in preventive fire protection

The rather general provisions of section 17 at least serve to define the overriding objective.

This is to maximize the hazard prevention effort so as to achieve a maximum degree of fire safety. In global terms, this goal implies the following:

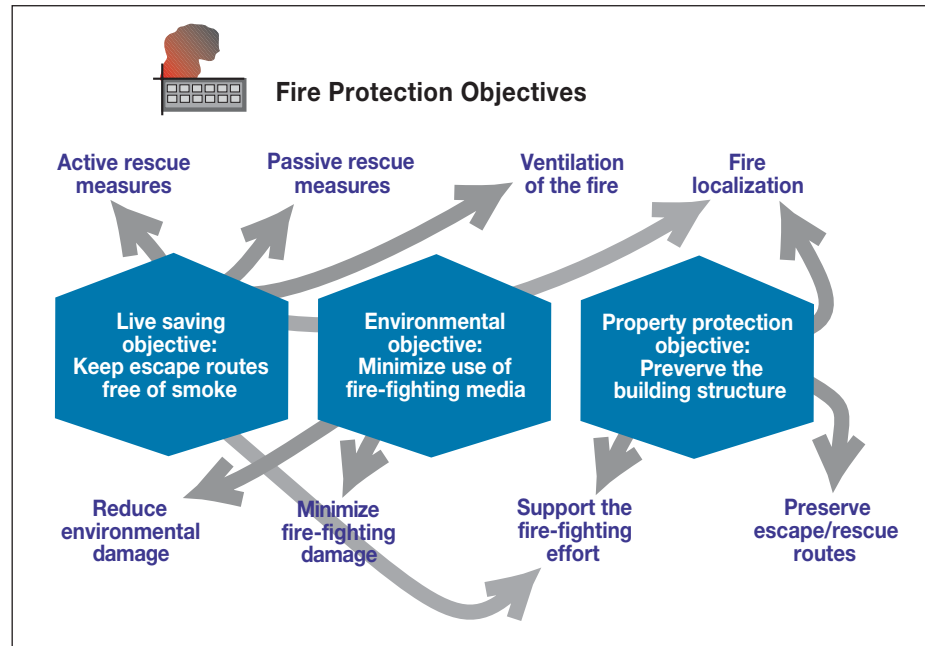
- Restriction of flame propagation
- Securing the rescue of human beings and animals
- Ensuring the feasibility of fire-fighting activities

Given the interrelationship between construction, building services and equipment technology, it emerges that the steps aimed at achieving these goals cannot be viewed in isolation but must always be judged and assessed in the common context. Smoke and heat control, which will always form an integral part of any overall building protection strategy, is no exception to this rule.

5.2 Personal liability

In the period since 1994, nearly all German states have amended their building codes in an effort to simplify and accelerate the construction process. The aim was to reduce the amount of regulatory intervention and to strengthen the responsibility of the building/project owner. In essence, preventive inspection and testing requirements are limited to a small number of building or structural criteria. Wherever the building authorities have thus shed their original responsibilities, liability now rests with the building owner. As a result, owners will usually have to enlist expert aid (architects, consultants) to have the building inspected on their behalf for compliance with all material aspects of the building code.

Not many building professionals such as architects, planners and experts are aware of the resulting responsibility and indeed, personal liability, they assume through the exercise of their profession. Thus, section 323 of the



German Criminal Code relating to environmental offences stipulates the following:

"Any person engaged in the planning, management or execution of a building construction activity who violates generally accepted rules of practice, thereby endangering the life or health of another, shall be punished with up to five years' imprisonment, or imposition of a fine."

It follows that planners, experts and other professionals, apart from being aware of the standards and guidelines described in section 3.3, should make a continuous effort to remain on top of the "accepted rules of practice".

This leads us to the question of how these rules are defined, and where they are published. By studying trade publications and corporate information material and by attending professional congresses and symposiums, the individual specialist should be able to maintain an up-to-date understanding of current practices.

At least, in the event of a loss involving human injury, such familiarity with the "state of the art" will be his best defence.





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5.3 Standards and guidelines

Design guidelines for mechanical smoke exhaust systems are defined in the European standard EN 12101-5 (draft) and the German DIN 18232, part 5 (pre-standard).

As a rule, the design and sizing process should be coordinated with the relevant authorities (fire safety experts, fire safety authority, local fire department, building supervision office, etc.) from the earliest planning stage.

Fire loads shall be determined in accordance with DIN 18230, parts 1 and 2.

Other sizing methods are possible where they are justified, e.g., in the case of

- different heat release modes
- use of suitable computing methods for determining smoke gas mass flows
- issuance of particular specifications by a fire protection expert
- special conditions, e.g., special types of building use

List of German and European standards for smoke and heat extraction systems

German standards

DIN 18232	Structural fire protection; smoke and heat control
DIN 18232 Teil 1, (draft)	Terms, safety objectives
DIN 18232 Teil 2, (draft)	Natural smoke and heat exhaust ventilators, requirements, design, installation
DIN 18232 Teil 3, (draft)	Natural smoke and heat exhaust ventilators, testing
DIN 18232 Teil 4, (draft)	Heat exhaust systems
DIN 18232 Teil 5, (preliminary standard)	Mechanical smoke exhaust systems, requirements, sizing
	Release of an EN standard is not to be expected in the near future.
DIN 18232 Teil 6, Vornorm (preliminary standard)	Mechanical smoke exhaust systems, testing
DIN 18232 Teil 7, (working paper)	Smoke exhaust systems for staircases (in preparation)

European standards

EN 12101	Smoke and heat control systems
EN 12101-1, (draft)	Specification for smoke curtains; requirements and test methods
EN 12101-2, (draft)	Specification for natural smoke and heat exhaust ventilators
EN 12101-3, (draft)	Specification for mechanical smoke and heat exhaust ventilators
EN 12101-4, (draft)	Natural and mechanical smoke and heat exhaust systems, installation and test methods
EN 12101-5, (draft)	Design and calculation methods for smoke and heat exhaust systems
EN 12101-6, (currently under revision)	Design, calculation methods and installation procedures for pressure differential systems for room flow control monitoring

6.0 Fundamentals

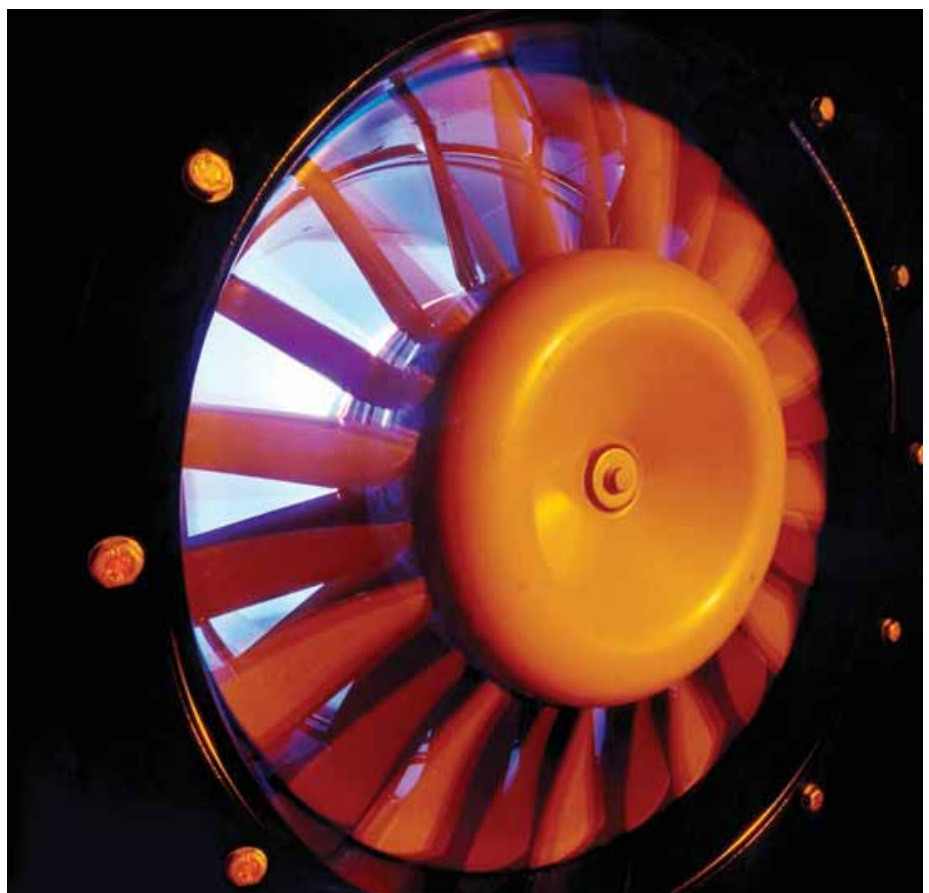
6.1 Initiation of fire

The outbreak of a fire and its subsequent propagation are contingent on the presence of

- an inflammable substance
- an ignition source of sufficient energy
- oxygen

6.2 Propagation

The evolution of a fire is essentially determined by the composition of the inflammable substance, the supply and concentration of oxygen, and the resulting combustion temperature.





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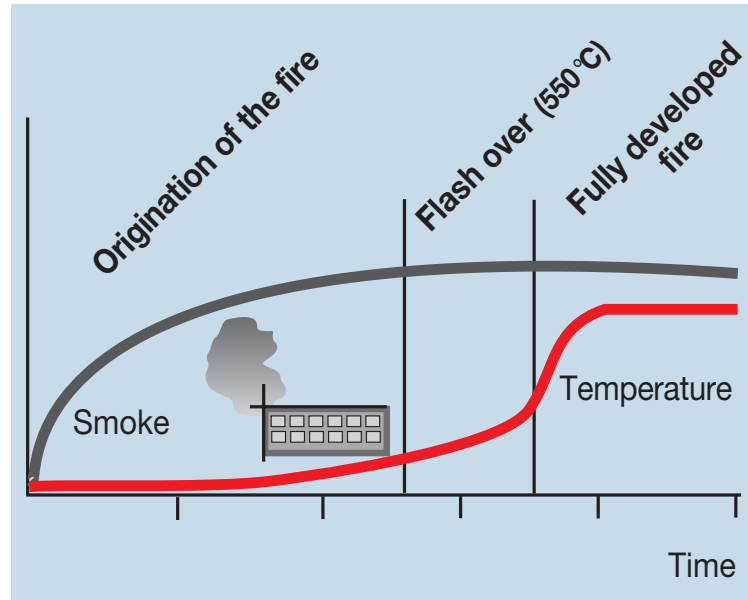
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6.3 Smoke formation and behaviour

The combustion process releases large amounts of combustion gases (oxides), smoke and thermal energy which will accumulate under the ceiling of the building, spreading both horizontally and vertically from there.

The key function of a smoke and heat exhaust system is to remove smoke from the building. Depending on the nature of the fire source, the smoke may be more or less toxic. The room in which a fire has started may fill with enormous volumes of smoke in just a few minutes.

Smoke and temperature development without smoke and heat extraction

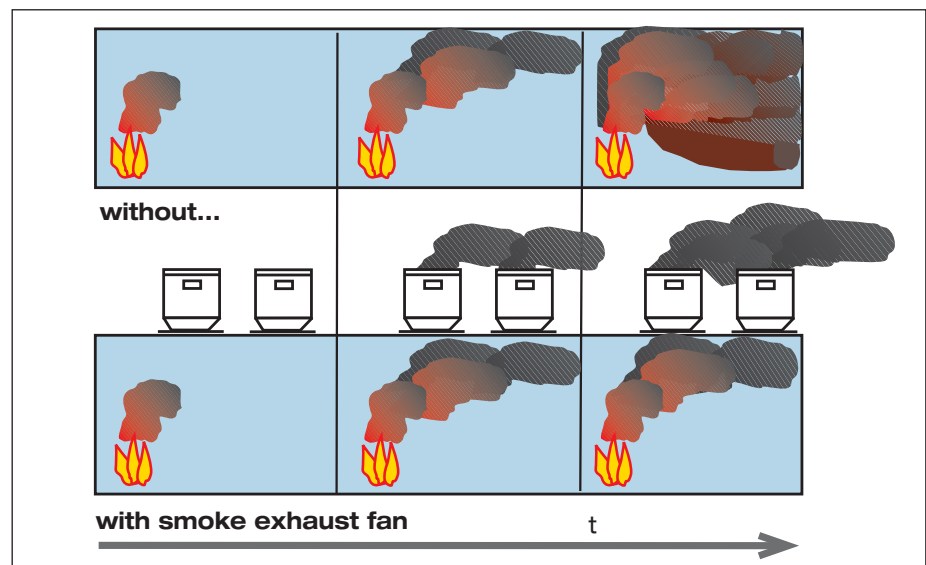


The following phases can be observed:

1. Ignition phase
2. Smouldering fire
3. Flash-over (eruption of a sudden blaze in the fire area)
4. Fully developed fire
5. Subsequent cooling phase

6.3.1 Smoke propagation example in case of fire

A staircase with a floor area of 16 m² and a height of 15 m can be filled with smoke and products of combustion more than 100 times over by the mere burning of 10 kg of foam rubber. The fire releases heat, combustion gases, and smoke. In a fully enclosed indoor space these will rise to the ceiling due to thermal buoyancy effects. The resulting layer of smoke and combustion gases originally gathered there will increase in density until it fills the entire room. At the same time, the environment heats up quickly due to the high energy release rate. When a temperature of 550 °C is exceeded, flash-over occurs, i.e., a sudden blaze erupts throughout the heat-affected area.



Propagation of smoke in the case of fire



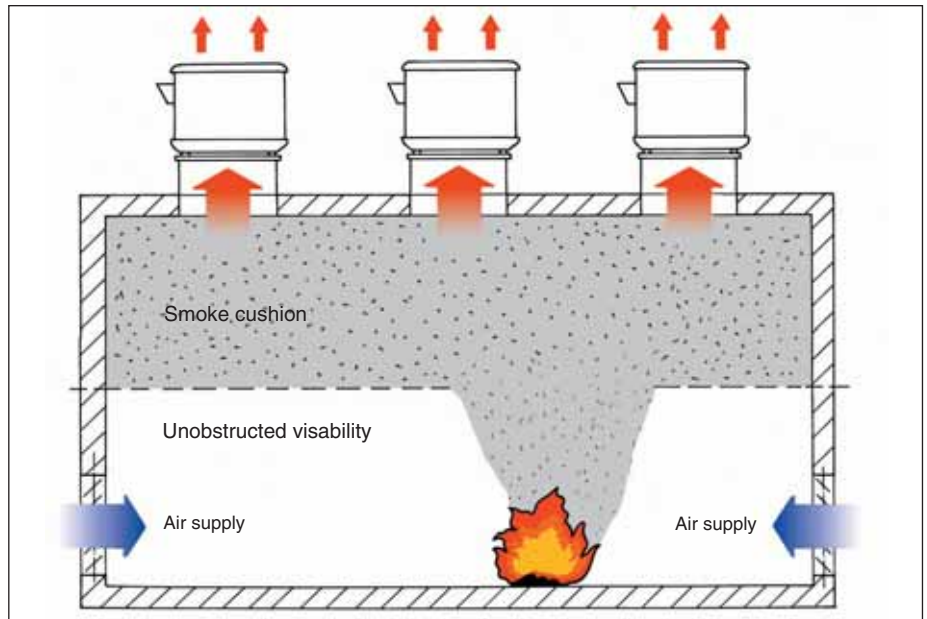
6.4 Operating principle of mechanical smoke and heat exhaust systems

Depending on the nature of the burning substance, varying degrees of smoke formation (density) may be anticipated. Originating in a small area, these gases eventually rise to the ceiling where they will form a smoke layer which initially does not mix with the cold air underneath. As the fire gains force, more and more combustion gas accumulates under the ceiling of the closed room. Eventually the gas cushion expands downwardly, towards the floor. Once it has fallen to below head level, the prospects for rescuing people and controlling the fire become critical.

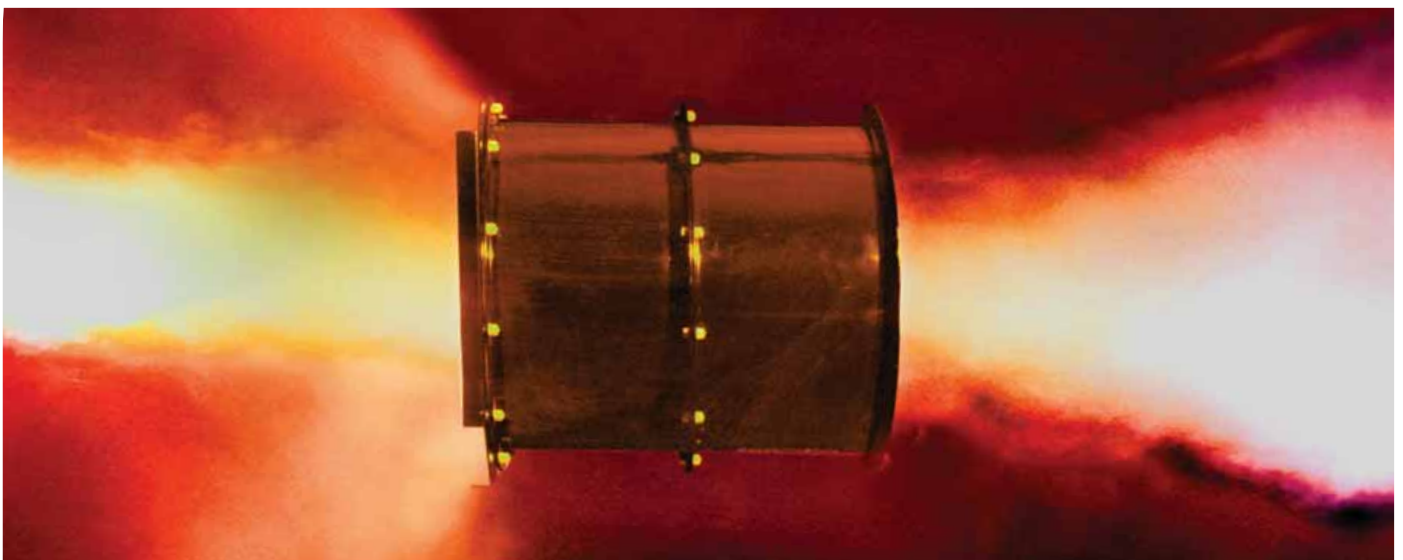
When the room containing the fire is opened at specific (planned) points, the thermal and smoke load is reduced by the resulting inrush of air and the simultaneous extraction of smoke. Initially, a pressure equalization with the surrounding ambient areas takes place. With time, an underpressure forms in the lower half of the room and more fresh air enters through the appropriate access openings.

If these openings are adequately sized for the dimensions and combustible content of the room, the evacuation of hot smoke and the ingress of fresh air will be ensured. Ideally, as the fire progresses, the gas cushion under the ceiling should remain at a constant height above floor level (**equilibrium condition between inflowing air and extracted smoke**), so that enough visibility and breathing air remains available underneath for human beings to leave the room and to conduct fire-fighting operations. This equilibrium can be achieved via simple openings toward the outside, as well as through me-

chanical smoke exhaust equipment. Fig. 2 illustrates this state. If one takes into account all relevant planning aspects, natural and mechanical smoke exhaust systems emerge not as competing solutions but as separate strategies complementing each other effectively. Apart from the building situation, the expected thermal conditions in the event of a fire are a key consideration.



Equilibrium state between air supply and extraction of smoke



The smoke exhaust fan is the heart of any mechanical smoke and heat exhaust system

**6.4.1 Difference between natural and mechanical smoke/heat extraction systems**

Natural smoke and heat extraction systems rely on the thermal behaviour of gases. They use the so-called "chimney effect", i.e., the draft created between the air supply and exhaust levels due to the density difference between the cooler fresh air and the hot combustion gases.

Advantage:

- Increasing volume flow as the fire progresses.

Disadvantage:

- Limited effect in the case of a low temperature and height difference between the supply/exhaust openings.
- Building characteristics and unforeseeable influences of wind limit the effectiveness of natural smoke/heat extraction systems.

Mechanical smoke/heat extraction systems utilize fans designed specifically for hot smoke and combustion gas duty.

These fans can be adapted to the individual building situation and extraction requirements by design.

Mechanical smoke/heat extraction systems would be preferred in the following cases where a natural system is either not feasible or would imply an unreasonable degree of complexity:

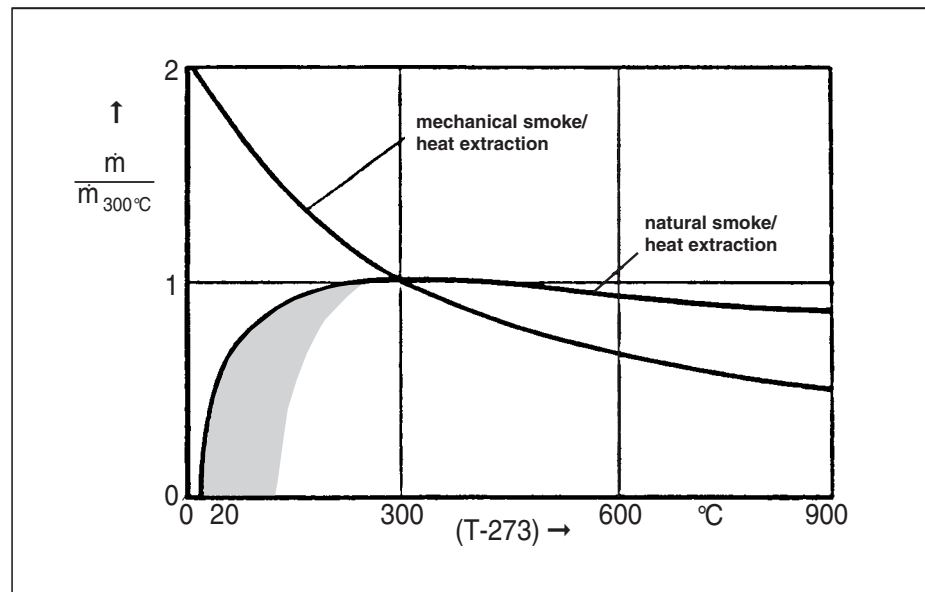
- Windowless rooms, or areas located deep inside the building structure
- Roof and building designs rendering natural exhaust systems ineffective due to wind attack conditions.
- Rooms in which high temperatures cannot form due to combustible content, combustion behaviour, size, or the presence of automatic fire-fighting installations (e.g. sprinklers)
- Cleanrooms in which the opening of a supply/extraction vent for testing or maintenance purposes would already create an operating disruption.

Disadvantage:

- Electrical installation requirements.

Advantage:

- The full air power is available as soon as the fan is activated or triggered. The goal of keeping escape routes smoke-free is effectively achieved, specifically in the important early stages of the fire.
- The volume flow remains nearly constant throughout the duration of the fire.



Mass flow comparison between natural and mechanical smoke/heat extraction systems

According to DIN 18232, a basic distinction is made between the following:

- | | |
|--|------------|
| ■ Natural smoke extraction systems (rooms subject to fire hazard) | NRA |
| ■ Mechanical smoke extraction systems (rooms subject to fire hazard) | MRA |
| ■ Pressure-based fire protection systems (stairwells, corridors) | RDA |



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6.5 Smoke exhaust fans

The relevant requirements are defined by the European product standard DIN EN 12101, Part 3 ("Smoke and heat control systems – Specification for mechanical smoke and heat exhaust ventilators"). All TLT smoke exhaust fans are tested to this standard and meet its severe requirements.

In addition, German building law requires each fan to be generally approved by the Building Supervisory Authority.

In accordance with this requirement, our smoke exhaust fans possess the supplementary General Building Supervisory Approval issued by the German Institute of Building Technology (DIBt), Berlin. Significant advances in standardization of preventive fire protection technology have allowed these standards to be integrated into building law. With the inclusion of smoke exhaust fans into the Building Rules List, their installation has become permissible only where the relevant units are tested and certified to legally valid standards.

6.5.1 Suitability testing and certification by the Building Supervisory Authority

Only one test institute in Germany is accredited to perform suitability testing of smoke exhaust fans according to the test and inspection provisions of EN 12101-3. This is the test institute of the Technical University of Munich (Domestic Services Research Laboratory).

The approval certificates of the Building Supervisory Authority, issued by the German Institute of Building Technology, a corporation under public law, acknowledge compliance with the technical requirements of the Building Rules List B2.

This document is published by the German Institute of Building Technology (Deutsches Institut für Bautechnik, DIBt).

The Building Rules List "B", Part 2, includes construction products which are sold and introduced into commerce under regulations governing the implementation of European Community directives, with the exception of regulations for the implementation of the Construction Products Directive, where such directives do not reflect key requirements of section 5(1) of the German Construction Products Act and additional proof of suitability for use is required under German building codes to meet these requirements. Such construction products must bear the DE label in addition to a conformity label according to the building codes of the German federal states. The specific requirements of section 5(1) of the Construction Products Act not met by the directives are stated in column 4 of the Construction Rules List "B", Part 2. Columns 5 and 6 indicate which suitability and conformity certificates a product must possess to fulfill such key requirements of the German state building codes.

Key requirements under section 45(1) of the Building Products Act relate to the following properties:

- mechanical strength
- stability
- fire protection
- hygiene
- health
- environmental protection
- safety for use
- acoustic insulation
- energy savings
- thermal insulation

The essential requirements are detailed in the basic documents under Article 12 of the Council Directive 89/106/EEC of December 12, 1988.

Building Rules List "B", Edition 97/1 (Excerpt)

The Building Rules List "B" is a compilation of construction products whose introduction into commerce and sale is subject to regulations of European Union member states – including Germany – and of signatory states of the Agreement on a European Economic Area, and which bear the CE label. For smoke exhaust fans, the Building Rules List "B", Part 2, shall be applicable.



All TLT smoke exhaust fans possess Supervisory Approval issued by Deutsches Institut für Bautechnik in Berlin.



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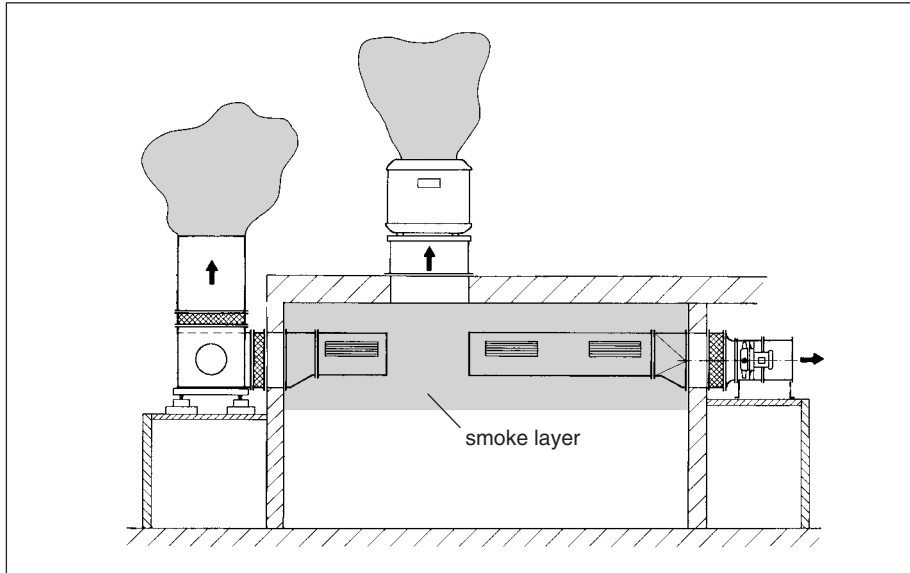
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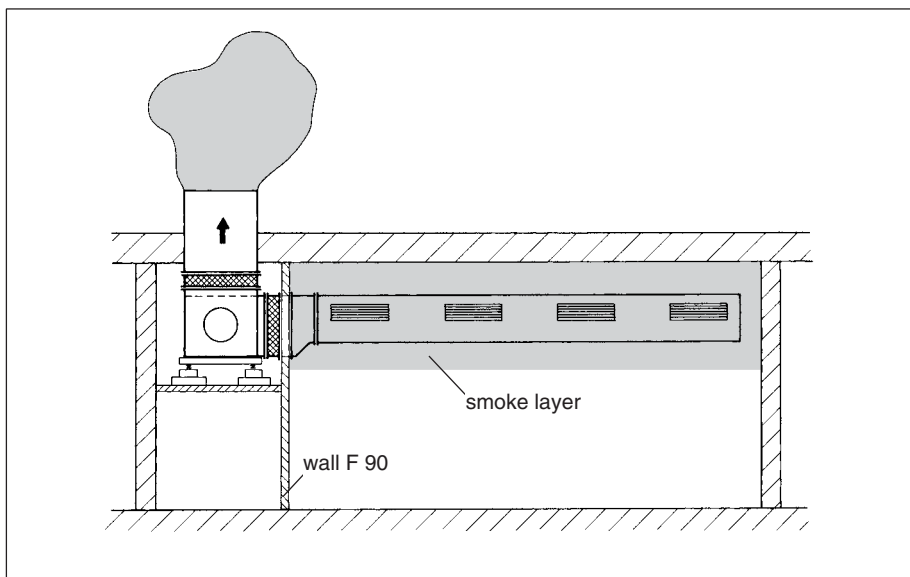
6.5.2 Various installation configurations

The diverse available models, designs and types cover the needs of virtually any application.



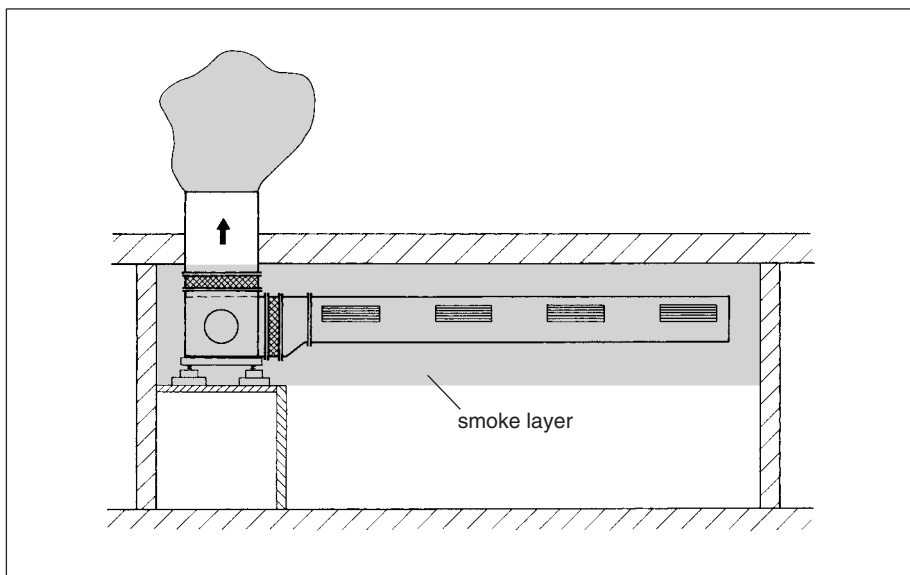
Fan installation outside the fire compartment and outside the building

These fans need no thermal insulation. The minimum distance to combustible materials must be met. (Belt-driven fans must, however, be fitted with heat insulation).



Fan installation outside the fire compartment but inside the building (in an adequately ventilated room)

The fan must be insulated in accordance with DIN 4102-4, or enclosed in mineral fibre lagging (density $\geq 90 \text{ kg/m}^3$) measuring at least 40 mm in thickness.



Fan installation inside the fire compartment

If the fan is suitable for installation within the fire compartment, no insulation is necessary.

(Fans depending on external air for cooling must be provided with an appropriate L90-grade cooling air supply duct. However, this requirement is not applicable to wall-mounted fans).



Complete test rig for roof-mounted smoke exhaust fans. Fumes are extracted from a furnace and returned to it via a duct connected to the fan outlet.



Heat-insulated repair switch, cooling air inlet nozzle

6.5.3 Test conditions and criteria

Our smoke exhaust fans are functionally tested under virtually realistic mounting conditions. Each fan series is run in smoke extraction mode according to its appropriate temperature/time category for at least the specified minimum operating duration; in most cases, the test is continued for much longer (Table 1).

6.5.4 Suitability testing criteria

- Volume flow decrease over the test interval ($\leq 10\%$)
- Reduction in static pressure head over the test interval ($\leq 20\%$)
- Surface temperature increase on insulated fans must not exceed 180 K at any one point

6.5.5 Tests

The prescribed tests relate to smoke exhaust fans operating as standalone units in an installed condition.

Many accessories, although not subject to testing themselves, are critical for the operation of the fan. It has the-

refore been our policy to test them on a voluntary basis in conjunction with the fan system. For each fan series, a minimum of two (up to a total of five) specimens had to be tested depending on type and model. The number of specimens reflects the criteria set forth in the test standard as well as the diversity of application conditions

for which TLT smoke exhaust fans are built.

Temperature / Time Category according to EN 12101, Part 3

Category	F300	F200	F400	F600	F842	not assigned
Temperature (i C) according to EN 12101-T3	300	200	400	600	842	as determined by supplier
Insulated fans minimum operating duration (min)	60	120	120	60	—	as determined by supplier
Tested operating duration of TLT fans (min)	120	120	120	120	—	—
In determining categories, existing classifications under national standards such as DIN, BS, etc., were taken into account.						

Table 1



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6.5.6 Supervisory Approvals and Test Reports

Fan type	Fan series	Temperature limit [°C]	Minimum operation duration [min.]	Report No.	General approval No.
Roof-mounting fans	BVD (SDI)	620	120	96/1162	Z-78.1-24
	BVD (SDI)	400	120	97/1188	Z-78.1-25
	BVW-D	600	120	96/1166	Z-78.1-29
Wall-mounting fans	BVW	600	120	96/1166	Z-78.1-29
	BWAXO	200/300	120	98/1196-1	Z-78.1-41
	BWAXN 12/56	200	120	96/1167-4	Z-78.1-18
	BWAXN 12/56	300	120	96/1167-2	Z-78.1-20
	BWAXN 12/56	400	120	96/1167-6	Z-78.1-21
Central service fans Centrifugal fans	BVRA *	620	90	91/196-1-a*	Z-78.1-16
	BVW for floor installation	600	120	98/1196-3	Z-78.1-29
	BV-REH	400	120	98/1196-4	Z-78.1-42
	BV-ERV	300	120	98/1196-2	Z-78.1-43
Axial-flow fans	BVAXO	300	120	98/1196-1	Z-78.1-41
	BVAXN 12/56	200	120	96/1167-4	Z-78.1-18
	BVAXN 12/56	300	120	96/1167-2	Z-78.1-20
	BVAXN 12/56	400	120	96/1167-6	Z-78.1-21
	BVAXN 8/56	600	120	96/1167-1	Z-78.1-17
Accessories	Inlet box for BVW types			96/1166	Z-78.1-29
	Outlet dampers for BVW types			96/1166	Z-78.1-29
	Automatic shutoff dampers			2140**	
	Flexible connectors (inlet or outlet side)			2140**	
	Bases for BVD + BVW-D				Z-78.1-24 Z-78.1-25
	Round silencer TSR			2140**	
	Noise-damping base SDS			2140**	

* to DIN 18232-6

** Expertise regarding use for preventive fire protection



6.5.7 Fan sizing

As a rule, any smoke and heat exhaust system must be sized in conformance with applicable laws and standards. This can only be accomplished through cooperation between the specifier and the building supervisory authority. As a result, the calculation steps and sizing criteria outlined below should only be viewed as a guide.

Sizing steps

1. Calculate the fire load of the room in question and the theoretical fire load with the aid of the formulas given above (from DIN 18230, Part 1, and the design specifications of EN 12101-5 or EN 18232-5).
2. Determine the requisite smoke exhaust volume flow.
3. Determine the smoke temperature. If the temperature thus obtained exceeds the proof temperature of the fan the number of air changes must be increased, or a bypass must be installed to mix the extracted smoke with cooler air.
4. Determine the leakage air flow and the requisite total air volume.

The leakage flow will vary as a function of pressure loss conditions and number and sizes of ducts in the system. In practice, long duct sections on the fan inlet side and the associated high pressure loss will often translate into leakage flows that exert a significant impact on the overall system throughput.

It should always be remembered that the exhaust volume flow of a mechanical smoke exhaust system is measured not at the fan, but in the assumed fire compartment under normal conditions.

The anticipated leakage loss must be taken into account in any fan sizing effort.

In this context the specifier should also check whether the air supply openings are sufficient for the total make-up air volume, and whether appropriate scavenging conditions exist in the room.

The air flow rate through the supply openings should be ≤ 3 m/s.

5. Determine the total pressure loss across the system.
6. Select the appropriate fan

Often it may appear expedient to use the fan for normal room ventilation purposes as well. In this case, a drive motor with two or three operating speeds may be selected. The lower rpm level is then used for normal venting, while the higher speed is activated in the event of a fire.

Fan use

Selecting the right fan in terms of temperature resistance, operating time and output does not suffice to ensure a proper smoke exhaust system. The following fan operating aspects must likewise be taken into account:

- The switchgear cabinet for the smoke exhaust fan must be installed outside the rooms exposed to a fire (or high temperature) hazard.

Switchgear cabinets or panels must not be fitted on an (interior or exterior) wall of the fire compartment.

Only the fulfilment of these aspects, which are all too often neglected in the use of smoke exhaust fans, can ensure an effective smoke and heat exhaust operation in conjunction with the correct fan sizing.

Please also see our Installation, Operating and Maintenance Instructions.

Smoke exhaust fans may be operated via a frequency converter when in normal venting mode, but not in smoke extraction service (except where the frequency converter is tested in conjunction with the fan).

To ensure a reliable smoke extraction performance the installation must conform to the fan manufacturer's specifications and to all requirements imposed by the Building Supervisory Authority, e.g., with regard to

- installation room cooling
- thermal installation
- use of tested and approved accessories (e.g., flexible connectors, spring-type antivibration mounts, silencers, shutoff dampers)
- uninterruptible power supply

**7.0 Fire load determination
according to DIN 18230,
Parts 1 & 2**

A method of determining the fire load and its relevant factors is defined in DIN 18230, Parts 1 & 2. According to this standard, the fire load q (in kWh/m²) is the aggregate amount of heat that can be released by all combustible materials in a given fire zone having a theoretical surface area A (in m²). This can be written as follows:

$$q = \frac{\sum (M_i \cdot H_{ui})}{A} \text{ in kWh/m}^2$$

The term "combustible materials", as used here, must be deemed to include all inflammable substances, whether building materials, operating fuels and consumables, stored products, packaging, or surface finishes (e.g., paneling, coatings or the like). More detailed instructions are presented in the standard m.a.

DIN 18230 and the resulting equation are intended for determining the requisite fire resistance time of the building components in a specific fire compartment. As a result, applications of the standard may deviate from those discussed in the present document.

While the parameters and assessment methods defined in the standard relate to a theoretical building section ("compartment") affected by fire, in the present case individual analyses for specific rooms or groups of rooms must often be conducted.

The theoretical fire compartment area A expressed in m² will therefore not always be the same as the surface area of a smoke compartment of a building to be assessed. In practice one room or flights of rooms having a smaller surface area than the fire compartment concerned will depend on the demands of the mechanical smoke extraction. For our purpose we must calculate the room surface area to be protected by the mechanical smoke extraction system.

In any event, each area in the affected fire compartment must be assessed in terms of the quality and quantity of combustibles it contains, i.e., we must determine the mass M_i (in kg) of each combustible substance and its net calorific value H_{ui} (in kWh/kg).

The result is the fire load for the fire compartment area A_R examined.

$$q' = \frac{\sum (M_i \cdot H_{ui})_R}{A_R} \text{ in kWh/m}^2$$

The calculated fire load q_r for unprotected combustibles is obtained after weighting with the combustion factor m_i .

$$q_r = \frac{\sum (M_i \cdot H_{ui} \cdot m_i)_R}{A_R} \text{ in kWh/m}^2$$

The calculated fire load used in design should be at least equal to 25 kWh/m².

The combustion factor m_i is thus directly reflected in the design of the smoke/heat exhaust system. It reflects the specific type, shape and

distribution as well as the combustion behaviour of the inflammable substances. Obviously, the mass of unprotected paper, cardboard, textile material, etc., that will be consumed by fire in unit time is much larger than the corresponding mass of wood or packaged products.

Depending on the material and its net calorific value and storage density, the combustion factor m_i will typically vary between 0,2 and 1,7.

For more detailed information, reference should be made to DIN 18230, Part 1, Addendum 1.



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021

Excerpt from the Addendum to DIN 18230, Part 1.

(More detailed data are given in DIN 18230, Parts 1 & 2)

Extract from annex to DIN 18230 - part 1

For details refer to DIN 18230, part 1 + part 2, preliminary standard

No.	Material	Compact-ness %	m _i -factor	H _{ui} kWh/kg
1 Wood and wooden materials				
1.1	spruce wood			
1.1.1	boards	50	1,0	
		70	0,8	4,8
1.1.2	squared timber 40 mm x 40 mm	50	1,0	4,8
1.1.3	squared timber 100 mm x 100 mm	50	0,7	4,8
		90	0,5	
1.1.4	squared timber 200 mm x 200 mm	50	0,3	
		95	0,2**)	4,8
1.1.6	spar, scalped diameter 150-300 mm	50	0,5	4,8
1.1.7	loose wood wool (pressed bale)	8	1,0	4,7
		60	0,2**)	
1.2	chipboard (DIN 4102 - B 2)	99	0,2**)	4,8
2 Paper, cardboard				
2.1	writing paper and printing paper	100	0,2**)	3,8
2.2	rolles or sizes of cardboard on paletts			
2.2.1	printed cardboard	90	0,2**)	3,8
		100	0,2**)	
2.2.2	unprinted cardboard	90	0,2**)	4,2
		100	0,2**)	
2.3	bales of wrapping paper	90	0,2**)	4,2
		100	0,2**)	
2.4	paper rolls, standing, lying or on pallets			
	cut to size			
2.4.1	printed paper	75	0,2**)	3,8
2.4.2	unprinted paper	75	0,2**)	4,2
2.5	sanitary crepe paper rolls, or packed in bags	80	1,7	3,7
3 Textile products				
3.1	cotton			
3.1.1	fibre bales	—	0,4	4,3
3.1.2	pressed fibre bales	—	0,2**)	4,3
3.2	pressed polyamide fibre bales	—	0,7	7,9
3.3	Pressed polyacrylonitrile bales			
3.3.1	fibres, not modified	—	0,8	8,2
3.3.2	fibres, modified with approx. 35% vinylidenchloride	—	0,2**)	6,6
3.4	waste			
3.4.1	pressed cotton, polyamide and polyacrilnetrile fibres bales	—	0,8	—
4 Plastics				
4.1	polyethylene			
4.1.1	granulate in individual sacks	—	0,8	12,2
4.1.2	moulded parts (empty beer boxes) piled up	—	0,5	12,2
4.2	polystyrole			
4.2.1	hard foam (DIN 4102 - B 3) PS 20	100	0,8	11,0
4.2.2	hard foam (DIN 4102 - B 1) PS 20 SE	100	0,4	11,0
4.3	polyurethane hard foam			
4.3.1	PUR hard foam (DIN 4102 - B 2)	100	0,3	6,7
4.3.2	PUR hard foam (DIN 4102 - B 1)	100	0,2**)	6,7
4.4	Polycarbodiimide hard foam	100	0,2**)	8,6
4.5	UP unsaturated polyester resins , glass-reinforced			
4.5.1	bars in loose piles	25	0,7	5,3
5 Solid fuel				
5.1	brown-coal briquettes, dropped charge	60	0,3	5,8
6 Combustible liquids in bath-tube combustion				
6.1	chlorbenzole	—	0,5	11,2
6.2	cyclohexane	—	0,6	8,9
6.3	dimethylformamide	—	1,3	6,1
6.4	glycole	—	1,3	4,6
6.5	oil fuel EL	—	0,4	11,7
6.6	oil fuel S	—	0,5	11,4
6.7	iopropylealcohol	—	1,2	7,5
6.8	methanole	—	1,0	5,4
6.9	oleoresin	—	0,6	11,5
6.10	xylene	—	0,4	11,1

*) bulk density = material volume / total volume or = bulk density / apparent density

**) incineration factors m_i < 0.2 can be evaluated according to DIN 18230 part 1, if the examination authority issued their comments according to advice and recommendations given in NABau-Arbeitsausschuss XII 45/2 "m-factor"

q = fire load in kWh/m²

q' = fire load in kWh/m², related to the fire department

q_r = calculated fire load in kWh/m²

A_R = Surface of the fire compartment in m²

M_i = mass of the individual combustible material in kg

H_{ui} = net calorific value of the individual combustible material in kWh/kg

m_i = combustion factor of the individual combustible material

w = heat exhaust factor

c = conversion factor in min. m²/kWh

t_a = equivalent fire duration in min.

l = cubic capacity of the room in m³

t_m = average fire room temperature in °C

n = air changes in h⁻¹ (number per minute)



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7.1 System design in accordance with DIN 18232, Part 5

The new standard DIN 18232, part 5, applies to large rooms with a minimum interior height of 3 m. However, it is not suitable for rooms with stationary gas extinguishing equipment, storage rooms with storage heights exceeding 1.5 m, hazardous material storage areas, and hazardous duty rooms.

The calculation of the volume flow to be extracted is based on the so-called dimensioning category. To obtain the appropriate dimensioning category it is necessary to determine the underlying fire development time and the fire propagation rate. The fire development time is the interval between the outbreak of the fire and the start of fire-fighting operations. In any case, it is assumed that the premises are protected by a fire alarm system in accordance with EDIN VDE 0832-2 (VDE 0833T2) with fire detectors as per DIN EN 54-7, or else that appropriately trained personnel is continuously present. The mechanical smoke exhaust system should be triggered by smoke detectors as soon as possible, as only this way the evacuation of occupants, who are mostly unfamiliar with the building, can be ensured.

As soon as the fire brigade has arrived at the scene, it will take charge of rescue operations and can also determine whether or not the mechanical smoke exhaust system should remain in operation. The time between the start of the initiation of the fire and the arrival of the fire brigade is therefore decisive. Where a company fire department is in place, an interval of 5 minutes is typically assumed. With volunteer fire brigades and under unusually adverse conditions, as much as 20 minutes may pass. In the normal case, calculations will be based on an average fire development time of 10 minutes.

Once this interval has been defined in consultation with the expert and/or local fire department, the fire propagation rate remains to be determined. It depends on the combustible materials present in the various fire compartments.

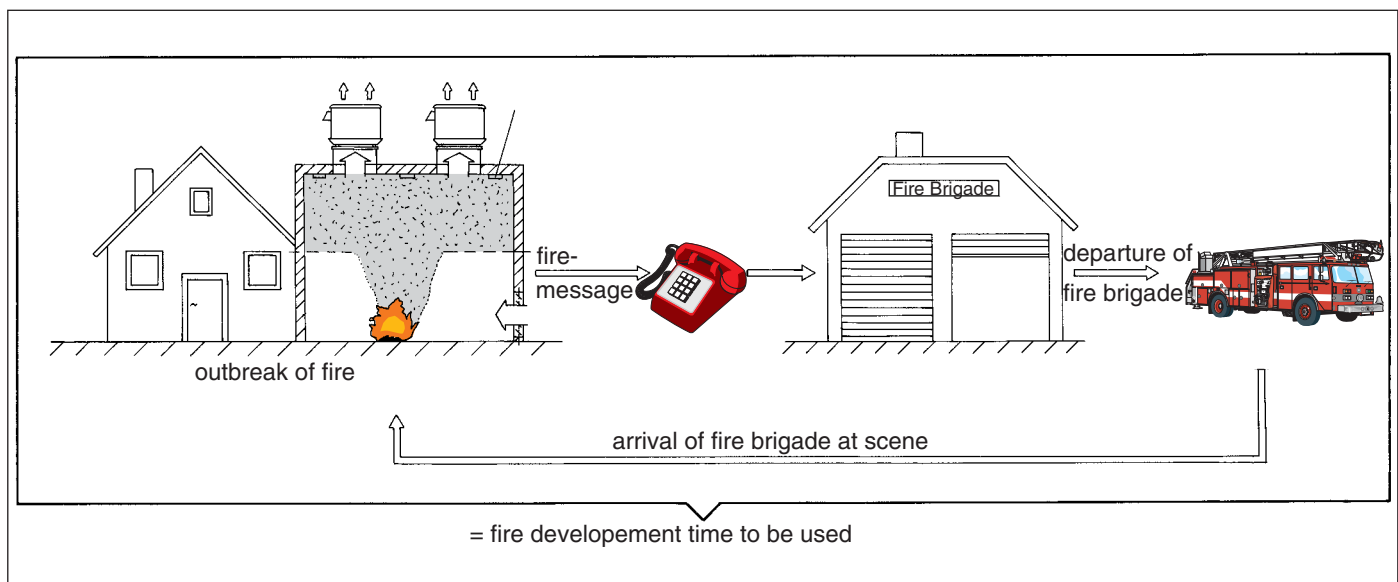
Combustible construction materials in non-combustible packaging, for instance, have a particularly low fire propagation rate. On the other hand, where substances such as benzene or rubberized products are stored, the flames will spread very quickly. Usually, an average propagation rate will be assumed.

A note in the standard tells us that the presence of a sprinkler system justifies the selection of the next lower dimensioning category. This statement must be viewed as exceedingly problematic. A discharge of water from the sprinkler system into the accumulated smoke layer will definitely increase the amount of smoke to be extracted. In addition, the water literally forces the smoke downwards into the escape routes, which should be kept clear by all means.

Our recommendation, therefore, is to leave the mechanical smoke exhaust system running for as long as occupant protection is still an issue, and to ensure that the sprinkler system will be triggered after the smoke exhaust fans.

Moreover, the standard assumes smoke compartment surface areas in the region of $\leq 1600 \text{ m}^2$.

The volume flow of smoke to be extracted and the fan temperature category can now be determined from the exhaust flow rate tables, depending on the desired depth of the low-smoke layer, the dimensioning group, and the energy release rate (a result of the fire load calculation).





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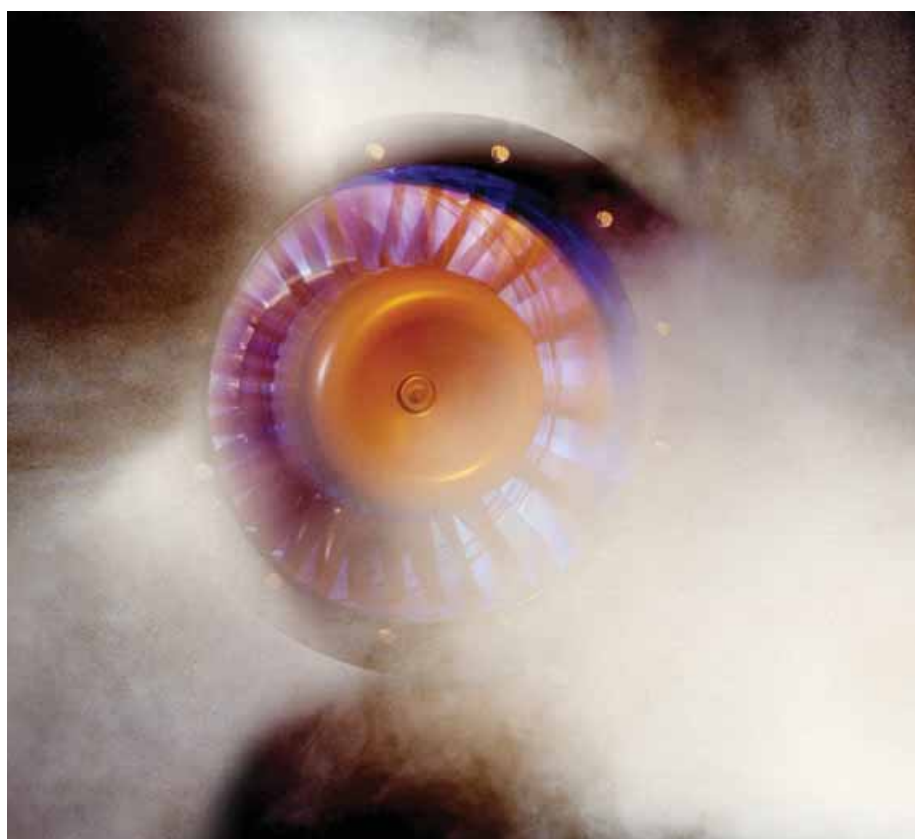
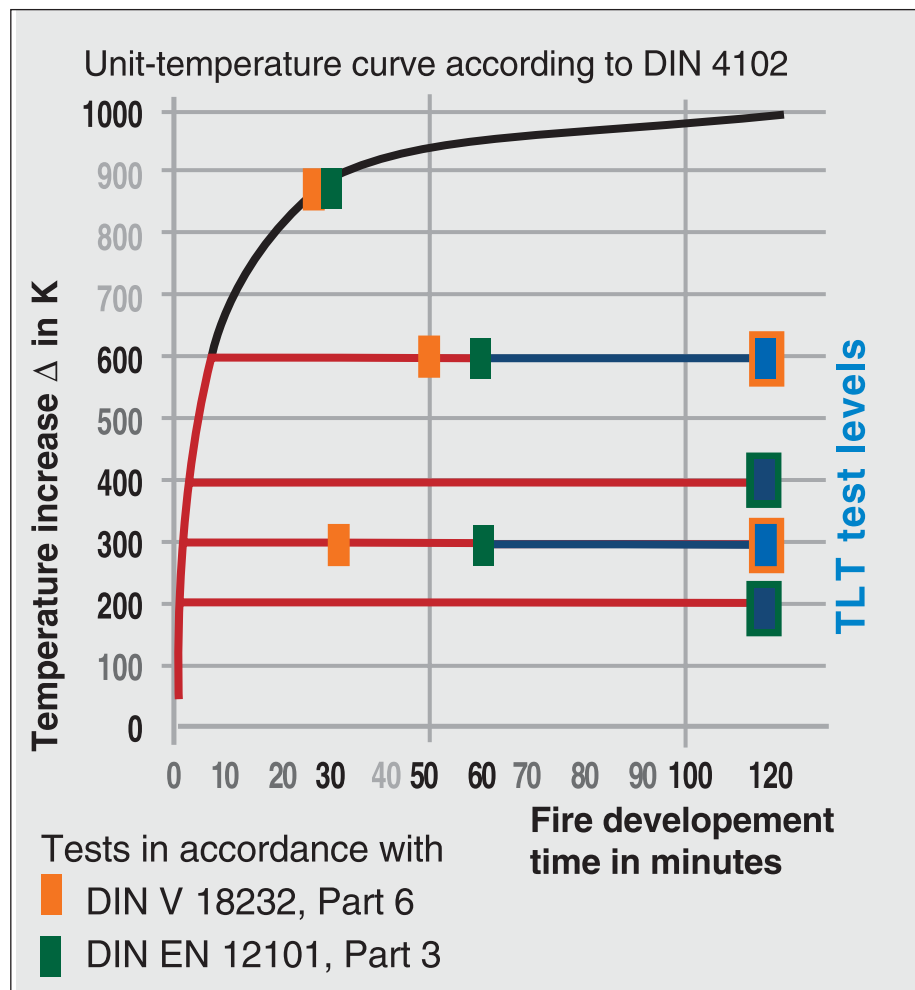
SMOKE (FUME) EXHAUST FANS FUNDAMENTALS

023

The pre-standard DIN 18232-5 gives tables for two different fire scenarios:

The energy release rate to be employed as a function of the calculated fire load is 600 kW/m² in one case and 300 kW/m² in the other.

The "installation rules" likewise provided in the standard shall be examined in detail in section 7.5.



**7.2 Design according to DIN 18230 and Quenzel**

For guidance, Fig. 7 plots the curve of the unit-temperature in the fire compartment over time. A few key critical temperatures have been marked in the diagram as average points of occurrence of the events identified.

For the smoke exhaust system designer the question arises in this context which temperatures (and specifically, which combustion gas temperature) must be expected in case of a fire.

A clear-cut law linking from the fire compartment temperature to the fire load cannot be established because of the diversity of effects governing each individual fire. However, we can identify a relationship between the fire load and the equivalent fire duration $t_{\bar{a}}$, a term introduced in DIN 18230. The equation incorporates the factors w and c :

$$t_{\bar{a}} = c \cdot q_r \cdot w \quad \text{in min}$$

The heat factor w is a coefficient expressing the specific ventilation conditions characterizing the fire scenario. Depending on the arrangement of the smoke extraction system and the make-up air supply (and possibly, the achievable number of air changes), a value of $w = 2.2$ to 3.2 may be assumed for a mechanical smoke exhaust installation.

The conversion factor c , according to DIN 18230, reflects the thermal insulation properties of the fire compartment enclosure walls. It is given as $c = 0.15$ to $0.25 \text{ min} \cdot \text{m}^2/\text{kWh}$, the higher value indicating the higher insulation level.

If the insulating capability of enclosure components is destroyed by the fire, e.g., because of windows shattering, a value of $c = 0.15$ may be adopted.

Where this computing method is taken into account in the system design process, it should be remembered that the various factors all have an uncertainty margin to the positive or negative side. Still, they should be used as a guide in calculating fire

events. Bearing this in mind, and in accordance with a calculated equivalent fire duration and the assumption that no fire-fighting action is taken, the unit-temperature curve permits an approximate calculation of the temperature increase (or fire temperature) to be expected. A real-case analysis of fire loads and building situations yields an equivalent fire duration of 20 – 55 minutes for most buildings, so that smoke temperatures of about 1020 to 1220 K (750 - 950°C) would have to be anticipated from the fire compartment.

The temperature in the fire compartment will not reach this level if a smoke and heat exhaust system generates sufficient air changes from the start.

In this case the average fire temperature should be described by the empirical formula:

$$t_m = 20 + 250 \log \left(4 \cdot t_{\bar{a}}^2 \cdot \frac{q_r}{n \cdot l} \right) \text{ in } ^\circ\text{C}$$

This formula including the number of air-changes.

This temperature is approximately equal to that of the extracted air, and may therefore be used to determine the temperature resistance of the mechanical smoke exhaust system.

$t_{\bar{a}}$	= equivalent fire duration (in min)
t_m	= average fire room temperature (in $^\circ\text{C}$)
q_r	= calculated fire load (in kWh/m^2)
n	= air changes (number per hour)
l	= cubic capacity of the room (in m^3)

7.3 Necessary number of air changes

An attempt is made in Fig 8 (page 025) to give a guidance to the necessary number of air changes as a function of the fire room height and prevailing fire load. It is assumed that the smoke concentration (k_{j2}) in the room is kept below 25% for 15 minutes after the smoke exhaust system is activated.

This 15-minute interval was selected since it will normally give enough time to evacuate occupants and initiate fire-fighting measures.

Smoke development is an important factor here since it has a major impact on visibility in the room.

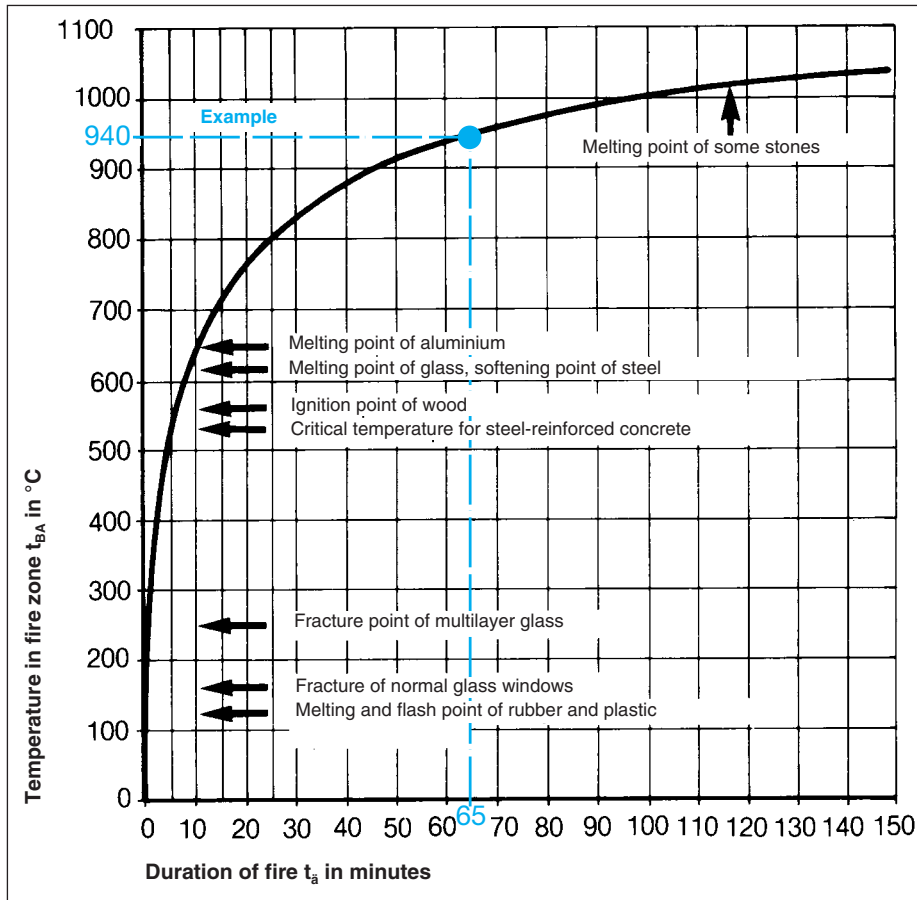


Fig. 7: Temperatur criteria during evolution of fire

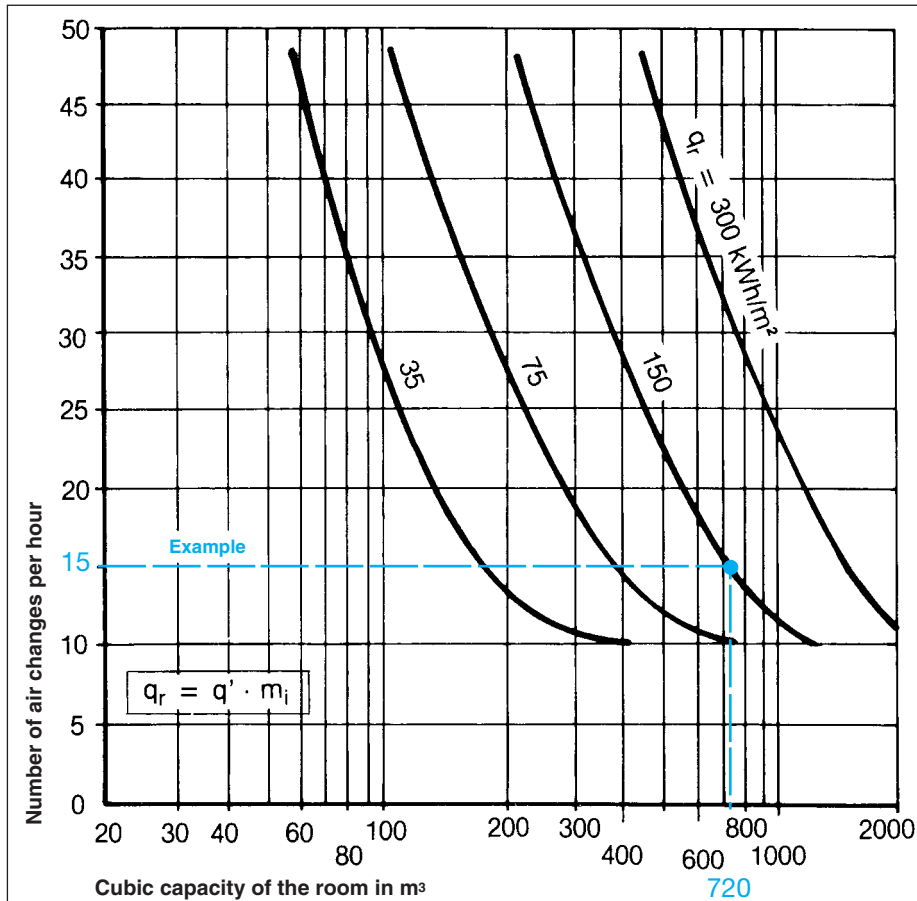


Fig. 8: Number of air changes required, as a function of the fire load and room size, to maintain $k_{12} = 25\%$ for 15 minutes after activation of the smoke and heat exhaust system.



SMOKE (FUME) EXHAUST FANS SIZING - APPLICATION EXAMPLE 1 CENTRIFUGAL SMOKE EXHAUST FAN FOR 600°C SERVICE SERIES BVW-R WITH INLET DUCT

026

8.4.8 Example 1

Bibliography: Dipl.-Ing. Karl-Heinz Quenzel, „Smoke and Heat Extraction Systems“, 2nd edition

A furniture warehouse in a multi-storey building is to be protected. Fig. 10 shows the floor plan and elevation, as well as the fan arrangement.

The floor plan geometry and arrangement of the air supply opening (door) permit a good transverse ventilation of the room with just a short fan connecting duct. A concentrated supply of make-up air, combined with an underpressure in the warehouse, keep the corridor and the fire-fighting access zone clear of smoke.

Sizing steps:

Ad 1. The room is assumed to contain a mix of stored materials in the following composition: 5600 kg wood, 3000 kg textiles, 672 kg plastics.

The calculated fire load can thus be determined as follows:

From: DIN 18230, Table 1				
Material	M _i (kg)	H _{ui} kWh/kg	m _i	M _i · H _{ui} · m _i (kWh)
Wood	5600	4,8	1	26880
Textiles	3000	4,3	0,4	5160
Plastics	672	6,7	0,4	1800
TOTAL				33840

By dividing this sum through the floor area of 240 m², we obtain

$$q_r = \frac{33840}{240} = 141 \frac{\text{kWh}}{\text{m}^2}$$

Ad 2. Taking into account the room volume of 720 m³ the resulting requisite number of air changes per hour is 15 (N=15). Please refer to fig. 8.

Ad 3. Using q_r, the equivalent fire duration t_a can now be calculated. For this purpose we assume

$$c = 0,2 \frac{\text{min} \cdot \text{m}^2}{\text{kWh}}$$

for the conversion factor, and w = 2.2 (from DIN 18230) for the heat exhaust factor. It follows that

$$t_a = c \cdot w \cdot q_r = 0,2 \cdot 2,2 \cdot 141 = 62,04 \text{ min.}$$

From this figure, a fire zone temperature of 940°C is obtained (see Fig. 7, page 019). The average fire zone temperature with the smoke exhaust system in operation is determined via the following empirical equation:

$$t_m = 20 + 250 \log \left(4 \cdot t_a^2 \cdot \frac{q_r}{n \cdot l} \right) \text{ in } ^\circ\text{C}$$

In our example,

$$t_m = 20 + 250 \log \left(4 \cdot 62^2 \cdot \frac{141}{15 \cdot 720} \right) = 595,65 ^\circ\text{C}$$

At 596°C, it does not exceed the 600°C operating temperature of the smoke exhaust fan.

Ad 4. A leakage air flow presumably does not have to be taken into account, since the ducts are routed inside the storage room only. The volume flow to be extracted can thus be written as

$$V = n \cdot l = 15 \text{ h}^{-1} \cdot 720 \text{ m}^3 = 10800 \text{ m}^3/\text{h}$$

Ad 5. The resistance of the duct system, including protection grids, is about 400 Pa at a volume flow of 10800 m³/h (3 m³/s). The pressure loss due to the cap is about 70 Pa, that of the inlet box about 60 Pa. A fan delivering a total pressure increase of approx. 530 Pa must therefore be selected.

Ad 6. A look at the characteristic curve (page 153) suggests that a centrifugal-type BVW-R 630/25-6 smoke exhaust fan with inlet duct would be a suitable unit.

**Centrifugal-type smoke exhaust fan
BVW-R 630/25-6 with inlet duct (intake box)**

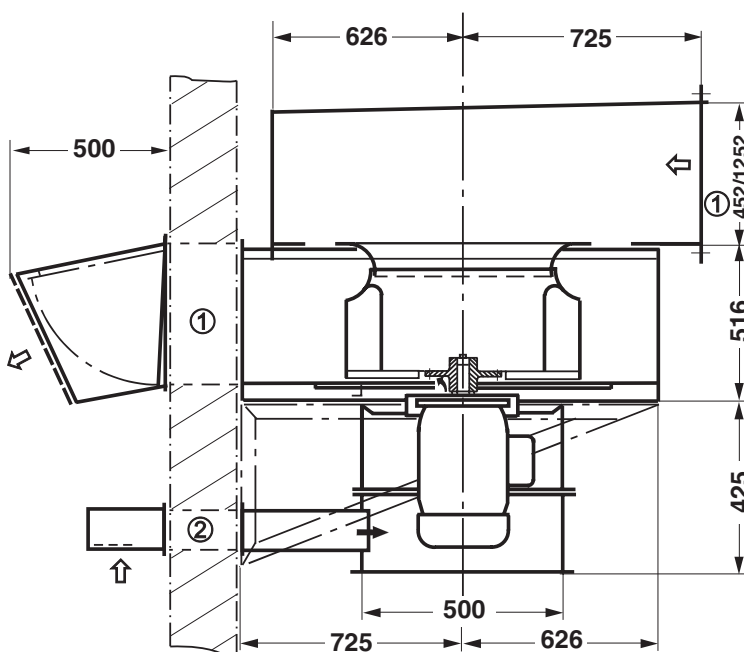
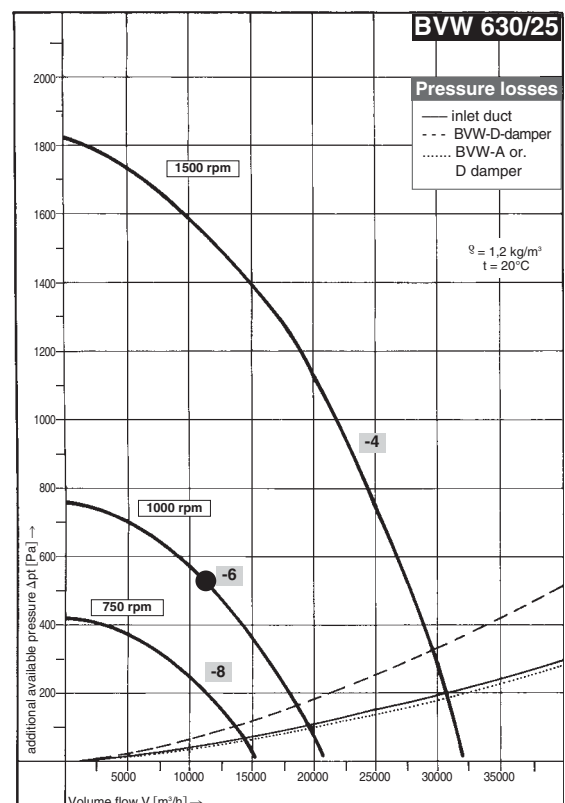


Fig. 9





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SMOKE EXHAUST FANS APPLICATION EXAMPLE 1 CENTRIFUGAL SMOKE EXHAUST FAN FOR 600°C BVW-R SERIES WITH INLET DUCT

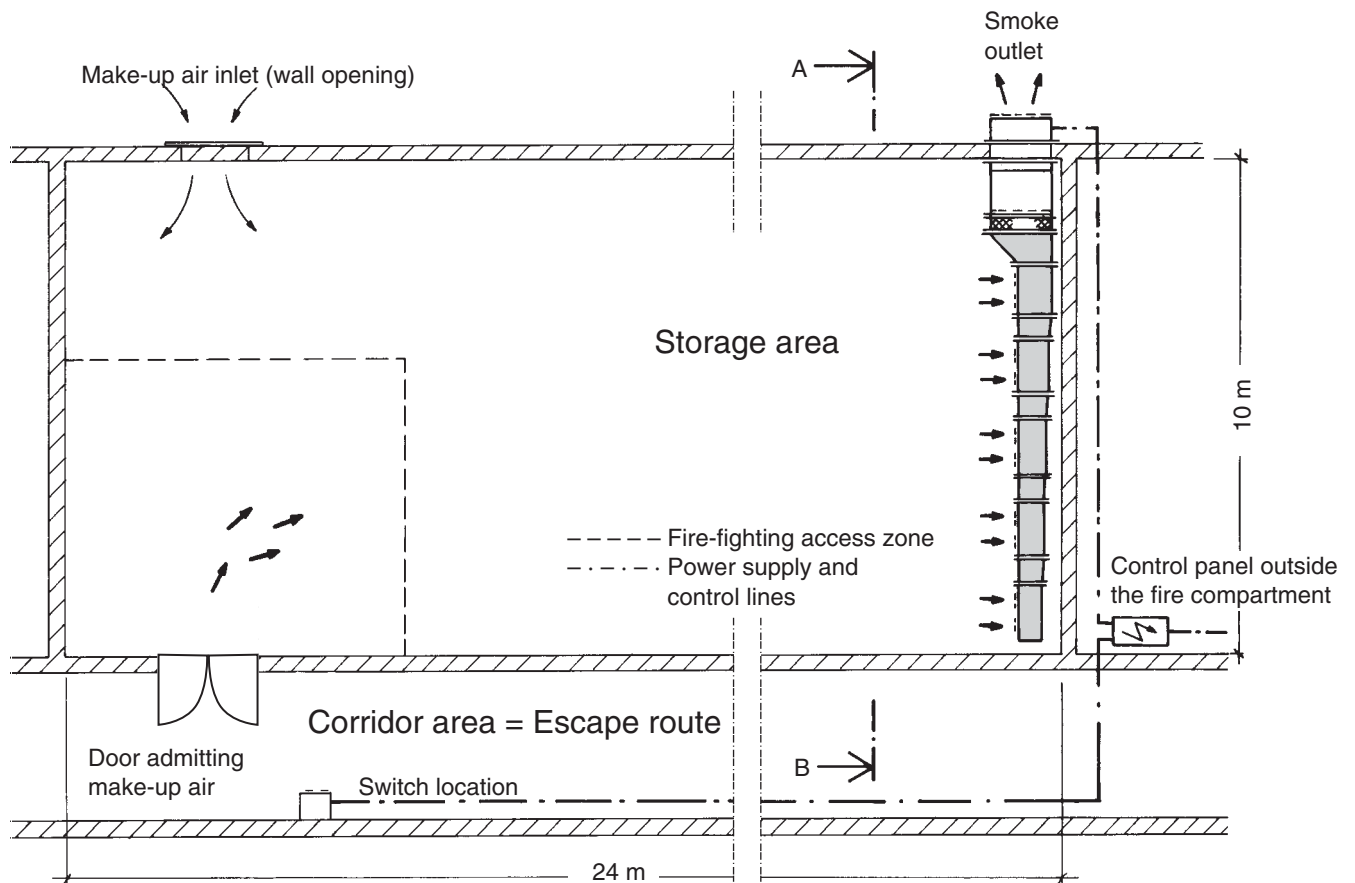
027

Example 1

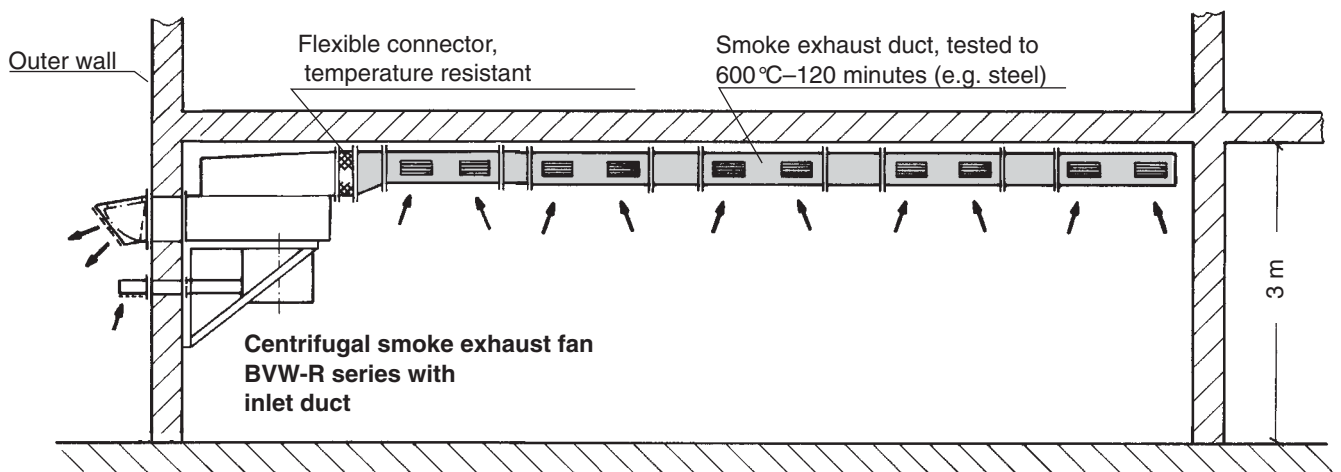
Furniture warehouse in a multi-storey building, equipped with a wall-mounted centrifugal smoke exhaust fan.

for 600°C – 120 minutes

For planning and installation please also refer to our Installation, Operation and Maintenance Instruction (MBW).



Scale 1:150



Section A-B

Scale 1:75

Fig. 10 Floor plan and sectional view of a storage room

■ = Customer supplied



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SMOKE EXHAUST FANS APPLICATION EXAMPLE 2 ROOF-MOUNTED SMOKE EXHAUST FAN FOR 400/620°C BVD SERIES

028

Example 2

Industrial shed ventilation and smoke exhaust system using 3 roof-mounted smoke exhaust fans.

400/620°C – 120 minutes

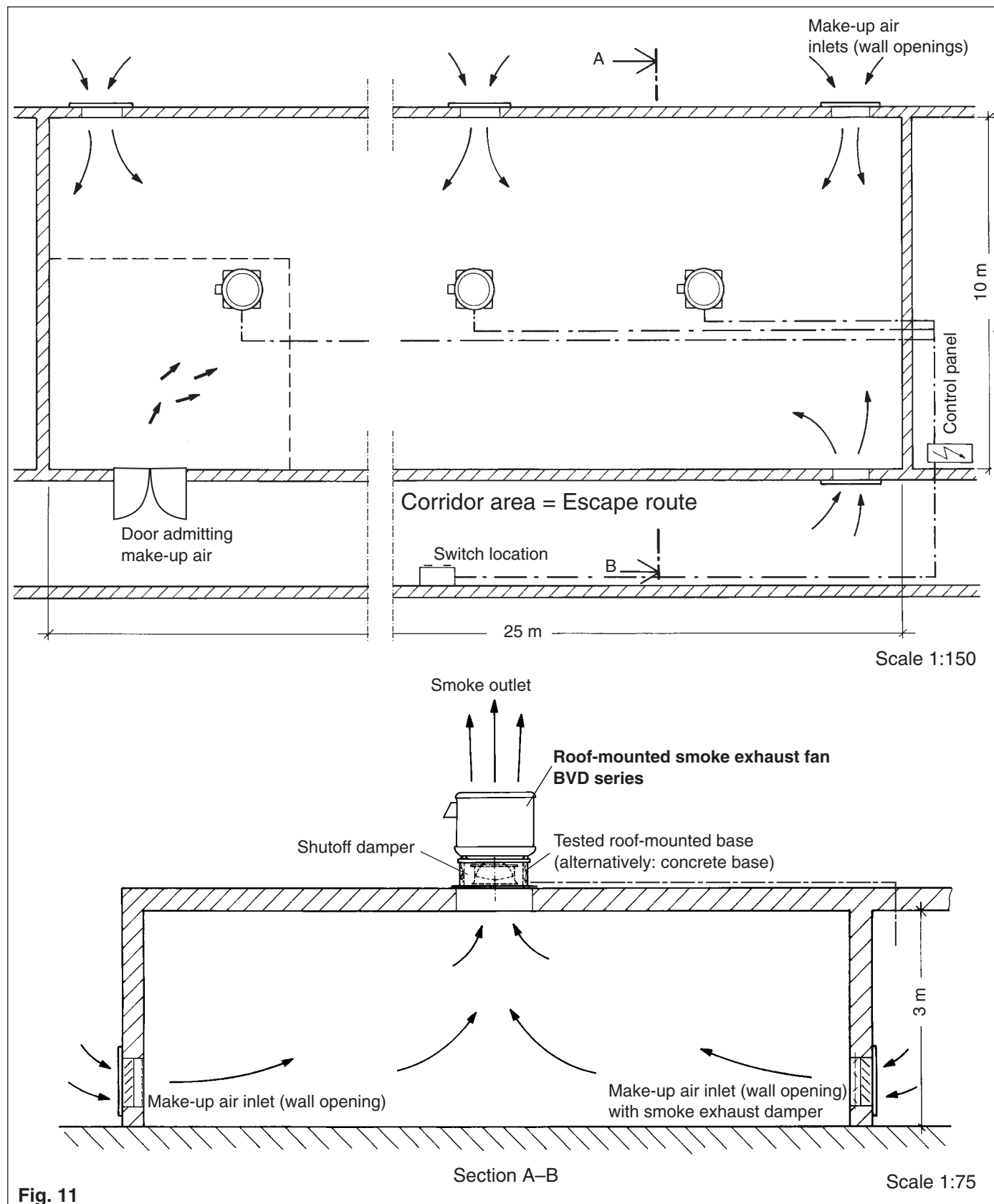


Fig. 11



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SMOKE EXHAUST FANS APPLICATION EXAMPLE 3

WALL-MOUNTED AXIAL FLOW SMOKE EXHAUST FAN FOR 200/300/400°C
BWAXN 12/56 SERIES

029

Example 3

Industrial shed ventilation and smoke exhaust system using wall-mounted axial flow exhaust fans

for 200/300 or 400°C – 120 minutes

For planning and installation please also refer to our Installation, Operation and Maintenance Instruction (MBW).

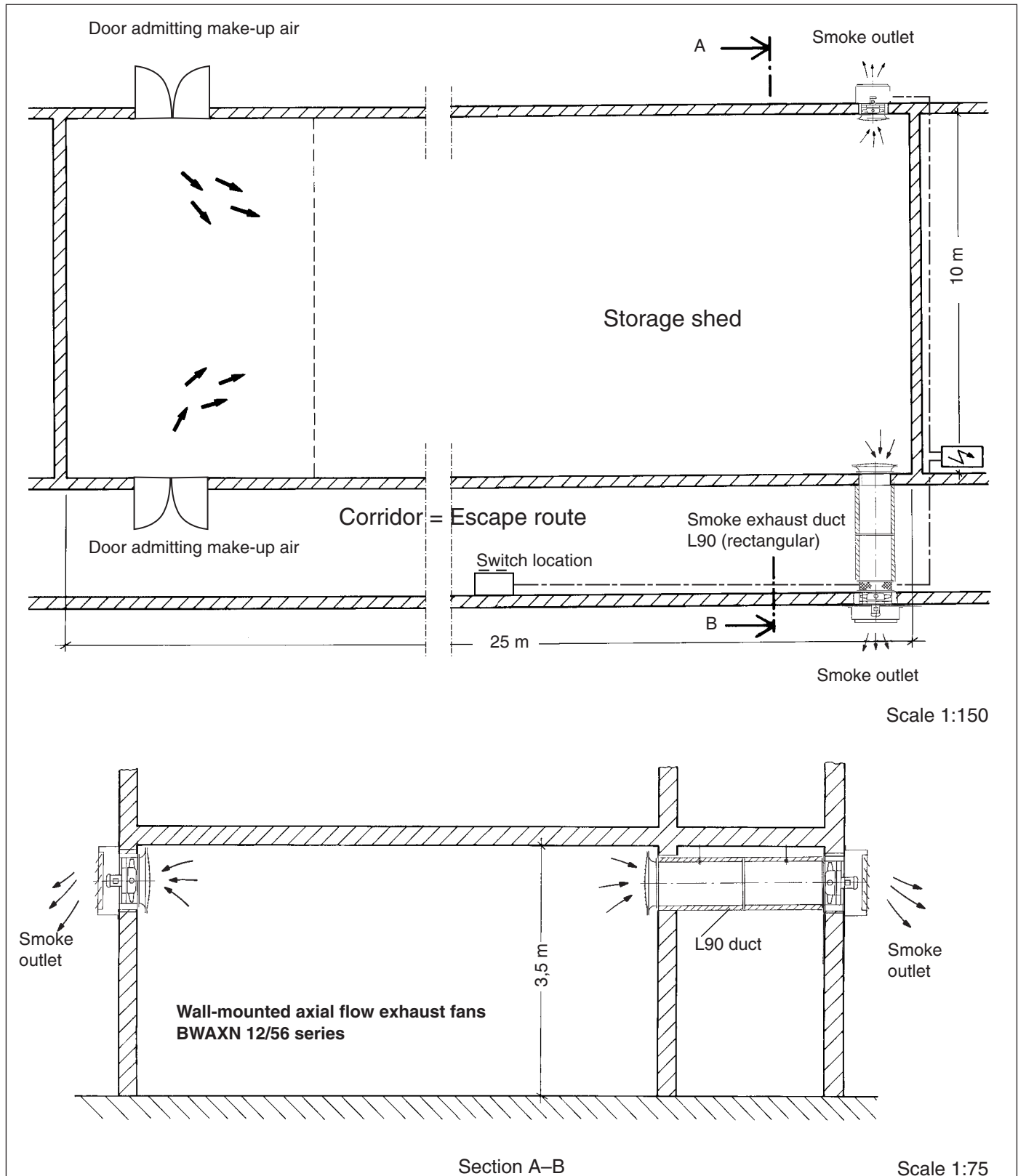


Fig. 12



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SMOKE EXHAUST FANS APPLICATION EXAMPLE 4 AXIAL FLOW SMOKE EXHAUST FAN FOR 200/300/400°C BVAXN 12/56 SERIES

030

Example 4

Ventilation and smoke exhaust system
using one axial smoke exhaust fan for
200/300 oder 400°C – 120 minutes

For planning and installation
please also refer to our
Installation, Operation and
Maintenance Instruction (MBW).

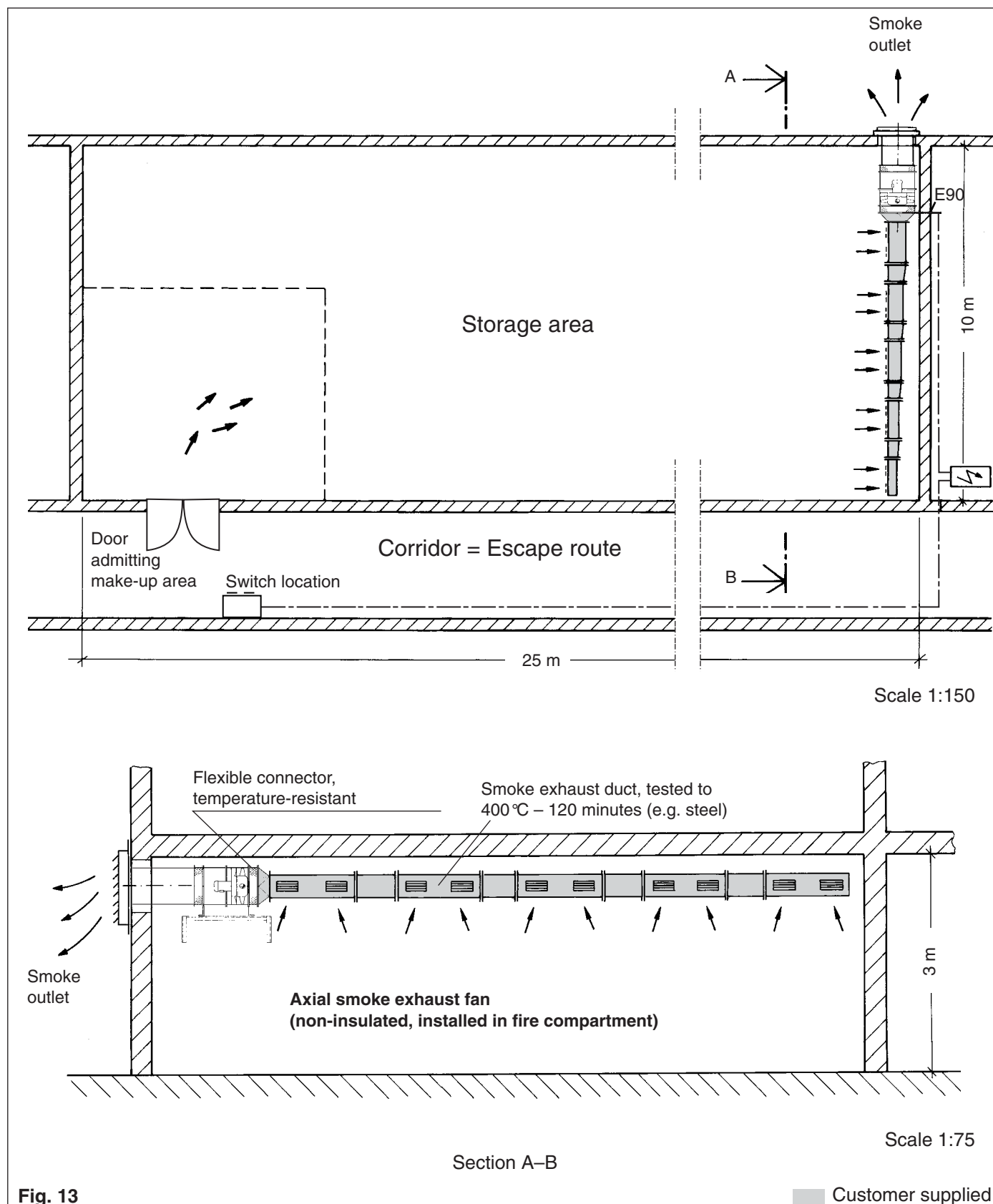


Fig. 13



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SMOKE EXHAUST FANS APPLICATION EXAMPLE 5 AXIAL FLOW SMOKE EXHAUST FAN FOR 600°C SERIES BVAXN 8/56

031

Example 5

Multi-storey building with basement ventilation and smoke exhaust system using a BVAXN 8/56 series axial smoke exhaust fan

for 600°C – 120 minutes

No cooling air fan required.

For planning and installation please also refer to our Installation, Operation and Maintenance Instruction (MBW).

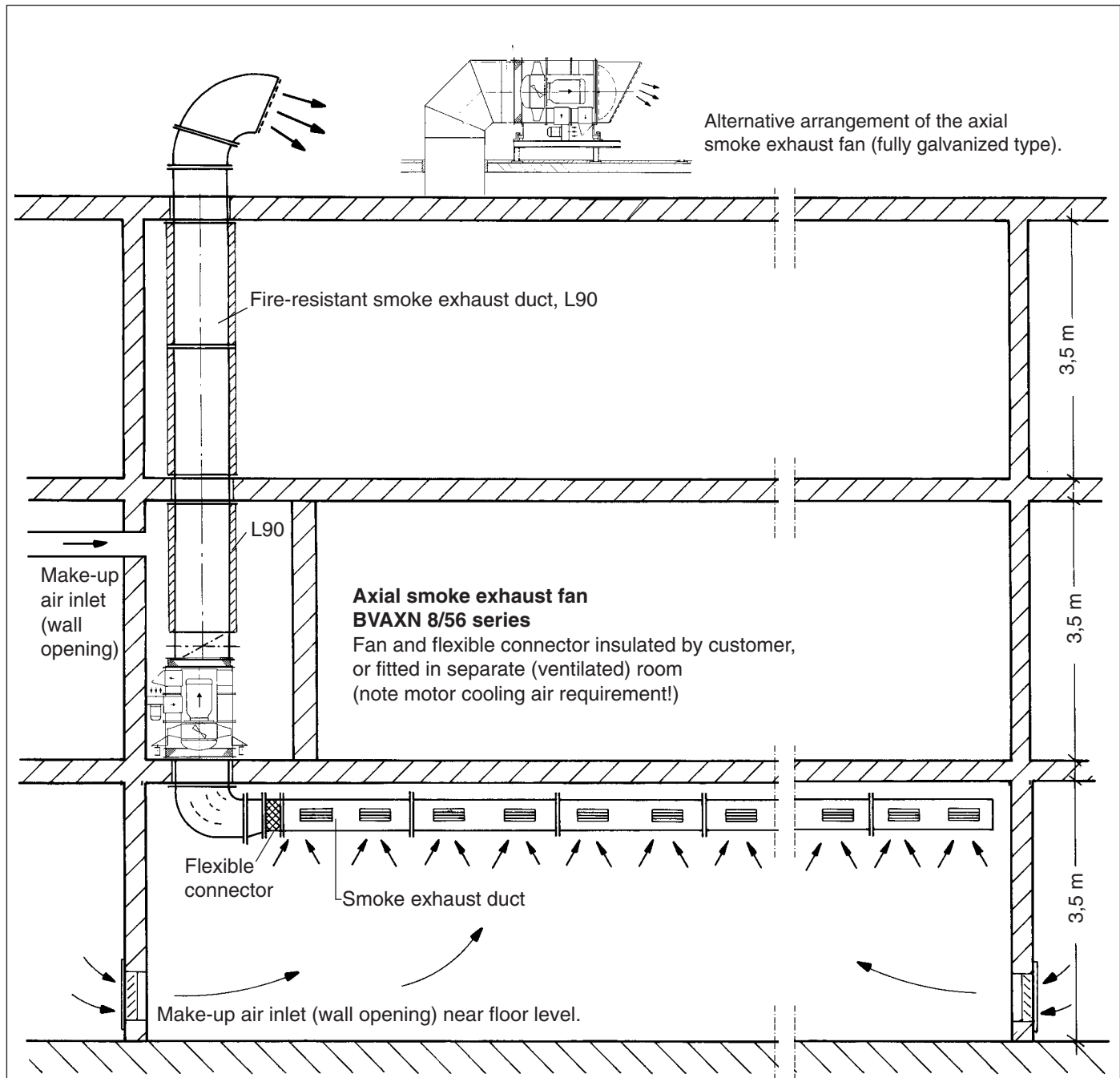


Fig. 14



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7.5 Installation notes for smoke exhaust fans

By embracing intelligent solutions at the planning stage and adopting a practice-oriented installation strategy for the smoke exhaust system, users can save significant installation and maintenance costs.

We are all familiar with practical examples of fans virtually inaccessible for maintenance, or whose disassembly requires an unreasonable effort and can therefore be carried out only on legal holidays – with the associated penalty of immense cost.



Installation example: BVAXN 8/56/1400 MD

Compliance with legal requirements and the use of appropriate practical know-how constitute effective safeguards against such errors.

Indoor fan installation outside the fire compartment

Fans for this application type must be heat insulated when installed in a ventilated room. Data concerning the requisite nominal air flows which must be ensured to keep the air temperature in the installation room below 40°C under any fan operating condition are available from the manufacturer upon request.

Insulation in the form of wire-net mineral fiber matting may be applied retroactively in a single layer. The thickness of the lagging must exceed 40 mm, at an apparent density > 90 kg/m³. Note also that the insulation material for fire-resistant air ducting must meet DIN 4102, Part 4. As regards electrical wiring, routing and execution requirements vary with the installation site. In any case, cables shall conform to the circuit integrity

maintenance specifications of DIN 4102, Part 12.

In practice, this means that the connecting cables must not contact the fan casing and must be routed in appropriate mechanical protection systems.

The specifications further describe the installation of switchgear components and maintenance switches, which must be provided in duly protected form in areas not exposed to a fire or temperature hazard and in any case, outside the fire compartment.

As an example, consider the placement of maintenance switches outside the fire zone. According to VDE 0113-1, such switches must be fitted in the immediate vicinity of the fan for maintenance and repair purposes, but this requirement applies only if the fan is not in the line of sight of an operator at the switchgear cabinet.

It should also be noted that the fan's radiant heat output must not interfere with maintenance switch operability, and that the switch must be secured against unauthorized operation in its energized state. (In no case shall switches be mounted in the fire zone without protection).

Always remember when designing circuits and control systems that the fan's smoke extraction function must take priority over all other functions the smoke exhaust system may have.

Thus, where a fan is started or energized via a suitable switchgear device, all thermal or electrical monitoring components must be bypassed or de-energized, and all switching devices must be rated for the projected (usually, maximum) fan rpm. The fan speed must NOT be variable for the duration of the fire, and indeed, such speed control would be counterproductive. Another important requirement is that all devices have undergone an appropriate acceptance procedure.

This acceptance must be conducted and documented at the system operator's initiative. The acceptance tests shall determine the system's full operability and appropriate installation, and specifically the proper interaction of all components. In the functional test, the fan's power consumption at normal temperatures of about 20°C must not exceed permissible values

and its direction of impeller rotation must be verified.

The circuit integrity, safety and reliability of the power supply must likewise be ensured. The system must be maintained in good repair at all times. Its power supply must be ensured throughout the smoke extraction operation. The option is essentially between a primary or secondary power supply. Secondary power may be derived from an emergency power unit or a second mains connection; in any case, it must be fully isolated from the primary power source. The change-over between primary and secondary supply must be automatic (second mains connection). The power requirement of a smoke exhaust system shall be rated under normal ambient conditions.

Another issue, ultimately, is the maintenance of smoke exhaust fans. It must be consistent with the fan manufacturer's maintenance instructions. As a minimum, component operability checks must be carried out at three-month intervals.

If due regard has been paid to accessibility at the planning stage, the following functional checks can be performed quickly and economically:

- Fan start-up test
- Check of measuring and triggering devices, smoke detectors and manual start functions
- Visual inspection of fans and smoke exhaust dampers
- Review of smoke extraction scenarios with regard to triggering, damper positioning and fresh air supply
- Sample check of individual volume flows and comparison with the acceptance condition



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SMOKE (FUME) EXHAUST FANS INSTALLATION EXAMPLES

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The **ideal mounting configuration** corresponds to that of the test airflow duct, with inlet and outlet tube diameters of $2.5 \times D$ (D = fan diameter).

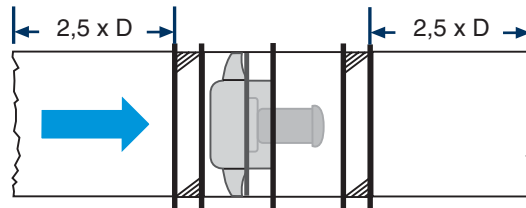
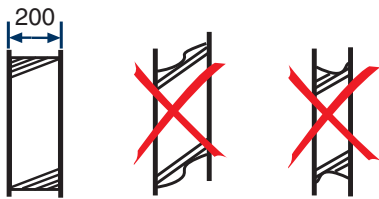
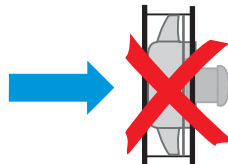


Fig. 1

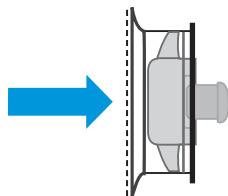


Flexible duct connectors upstream and downstream of the fan must be fitted carefully with zero offset, taking into account the installed length. Failure to observe this rule will result in performance loss and increased acoustic emissions. Flexible connectors are not intended as "elastic fit" adapters compensating for installation inaccuracies!

Fig. 2/2.1/2.2

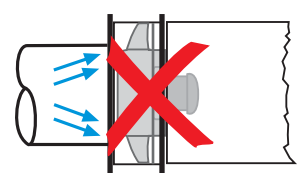


On free inlet fans, the use of an optimized bellmouth is mandatory. Failure to install this would result in severely degraded fan performance and increased noise levels.

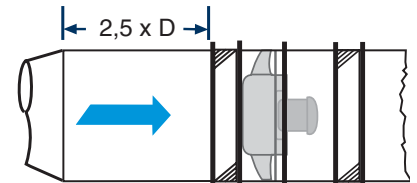


To satisfy accident prevention rules, a wire guard must be fitted to the front of the bellmouth.

Fig. 3/3.1

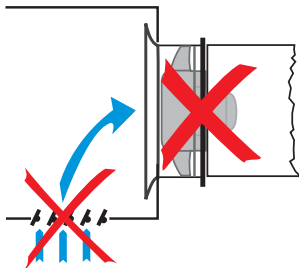


Connections of the above type are absolutely unacceptable in practice.

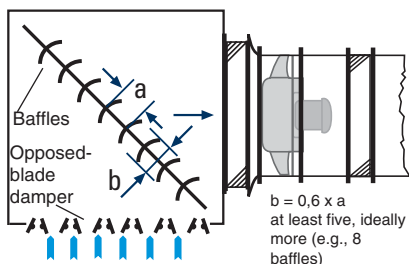


In special cases, i.e., where no alternative is feasible, an adapter cone and $2.5 D$ tube section (D = fan diameter) must be fitted as shown.

Fig. 4/4.1

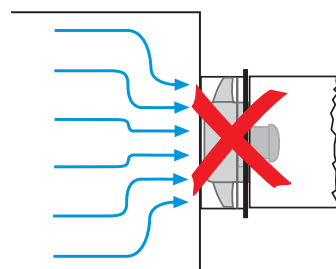


Where dampers must be fitted in airflows arriving vertically from below (e.g., through a ceiling or inlet duct), an opposed-blade damper type should be used to ensure an appropriate approach flow onto downstream deflector or baffle elements.

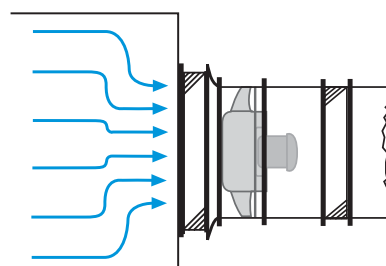


The flexible duct connector (two nominal sizes > nominal fan size) ensures an additional improvement in incoming flow conditions and superior acoustic performance.

Fig. 5/5.1

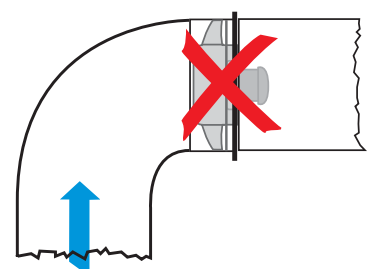


With horizontal approach flows from a larger duct or inlet chamber, an oversized flexible connector (two nominal sizes > nominal fan size) in conjunction with the bellmouth will greatly improve incoming flow conditions and noise output.

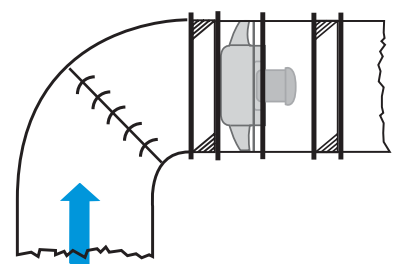


An approach flow situation as shown in Fig. 6 will result in a greatly impaired fan performance.

Fig. 6/6.1



Installation of an axial-flow fan directly downstream of a curved duct section will give rise to substantial performance losses and noise increase.



If a $2.5 \times D$ inlet flow section cannot be fitted, baffles should be used (for configuration and sizes refer to Fig. 5.1)

Fig. 7/7.1



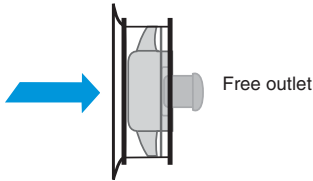
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SMOKE (FUME) EXHAUST FANS INSTALLATION EXAMPLES

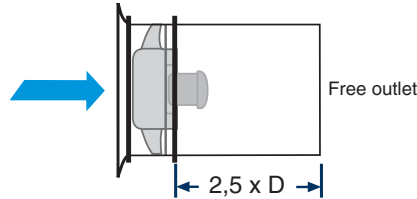
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Maximum impact loss



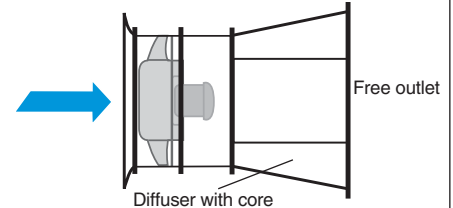
In a free-outlet configuration, the dynamic pressure acting on the fan's annular surface area (fan surface minus hub surface) must be taken into account as impact loss.

50% reduced impact loss



On a free outlet system with $2.5 \times D$ outlet duct, the entire surface area as determined from the nominal fan size may be used for the impact loss calculation (rectified flow).

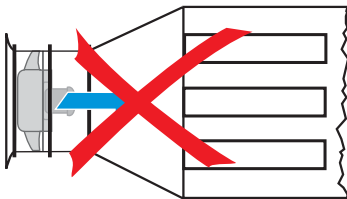
70% reduced impact loss



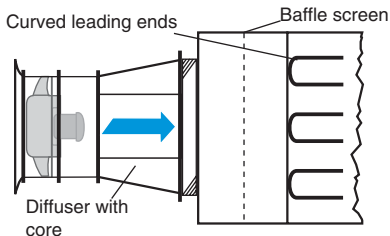
Diffusers can reduce impact loss by about 70% when compared to the configuration shown in Fig. 8.

Fig. 8/8.1/8.2

High impact loss

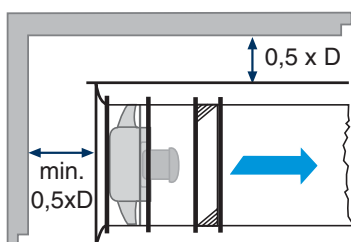


To avoid high impact loss, turbulence effects and excessive noise, downstream splitter attenuators should be connected via a diffuser with internal core and an interposed pressure chamber. In systems with large cross sections, the pressure chamber may be additionally provided



with a built-in baffle screen (perforated metal panel). This recommendation also applies to filters, heaters, etc. The splitters should have curved leading ends.

Fig. 9/9.1

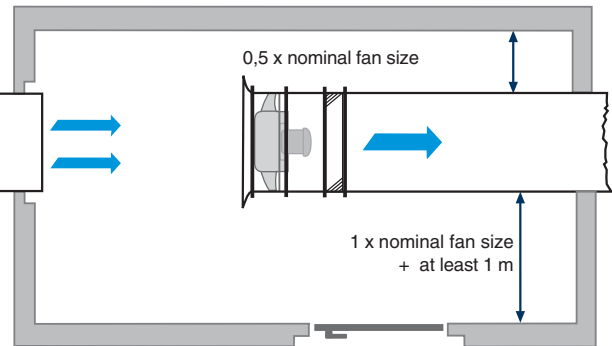


For in-chamber installation specified minimum distance must be observed. If multiple fans are mounted next to each other, the distance between their bellmouths must be at least $0.5 D$.

Fig. 10

In-chamber installation

The same applies by analogy for installation in tube or channel ducts.



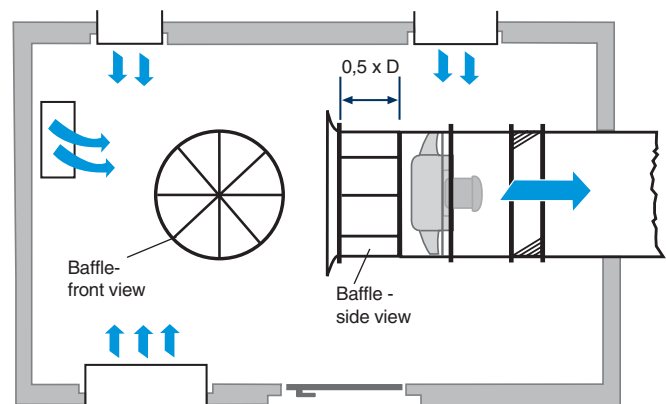
In practice, fans are often mounted in such cramped conditions that proper maintenance or repairs are impossible or extremely costly to carry out. Fans are machines which comprise wearing parts. It is therefore important to provide adequate free space around the unit for maintenance or repair access. On roofs (especially warm

roofs), the availability of sufficiently strong support areas is important. It should be possible to erect scaffolding above and around the fans for installation and maintenance.

Fig. 11

Plenum inlet chamber

Vortex flow effects are often encountered in configurations of this type. The use of an anti-vortex baffle is recommended.



In large inlet chambers with multiple air streams, vortex effects may impair the airflow at the fan inlet. Performance losses are an inevitable result. In this type of operating situation, the recommended anti-vortex baffle should either be fitted from the start or planned in such a way it can be installed later.

Please also observe other fan technology fundamentals as described in the relevant academic and trade literature (e.g., TLT Fan Primer, published by Promotor Verlag, Karlsruhe). Our staff will be glad to answer your questions on this subject.

Fig. 12



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8.0 Individual system components

8.1 Smoke exhaust dampers

Since work on the relevant European standard (prEN 1366-10) is still continuing, the relevant national approval mechanisms have remained applicable. In Germany, these are enshrined in the Building Rules List established by the new Building Code (the currently valid list is designated 99-1). According to this document, all smoke exhaust dampers require approval by the building supervisory authority.

Smoke exhaust dampers are known to have two safety positions:

- a) the closed position (standby, with or without fire resistance)

- b) the open position (during extraction of hot gases).

Moreover, their power supply must be reliably ensured since a smoke exhaust damper is required to retain its opening and closing capability even after 25 minutes of fire exposure, so that consistent with the Model Guideline for Ducting (draft 98), the exhaust duct equipment will remain operable for at least 90 minutes.

The drive units for smoke exhaust dampers are tested for a fire resistance of 90 minutes. In the case of a power failure, the de-energized drive units must secure the damper in its open position, e.g., via a mechanical locking feature.

Such equipment is designated ETK90, i.e., it has a fire resistance of 90 minutes at the ISO 834 unit-temperature curve (in the future, the relevant document will be EN 1363-1), and its smoke extraction functionality, based on the same curve, remains ensured for the same period.



8.2 Smoke exhaust ducts

The fire resistance behaviour of smoke exhaust ducts is currently governed by the national standard DIN 4102-6, while their smoke extraction capabilities are subject to DIN 18232-6.

DIN 4102-6 is scheduled to be replaced within the next 6 months by EN 1366-1, while DIN V 18232-6 will remain applicable until the European standard for smoke exhaust ducts (EN 1366-8) becomes available. This is expected to happen in about two years' time.

The differences between the two European standards and their German counterparts are minimal, except for the characteristics and length of the suspension elements. The calculations use the same baseline value of 6 N/mm².

With the publication of DIN EN 1366-1, this European specification has come to reflect the state of the art. It is to replace DIN 4102, Part 6.

According to the European testing criteria, the elongation of the suspension elements must be measured and recorded in the test record upon completion of the fire test. The measured elongation applies for a maximum hanger length of 1.5 m. Where longer suspension elements are needed, their elongation shall not exceed the

value measured in the test, e.g., 40 mm for a 1.5 m (uncovered) hanger. For longer elements to remain within this elongation range, they must be enclosed in a fire-resistant material.

The tightness of the ductwork is another criterion. Practical experience shows that ducts assembled on site exhibit the greatest installation flaws.

Leakage flows shall not exceed 10 m³/h per square meter of inside surface area. Thus, for instance, an Li 1.0 x 1.0 m duct has an interior circumference of 4.0 meters, and a 5-meter length of this duct has an inside surface area of 20.0 m.

Its maximum acceptable leakage would thus be 2.0 x 10 = 200 m³/h. In the case of multi-range systems, allowance must also be made for permissible cold leaks of 200 m³/h per square meter of cross-sectional area (smoke exhaust dampers) and for the acceptable exhaust fan power loss.

In sizing a smoke exhaust fan, all acceptable sources of leakage or power loss have to be duly taken into account.



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Engineering Standards	DIN... EN...	Contents
Smoke exhaust fans	DIN V 18232-6 EN 12101-3	Mechanical smoke exhaust systems Requirements for components and suitability testing Smoke and heat control systems Part 3: Specification for mechanical smoke and heat exhaust ventilators (test and product standard)
Fire protection dampers	DIN EN 1366-2	Fire protection dampers
Smoke exhaust dampers	DIN V 18232-6	Mechanical smoke exhaust systems Requirements for components and suitability testing
Ducting	DIN V 18232-6 DIN 1366-1 pr EN 1366-8 pr EN 1366-9	Mechanical smoke exhaust systems Requirements for components and suitability testing Fire resistance tests on service installations, Fire-resistant ventilation ducts Fire resistance tests on service installations in buildings, Smoke extraction ducts Fire resistance tests on service installations in buildings Smoke extraction ducts in a fire zone
Sizing of smoke exhaust systems	DIN V 18232-5 pr EN 12101-5	Smoke and heat extraction systems Mechanical smoke exhaust systems Requirements and design Smoke and heat protection systems Functional requirements and calculation methods for smoke and heat exhaust systems
Pressure-based smoke protection systems	DIN 18232-7 (draft) pr EN 12101-6	Smoke and heat extraction systems Pressure-based smoke protection systems for safety staircases Smoke and heat control systems Pressure differential systems, kits
Smoke exhaust systems	pr EN 12101-4	Smoke and heat control systems Design of smoke and heat exhaust systems



8.3 Control of smoke exhaust systems

8.3.1 Triggering devices and single-range systems

Smoke exhaust fans and fire protection dampers must be approved by the German Institute of Building Technology (DIBt) according to Building Rules List "B", Part 2, in conjunction with the relevant smoke detectors. Compliance with the codes is demonstrated via certification tests performed by independent testing institutes.

The smoke exhaust system is triggered by pushbuttons or automatically via smoke detection switches. The signals that activate the mechanical heat and smoke exhaust installation and move the fire protection and smoke exhaust dampers into their safety position are transmitted by a controller. The various devices cooperate to ensure a high-speed fire detection, alarm, and smoke exhaust.

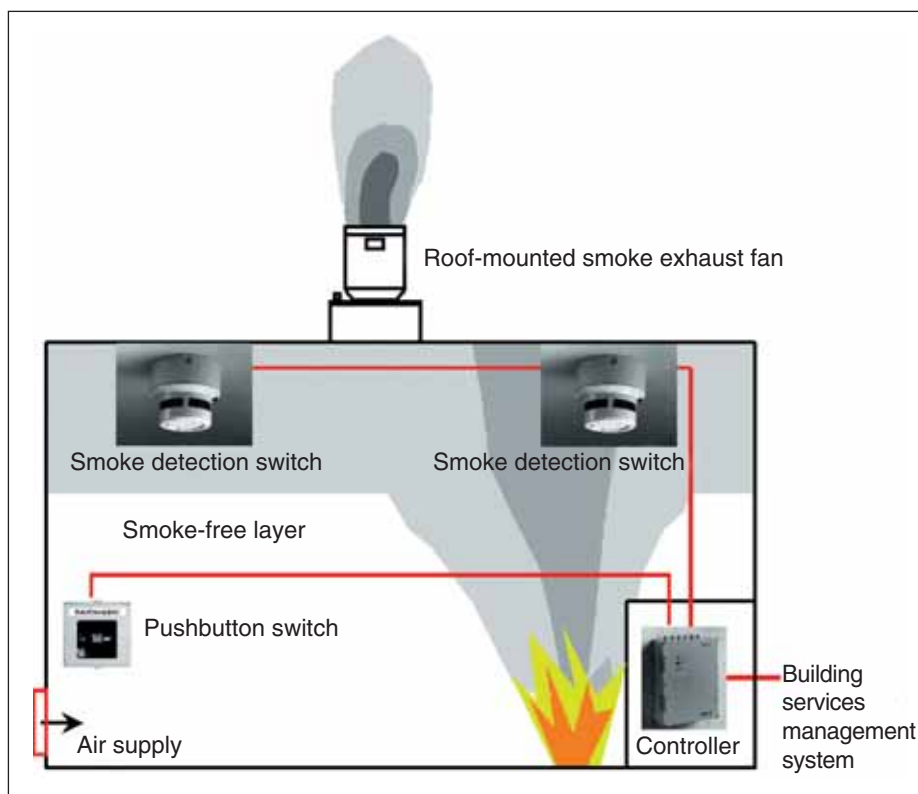
Past fire disasters have shown that an effective rescue of human beings can only be achieved through an early and effective extraction of smoke from escape and safety routes until

the arrival of fire-fighting services. To ensure the direct and immediate activation of the smoke exhaust system, smoke extraction fans must be equipped with automatic triggering devices that sense the presence of smoke (smoke detectors).

Smoke exhaust systems designed for human safety must not require manual activation, since the occupants at risk must be able to leave the building safely within the first few minutes after a fire has started. If, in the course of the planning process, the fire authorities should insist on manual activation by the fire brigade, the system no longer qualifies as a smoke exhaust installation for human safety, since experience shows that it will usually take 5 – 15 minutes for fire fighters to arrive.

The foregoing does not apply where smoke exhaust dampers form part of the smoke exhaust system. In this case the fans may be integrated with the wiring of the smoke exhaust damper and the associated triggering device, which meets the same protection objective. Still, it must be possible to start the fans manually via pushbuttons.

Obviously, all triggering devices must be approved by the building supervisory authorities. The layout and number of smoke detectors used must conform to DIN VDE 0833-1.





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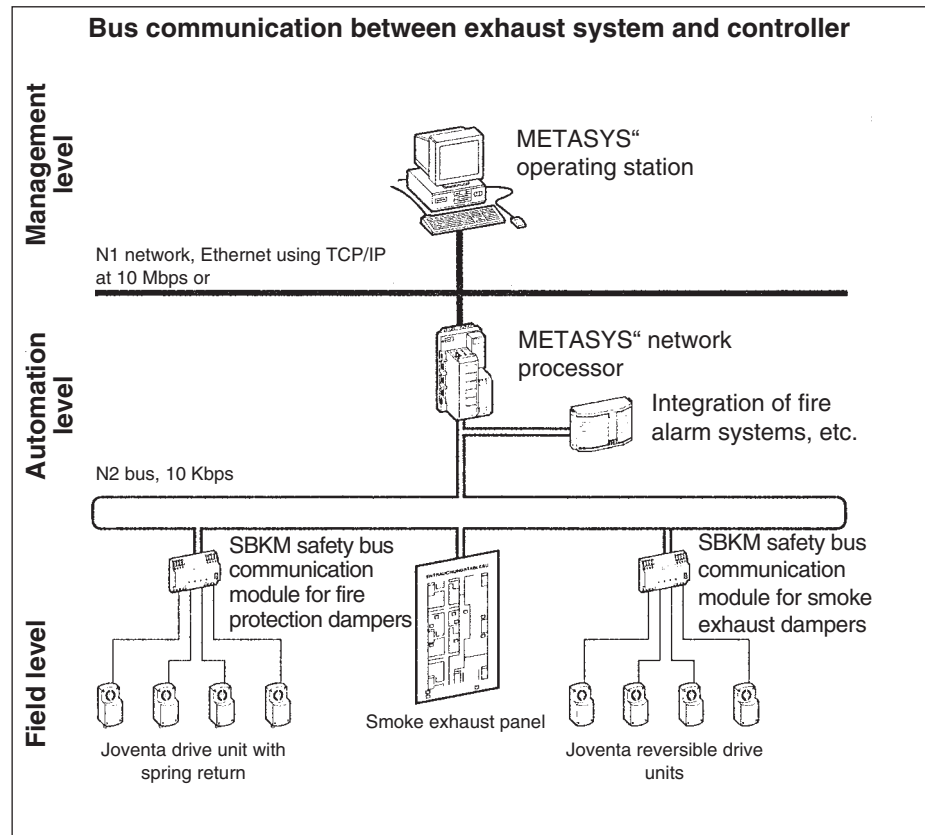
8.3.2 Control via LON bus (ICI)

The integration of all equipment such as central fire detection, emergency lighting and fire compartment doors into the building services automation structure provides an overall functionality and comprehensive control capability offering numerous benefits. On one hand, it ensures that escape and rescue routes will be kept clear of smoke for a defined interval to protect occupants and fire-fighting services. On the other, it enables a continuous documentation of all processes in conjunction with the building services automation system allowing full records of incidents for subsequent analysis. In addition, maintenance-free fire protection dampers (or dampers with extended service intervals) can be installed if the system allows these units to be periodically actuated with full performance logging. High maintenance costs can thus be effectively reduced, given that according to the "General Building Supervision Approval", conventional fire protection dampers must be serviced annually.

Considerable cost savings

Bus communication is a key advantage of digital building automation solutions. It implies considerable cost savings because of a significant reduction in installation costs. The need for traditional star-pattern wiring, with its high cabling investment (at least E30 for smoke exhaust applications), is eliminated. This is illustrated in the following example.

At the field level the bus is arranged as a ring circuit for the transmission of data and control signals, thus offering a high degree of safety. From the control module the individual actuating motors of the smoke exhaust and fire protection dampers are fed and operated via a 2-wire system (power supply plus data/control signals). The amount of cabling required and hence, the fire load, are greatly reduced. The 2-wire connections can even be interchanged during assembly. Only



Cost saving and more security are arguments in favour of N2 bus wiring in building services automation controlling a smoke extraction system.



a bus system can ensure a full closed-loop and open-loop control of the smoke extraction process without additional interfaces, with full integration into the building automation system for the entire building.